Current practices in the delivery of pharmacogenomics: Impact of the recommendations of the Pharmacy Practice Model Summit

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Purpose. This report examines and evaluates pharmacogenomics as an emerging science as it relates to the Practice Advancement Initiative and its predecessor the Pharmacy Practice Model Initiative's consensus statements for optimal pharmacy practice models.

Summary. Pharmacogenomics is one of many emerging sciences to impact medication management and delivery of patient care. Increasingly, biomarkers are included in drug labeling and can assist pharmacists with personalizing medicine to optimize patient therapies and avoid adverse effects. The 2011 ASHP Pharmacy Practice Model Summit generated a list of 147 consensus statements for optimal pharmacy practice. Of these, 1 statement explicitly describes adjustment of drug regimens based on genetic factors as an essential activity of pharmacist-provided drug regimens, and 9 other statements provide additional support for incorporation of this emerging science into all aspects of patient care provided by pharmacists. We describe 4 institutions that have made significant inroads to implementing pharmacogenomics, to provide a framework and serve as resources for other institutions initiating their own pharmacogenomics implementation journeys.

Conclusion. Through prioritized efforts of the pharmacy profession and health care institutions, pharmacogenomics will be disseminated and implemented, and the goal of the Pharmacy Practice Model Initiative's consensus statements of improving health care using patients' genetic characteristics will be realized.

Keywords: pharmacogenetics, pharmacogenomics, pharmacy service/hospital, pharmacy, precision medicine

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The profession of pharmacy is at a critical juncture where there is an urgent need to maintain the level of practice ahead of the ever-changing landscape of health care delivery. In a bold effort to engage key stakeholders to create forward-thinking hospital and health-system practices, the American Society of Health-System Pharmacists (ASHP) and the ASHP Research and Education Foundation initiated the Pharmacy Practice Model Initiative (PPMI) and its successor the Practice Advancement Initiative (PAI). A Pharmacy Practice

Model Summit was convened in 2011, and the goal of the PPMI was to significantly advance patient health and well-being by developing and disseminating a futuristic practice model that supports the most effective use of pharmacists as direct patient care providers.¹ In order to fulfill this goal, pharmacists will need to make use of current and emerging technologies and science to lead initiatives impacting medication management and delivery.

Emerging sciences currently impacts medication management and delivery.

Examples include pharmacogenomics, gene therapy, biosimilars, and nanotechnology. Among these, pharmacogenomics has been in the spotlight as a means of personalizing medicine to identify the most effective medications and to avoid those of potential harm for individual patients. Pharmacogenomics is defined as the study of how genes affect a patient's response to medications.² An increasing number of newly approved medications include genomic biomarkers in the drug labeling which can help predict response, and research continues to identify predictive genomic markers for existing medications. If the profession of pharmacy is to accomplish the goal of the PPMI by developing futuristic pharmacy practice models, then the science of pharmacogenomics will need to be incorporated into patient care.

A list of 147 points of consensus for optimal pharmacy practice was created in 2011 at the ASHP Pharmacy Practice Model Summit.³ Ten recommendations were reviewed and included by the Emerging Sciences Section Advisory Group goals for implementation of pharmacogenomics in hospitals and health systems for optimal patient care. Included in the PPMI recommendation is a statement for optimal pharmacy practice model that pharmacists should be able to make adjustments of medication regimens based on genetic characteristics of the patient (B23f). Although this is the only goal explicitly stating that genetics has a clear role in the delivery of care, one can easily extend this to several other goals where the use of this science is essential in providing advanced care (B21, B23h, B23i, B23q, B24g, B24k, B26, C13, and C14) (Table 1).³ Upon closer inspection of these goals, one can see the powerful potential of emerging genomics knowledge on patient care and that pharmacists are perfectly positioned to lead this aspect of precision medicine.

With this growing evidence and the importance of using genomic information to guide medication therapy, a number of health systems and universities have prioritized the incorporation of pharmacogenomics information into their routine delivery of care.⁴⁻⁷ The

KEY POINTS

- A framework for implementing pharmacogenomic practices is essential for those considering these types of initiatives.
- Interdisciplinary effort including clinicians, health-system administrators, information technology specialists, and laboratory medicine representatives will be required to successfully implement pharmacogenomic services.
- Institutions described herein can be viewed as a point of contact for those who want to learn more about how these initiatives were developed.

institutions represented in this article consider pharmacogenomics and other mechanisms of providing precision medicine as a core element in fulfilling the goals of the ASHP PPMI and PAI. The intent of this article is to demonstrate different approaches and areas of focus for several institutions throughout the United States have implemented initiatives in pharmacogenomics. These institutions no longer consider pharmacogenomics as a developing science of the future, but as a current available technology being used in our current pharmacy practices. Table 2 summarizes key characteristics of these institutions' pharmacogenomics programs.

Personalized Medicine at Vanderbilt University Medical Center, Nashville, TN

In 2007, Vanderbilt University Medical Center (VUMC) launched BioVU—a biobank featuring DNA samples and longitudinal, anonymized electronic health record (EHR) data. Having now accrued over 215,000 samples, BioVU is critical to a pipeline of genomic discovery at VUMC, through local and National Institutes of Health sponsored research. As a companion

to BioVU and to facilitate clinical translation, VUMC subsequently created the Pharmacogenomic Resource for Enhanced Decisions in Care and Treatment (PREDICT) in 2010.⁸ The overarching mission of PREDICT is to establish an infrastructure for genetic testing, EHR and personal health record return of results, and clinical decision support to enable genotype-guided therapeutic decisions. Genetic variants on the PREDICT panel are selected based on biological validity of their association with drug efficacy or safety, and the clinical utility of using the interaction to tailor prescribing. A Steering Committee drawn from multiple VUMC clinical departments provides oversight, and program policies are governed by the Pharmacy and Therapeutics Committee and the Laboratory Formulary Committee. Currently, PREDICT has implemented 5 drug-gene interactions: clopidogrel/*CYP2C19*, warfarin/*CYP2C9* and *VKORC1*, tacrolimus/*CYP3A5*, and thiopurines/*TPMT*, simvastatin/*SLCO1B1*. Several others are under development as part of a shift to a new genotyping platform with an expanded set of single nucleotide polymorphisms (SNPs).

From 2010 to 2013, patients were preemptively selected for genotyping with institutional financial support to implement a prediction algorithm involving common clinical data to anticipate which patients will be prescribed one of the drugs targeted by PREDICT in the subsequent 3 years. Prior to a patient's appointment, the available EHR data were accessed to generate a score based on demographics and medical diagnoses. If not already tested, an indicator suggesting clinical genotyping test was displayed in the EHR. After the initial 3-year phase, the preemptive testing model was deemed not supportable by payers, and preemptive testing transitioned to specific research projects. Currently, pharmacogenomics panel testing is ordered by clinicians with a specific indication and CPT and ICD10 codes and, as it is not a research program, no informed consent is required since it is handled as routine clinical care.

Table 1. Pharmacy Practice Model Initiative Imperatives and Expected Pharmacogenomic Impact for Pharmacists

PPMI ^a Imperatives	Pharmacogenomic Impact for Pharmacists
B21: Pharmacists should use patient-specific data to be leaders in disease prevention and wellness.	If pharmacists are to be able to use patient-specific data to be leaders in disease prevention and wellness, then clearly they will need to be knowledgeable of known genetic drivers of disease and medication response in order to identify higher risk patient populations.
B23h: Authority to order serum medication concentrations and other clinically important laboratory analyses.	Pharmacogenomic laboratory tests are sure to be included in those essential tests which pharmacists should have the authority to order and interpret.
B23i: Authority to adjust dosage for selected medications.	Pharmacogenomic markers are currently part of dose adjustment strategies for a variety of drugs.
B23q: Pharmacist expertise in literature evaluation.	Being able to interpret clinical trials evaluating pharmacogenomics-guided treatment will be essential for pharmacists to make decisions on the clinical utility of these markers.
B24g: Play a critical role in ensuring that the hospital or health system adheres to medication-related, evidence-based practice guidelines.	If these tests are deemed to be part of the treatment plan, then pharmacists will need to be equipped to use this information to ensure hospitals or health systems are adhering to medication-related, evidence-based practice guidelines.
B24k: Identify problem-prone and high-risk therapies using preestablished criteria.	Pharmacogenomics is being used to identify populations who should avoid or could benefit from problem-prone and high-risk therapies.
B26: Contemporary pharmacy education must prepare pharmacists for an expanded role in drug therapy management in hospitals and health systems.	If pharmacists are to be competent in using pharmacogenomics, then contemporary pharmacy education will need to prepare pharmacists for this expanded role in implementing pharmacogenomics in drug therapy management.
C13: Pharmacy residency programs should provide informatics training to ensure residents' success in optimal practice models.	In order to integrate pharmacogenomic information into routine care, pharmacist informatics training and education will need to include this new technology into proactive decision support tools.
C14: Advanced training in pharmacy informatics with residencies and postgraduate education should be expanded.	In order to integrate pharmacogenomic information into routine care, pharmacist informatics training and education will need to include this new technology into proactive decision support tools.

^aPPMI = Pharmacy Practice Model Initiative.

After institutional approval previously by the Pharmacy and Therapeutics Committee and now by the new Laboratory Formulary Committee, implementing drug-gene interactions in PREDICT requires translation of variant results to a drug phenotype and submission to the institutional EHR and personal health record accessible to patients through My Health at Vanderbilt, a patient portal. Drug-gene interactions are displayed prominently on the clinical summary page of the chart that is viewed whenever a chart is first accessed. When targeted drugs are prescribed either in the inpatient or outpatient setting, rule-based clinical decision support (CDS) is activated to suggest alternatives or to guide dosing. Within the CDS view, the drug-gene interaction risk is outlined for the prescriber along with

recommendations for alternative therapies. Additionally, for selected scenarios in cardiology and transplant medicine, a clinical pharmacist assists with use of the variants.

PREDICT is designed to address several barriers to implementation and has been particularly successful at achieving scale across the enterprise and enabling preemptive testing for high-risk patients. Significant challenges remain, including maintaining provider, staff, and patient education, maintaining high-quality laboratory assay performance, navigating insurance reimbursement policies for panel assays, and keeping the genotype to phenotype knowledgebase updated. To address the significant staff education needs for PREDICT, a 4-fold approach has been used. Clinicians at all experience levels receive training on the

online documentation system (mydrug-genome.org and intranet web resources) linked to the EHR and on-screen prompts. Additionally, education is provided by clinical champions, pharmacogenomic educational conferences and updates to targeted specialty practices, and pharmacist experts. Addressing clinician education needs remains a constant challenge due to academic team rotation and turnover.

Individualizing Medicine Program, Mayo Clinic, Rochester, MN

The Mayo Clinic is a large, multi-site academic medical center with key institutional sites located in Rochester, Minnesota; Jacksonville, Florida; and Scottsdale-Phoenix, Arizona. To personalize medicine to the needs of every

Table 2. Summary of Key Pharmacogenomics Program Characteristics^a

Site	Program Initiation	Drug–Gene Pairs	Oversight/ Governance	Testing	Education and Training Opportunities
Vanderbilt University Medical Center	2010	clopidogrel/ <i>CYP2C19</i> ; warfarin/ <i>CYP2C9</i> and <i>VKORC1</i> ; thiopurines/ <i>CYP3A5</i> ; <i>AZA/TPMT</i> ; simvastatin/ <i>SLCO1B1</i>	<ul style="list-style-type: none"> • P&T Committee • Steering Committee for PREDICT • Laboratory Formulary Committee 	Preemptive and indication-triggered	<ul style="list-style-type: none"> • Coursera course in Personalized Medicine • Lecture series in Personalized Medicine (CME) • Graduate school degrees in Human Genetics and Biomedical Informatics
University of North Carolina Healthcare	2007	clopidogrel/ <i>CYP2C19</i> ; warfarin/ <i>CYP2C9</i> and <i>VKORC1</i> ; abacavir/ <i>HLA-B*57:01</i> ; irinotecan/ <i>UGT1A1</i>	<ul style="list-style-type: none"> • P&T Committee • UNC Molecular Genetics and Pathology Laboratory • CPIT faculty oversight 	Preemptive and indication-triggered	<ul style="list-style-type: none"> • Pharmacogenomics graduate and fellowship programs in the Division of Pharmacotherapy and Experimental Therapeutics • Graduate level course in Clinical Pharmacogenetics, and a graduate level course in Pharmacogenomics Methods • Clinical pharmacogenetics elective in the professional program • CPIT Genotyping and Education in professional program
Mayo Clinic	2012	abacavir/ <i>HLA-B*57:01</i> ; CBZ/ <i>HLA-B*15:02</i> and <i>HLA-A*31:01</i> ; MP, TG, and <i>AZA/TPMT</i> ; codeine/ <i>CYP2D6</i> ; tramadol/ <i>CYP2D6</i> ; tamoxifen/ <i>CYP2D6</i> ; clopidogrel/ <i>CYP2C19</i> ; simvastatin/ <i>SLCO1B1</i> ; warfarin/ <i>CYP2C9</i> and <i>VKORC1</i> ; allopurinol/ <i>HLA-B*58:01</i> ; citalopram/ <i>CYP2C19</i> ; escitalopram/ <i>CYP2C19</i> ; fluoxetine/ <i>CYP2D6</i> ; fluvoxamine/ <i>CYP2D6</i> ; paroxetine/ <i>CYP2D6</i> ; venlafaxine/ <i>CYP2D6</i> ; tacrolimus/ <i>CYP3A5</i> ; 5-fluorouracil/ <i>DPYD</i> ; and capecitabine/ <i>DPYD</i>	<ul style="list-style-type: none"> • CIM Pharmacogenomics Task Force • P&T Committee • Pharmaceutical Formulary Committee • Disease-Oriented Task Forces • Clinical Decision Support Subcommittee 	Preemptive and indication-triggered	<ul style="list-style-type: none"> • Pharmacogenomics graduate programs in Molecular Pharmacology and Experimental Therapeutics • Pharmacogenomics educational modules (foundational and case-based) for practicing pharmacists on all campuses • MTM pharmacist experiential program in pharmacogenomics • Monthly interdisciplinary pharmacogenomics case conferences available on all campuses • Annual Individualizing Medicine Conference with interdisciplinary workshops • Pharmacogenomics Grand Rounds
University of Florida	2012	clopidogrel/ <i>CYP2C19</i> ; codeine/ <i>CYP2D6</i> ; tramadol/ <i>CYP2D6</i> ; MP, TG, and <i>AZA/TPMT</i> ; peg-interferon alpha/ <i>IL-28B</i>	<ul style="list-style-type: none"> • UF Health P&T Committee • Personalized Medicine Subcommittee 	Preemptive and indication-triggered	<ul style="list-style-type: none"> • Personalized and Evidence-Based Medicine APPE elective for 4th-year pharmacy students • PGY2 Pharmacogenomics and Drug Information Residency • Cardiovascular Pharmacogenomics Fellowship • Annual Precision Medicine Conference • Pharmacogenomics Certificate

^aTPMT = thiopurine methyltransferase; TG = thioguanine; MP = mercaptopurine; AZA = azathioprine; CBZ = carbamazepine; P&T = Pharmacy and Therapeutics; CIM = Center for Individualized Medicine; PGY2 = postgraduate year 2; APPE = Advanced Pharmacy Practice Experience; MTM = medication therapy management; ACPE = Accreditation Council for Pharmacy Education; CME = continuing medical education; CPIT = Center for Pharmacogenomics and Individualized Therapy.

patient, the Mayo Clinic Center for Individualized Medicine (CIM) has created translational programs and infrastructure across its multi-campus academic health system.⁹ The translational programs connect patient care with emerging genomic discoveries including clinomics, epigenomics, microbiome, biomarker discovery, and pharmacogenomics. The infrastructural programs provide technical expertise for genomic discoveries including bioethics, bioinformatics, biorepositories, information technology, medical genome facility, and administration.⁹

The CIM has spearheaded institutional pharmacogenomics efforts through the Pharmacogenomics Task Force to integrate drug-gene alerts into clinical decision support tools for inpatient and outpatient order prescribing systems across the academic health system.^{9,10} The pharmacogenomics-based CDS alerts bring drug-gene information and education to the prescribers for selection of drug and dose to enhance clinical care for all patients using genomics. Historically, the Rochester campus used one EHR system (Centricity Enterprise, GE Healthcare, Seattle, WA)

and the other campuses used a different EHR system (Cerner Corporation, North Kansas City, KS); both EHR systems supported the delivery of personalized medicine. All campuses migrated to a single EHR system (Epic, Verona, WI) by the end of 2018, and CDS-alerts for pharmacogenomics have been incorporated into the new EHR system.

Two preemptive genotype testing approaches have been implemented. In an initial 1,000 patients the Right Drug, Right Dose, Right Time—Using Genomic Data to Individualize Treatment Protocol (RIGHT Protocol), a preemptive genotyping approach, was recently investigated. The initial phase of the project resulted from the collaborations of the National Institutes of Health, the Electronic Medical Records and Genomics Network (<http://emerge.mc.vanderbilt.edu>), and the Pharmacogenomics Research Network (www.pgrn.org), and was designed to investigate the impact of preemptive genotyping delivered through an electronic medical record resulting in genomic-driven drug therapy.¹⁰ The expansion of the project (RIGHT10K) to include 10,000 participants is underway.

More commonly, reactive clinical genotyping is performed secondary to a prescriber's order after receiving a CDS drug-gene alert that prompts prescribers to order genotype testing for severe drug-gene interactions such as hypersensitivity and toxicity reactions.⁹ An example of a CDS alert is shown in Figure 1. Actionable pharmacogenomics results are standardized, interpreted, and placed into a patient's electronic medical record as a molecular diagnostic lab result.¹⁰ The lab result triggers the CDS rules.

The process of selecting relevant drug-gene pairs involves significant input from and coordination with multi-disciplinary groups located across the multi-campus academic health system. Pharmacogenomic drug-gene candidates are vetted through the Pharmacogenomics Task Force, 13 Disease-Oriented Task Forces, Pharmaceutical Formulary Committee, and Clinical Decision Support Subcommittee for integration into clinical care.¹⁰ Active drug-gene pairs include abacavir/*HLA-B*57:01*, carbamazepine/*HLA-B*15:02* and *HLA-A*31:01*, thioguanine/*TPMT*,

Figure 1. Clinical decision support (CDS) alert for thiopurines-thiopurine methyltransferase (*TPMT*) testing. Used with permission of Mayo Foundation for Medical Education and Research. All rights reserved.

mercaptopurine/*TPMT*, azathioprine/*TPMT*, codeine/*CYP2D6*, tramadol/*CYP2D6*, tamoxifen/*CYP2D6*, clopidogrel/*CYP2C19*, simvastatin/*SLCO1B1*, warfarin/*CYP2C9* and *VKORC1*, allopurinol/*HLA-B*58:01*, citalopram/*CYP2C19*, escitalopram/*CYP2C19*, fluoxetine/*CYP2D6*, fluvoxamine/*CYP2D6*, paroxetine/*CYP2D6*, venlafaxine/*CYP2D6*, tacrolimus/*CYP3A5*, 5-fluorouracil/*DPYD*, and capecitabine/*DPYD*.^{9,10} CDS rules will continue to be developed and integrated into the electronic prescribing systems in the future based upon evidence and with institutional support from the clinical practice Disease Oriented Task Forces, CIM Pharmacogenomics Task Force, Pharmacy and Therapeutics Committee, Pharmaceutical Formulary Committee, and Clinical Decision Support Subcommittee.

Pharmacogenomics face-to-face patient visits, electronic consultations, and questions are triaged to Medication Therapy Management Pharmacogenomics Pharmacists at each of the main sites (MN, FL, and AZ) who support rapidly expanding Pharmacogenomics Practices that includes advising prescribers on ordering pharmacogenomics tests, evaluating results, and counseling patients through medication therapy management (MTM) appointments. With implementation of the RIGHT10K project and other research pilot projects, pharmacogenomics is broadly impacting patient care throughout the health care system. As a result, additional pharmacist resources are being allocated and trained to support the growth of pharmacogenomics consultations. Additionally, we continue to develop and deliver pharmacogenomics education to provide just-in-time education for inpatient, outpatient, and MTM pharmacists to understand, interpret and provide therapeutic options for prescribers in the health care continuum.¹¹

These interdisciplinary efforts represent key steps toward integration of genomics into clinical care to provide individualized therapeutic treatments. Future directions include expanding

continuing professional development opportunities to support and enhance pharmacogenomics education for pharmacists and other health professionals throughout the multi-campus academic health system and nationally. Development of postgraduate year 2 (PGY2) pharmacogenomics specialty residencies are being planned. Formal training opportunities include graduate studies in the Mayo Clinic Molecular Pharmacology and Experimental Therapeutics program on the Rochester campus, and other pharmacogenomics training opportunities include competency-based educational modules, individualized medicine grand rounds and monthly interdisciplinary case conferences.

University and Academic Medical Campus Collaboration, University of North Carolina Healthcare, Chapel Hill, NC

In order to optimize the delivery of various emerging sciences to improve the care provided to patients, an interdisciplinary approach is necessary. This strategy ensures that all stakeholders are represented and the expertise of all disciplines is used. Several examples of this collaborative research and practice can be seen in universities and academic medical centers throughout the United States. One such interdisciplinary practice has been highlighted.¹²

The University of North Carolina at Chapel Hill initiated one of the first comprehensive academic programs in the field of pharmacogenomics, which was first entitled the Institute for Pharmacogenomics and Individualized Therapy, but is now known as the Center for Pharmacogenomics and Individualized Therapy (CPIT). The Institute for Pharmacogenomics and Individualized Therapy was established in 2007 by Dr. Howard McLeod, and CPIT is currently led by center director Dr. Tim Wiltshire. It is administratively supported through the UNC Eshelman School of Pharmacy and is centered within the UNC Genetic Medicine Building. The mission of CPIT is to

employ an interdisciplinary approach to develop therapies and enable the delivery of individualized medical practice. This required developing a structure which extends across traditional divisional/departmental/school boundaries that can impede scientific discoveries and implementation of pharmacogenetics into routine clinical practice. CPIT members include faculty from the Schools of Pharmacy, Medicine, Public Health, Nursing, Business, Social Work, Law, and Information and Library Sciences. The program also integrates adjunct faculty from external organizations such as the United States Food and Drug Administration, North Carolina State University, and local private enterprises.

CPIT has been able to take advantage of existing core facilities on campus, as opposed to replicating these efforts. These facilities include a Molecular Genomics Facility, which provides high-throughput processing of samples for SNP analyses. The Cellular Phenotyping Facility provides high-throughput assays for the assessment of cellular functions.

The ongoing research programs range from bench to bedside. Basic/translational (bench) research includes initiatives that leverage technologies aimed at expanding the ability to identify common and rare genetic mutations that associate with phenotypes of interest (i.e., efficacy or resistance to certain chemotherapy drugs, or drug-induced toxicities). One such example is the development of a custom-designed gene capture approach for Next-Generation Sequencing molecular inversion probes in CPIT, named DNA2Rx. The DNA2Rx assay set allows CPIT researchers to test genotype-phenotype associations in 23 genes that have been deemed by CPIT faculty to be central to the “actionable pharmacogenome.” Criteria for gene inclusion on the DNA2Rx panel (e.g., central to the “actionable pharmacogenome”) include genes with robust experimental clinical and translational data that are supported by guidance information by the FDA (in the medication package insert) and/or by Clinical Pharmacogenetics Implementation

Consortium guidelines. CPIT researchers have also traditionally collaborated on clinical research (bedside) initiatives, such as prospective trials evaluating the role of genotype-guided dosing in medications such as warfarin, tamoxifen, clopidogrel, and tacrolimus. Such clinical trials include evaluations of *CYP2D6* testing on tamoxifen, *VKORC1* and *CYP2C9* on warfarin, and *CYP2C19* on clopidogrel.¹³⁻¹⁵ Pharmacogenomics implementation sciences research, including development of clinical decision support tools, inclusions and use of the pharmacogenetics information in the institutional EMR (Epic), education for pharmacy school students, education for community pharmacists and physicians, and pharmacoeconomics studies are also underway. These studies not only answered valuable questions, but also assisted in developing practice models which made use of pharmacists and pharmacy systems to identify potential patients, interpret results, and develop action plans for modifying therapy. CPIT also includes researchers who evaluate health care policy and ethical, pharmacoeconomic, and implementation science questions central to integrating personalized medicine in routine clinical practice.

There is also a robust set of graduate and professional programs designed to educate future pharmacists, clinical pharmacologists, other health care professionals, and translational researchers on these emerging sciences. Training opportunities include graduate studies and the fellowship program within the UNC Eshelman School of Pharmacy's Division of Pharmacotherapy and Experimental Therapeutics. In addition, CPIT has developed an interactive teaching paradigm for the students in the professional program. Using the molecular inversion probes set, second-year Doctor of Pharmacy students at UNC can have their DNA genotyped, and, subsequently, CPIT faculty educate the students on how to interpret and apply pharmacogenetic information to their respective pharmacy practices. To date, over 250 UNC students have been genotyped as part of this

educational program. The UNCCenter for Pharmacogenomics and Individualized Therapy is an example of universities and academic medical centers that take broad, interdisciplinary approaches to the advancement of emerging sciences by optimizing resources and delivering high quality results which will advance medical knowledge to improve the care of our patients.

Education and Training Program, University of Florida, Gainesville, FL

The University of Florida (UF) Health Personalized Medicine Program (PMP) is a pharmacist-led program established to develop and launch the clinical infrastructure required to generate electronic health record alerts to allow physicians to consider genetic information when prescribing certain medications.¹⁶ Beginning in June 2012, all patients undergoing cardiac catheterization received preemptive pharmacogenomic testing on a custom genotyping chip that queries 256 SNPs, including 7 *CYP2C19* SNPs, as part of their clinical care for genotype-guided clopidogrel therapy. The prescribing physician and a clinical pharmacist are alerted through CDS in the electronic health record when a pharmacogenomic test indicates a potential reduced response to clopidogrel and the need for a drug therapy change. To date, over 1,000 patients have been genotyped and this service remains standard of care in the cardiac catheterization laboratory. In June 2013, this service transitioned from a preemptive model that was supported in part by research funds to a clinical billing model in which the test is targeted to patients undergoing a successful percutaneous coronary intervention (PCI). The program has also implemented and provides clinical pharmacist support for genotype-guided therapy for codeine/*CYP2D6* and tramadol/*CYP2D6*; azathioprine/*TPMT*, mercaptopurine/*TPMT*, and thioguanine/*TPMT*; and pegylated-interferon alpha/*IL28B* (*IFNL3*).

The PMP initiated a PGY2 pharmacogenomics and drug information pharmacy residency in collaboration with UF

Health Shands Hospital in July 2012.¹⁶ The pharmacy resident was corecepted by the PMP and Drug Information Center Directors. Initial resident responsibilities within the program included coordinating literature evaluation for drug-gene pairs, serving as liaison between the PMP subcommittee and the UF Health Pharmacy and Therapeutics Committee, assisting with CDS implementation, facilitating drug-therapy changes based on pharmacogenomic test results, and tracking quality improvement measures of PMP initiatives. In the first year of the program, the resident also implemented an evidence-driven revision of the *CYP2C19*-clopidogrel CDS protocol and spearheaded development of a *CYP2D6*-codeine initiative.

Based on experiences in year 1, program modifications made in year 2 included expansion to 2 residency positions and addition of a clinical pharmacist PMP Associate Director to serve as residency director and educational coordinator. In recognition of differences between the evaluation of pharmacogenomics literature and a traditional drug information practice, residency goals and objectives shifted to focus on pharmacogenomics and this program is now accredited by ASHP as a PGY2 pharmacogenetics specialty residency. In addition to previously described responsibilities, current residents evaluate and provide clinical recommendations for pharmacogenetic tests within UF Health; provide clinical services in patient care areas targeted for drug-gene implementations; provide pharmacogenetic consultations; assist with development, approval, and building of Best Practice Advisories within the Epic electronic health record; participate in program quality improvement and data collection activities; create and maintain an evidence database for all clinical implementations; participate in establishing new clinical services; and serve as an assistant editor for *SNP•its*, a clinical pharmacogenetics newsletter published by UF Health PMP (available at <http://personalizedmedicine.ufhealth.org>). Residents also participate in health-system formulary, medication

safety, and informatics initiatives related to pharmacogenetic implementations. To date, 5 residents have graduated from this program. All graduates currently practice in clinical and/or academic positions focusing on implementing pharmacogenomics in the clinical setting.

PMP pharmacists have also developed and offer an advanced pharmacy practice experience in Evidence-Based and Personalized Medicine; an elective course for Doctor of Pharmacy students focusing on clinical aspects of pharmacogenomics and genomic medicine; interprofessional continuing education courses for pharmacists, physicians, and nurses; and a certificate training program for pharmacists in pharmacogenomics.¹⁷ These educational offerings incorporate participant genotyping and use of individual genetic information to complete patient cases and other course activities.

Summary

As the world of pharmacogenomics continues to evolve and expand, many new jobs are being created, and pharmacists should take advantage of these unique opportunities. In addition to academic medical centers, community hospitals are starting to implement pharmacogenomic testing in their patients, and pharmacists are being recruited because of their drug knowledge expertise. One new pharmacogenomic practice setting is companies such as Genelex (Seattle, Washington), the makers of the YouScript software (<http://youscript.com/>). These companies are looking to hire pharmacists who are versed in pharmacogenomics in order to help health care professionals provide personalized medicine therapies to their patients. Other startup companies with similar interests are emerging across the United States. Training programs which focus on or incorporate the principles of pharmacogenomics will be essential in ensuring qualified pharmacists can meet this growing demand.

The future of pharmacogenomics and pharmacy practice continues to offer opportunities and challenges

for pharmacists, both practicing and in professional training programs. Improving laboratory and information technologies and decreasing price points for pharmacogenomics testing will enhance the incorporation of drug-gene information into the EHR. Enhanced drug-gene-drug interaction modeling, prediction, and IT software will assist pharmacists in applying pharmacogenomics clinically. Although this will in large part be driven by consumer demand to personalize and optimize patients' health care needs, the cultural, financial and health system changes that will be needed to support this changing direction will be the rate-limiting step for rapid adoption. Focus on ethical, legal, and social issues will also need to keep pace with this growing and constantly evolving area to prevent genetic discrimination and genomic health disparities. Existing pharmacists will thrive with a new mindset open to change and flexibility to adapt to continuing growth in pharmacogenomics and who actively pursue pharmacogenomics education in the forms of continuing education programs and accredited pharmacogenomics certifications.

It is our hope that readers will be able to take several points away from examples provided in this article. The first point is to demonstrate the interrelationship of pharmacogenomics and PPMI goals established by ASHP and the ASHP Research and Education Foundation. Pharmacogenomics is an essential tool in the delivery of personalized medicine, and we hope that hospitals and health-systems view this as a current priority. The second point is to provide pharmacists with a framework for implementing pharmacogenomic practices for those considering these types of initiatives. Operational complexities exist for delivering this technology as part of a new practice model. Additionally, an interdisciplinary effort including clinicians, health-system administrators, information technology specialists, and laboratory medicine representatives will be required. Oversight committees, including institutional Pharmacy and Therapeutics Committees, are essential

for ensuring that appropriate interdisciplinary groups are involved and decisions are made that using the highest level of evidence-based medicine. Finally, institutions described herein can be viewed as a point of contact for those who want to learn more about how these initiatives were developed and begin their first steps towards implementing pharmacogenomics clinically with 1 or 2 drug-gene pairs, leveraging IT resources to support CDS alerts and educational resources.

Barriers exist for institutions to fully operationalize and make use of pharmacogenomics. The institutions highlighted in this work were all able to receive grant funding to aid in the implementation of pharmacogenomics, which may not be possible for many hospitals or health systems. Demonstration of the cost-effectiveness of pharmacogenomics services is needed not only to maintain established resources but also to share this knowledge so that other institutions can use it to justify pharmacist positions and other resources to their hospital administration. Even with approved funding for resources, there is a relatively small workforce trained in the clinical, administrative, and technological skills needed to implement pharmacogenomics in a structured manner. Finally, ethical, legal, and social issues continue to serve as potential issues in the implementation of pharmacogenomics. Concerns related to the need for informed consent, fear of genetic discrimination, and potential impact on relatives to the patient need to be addressed and education is needed for both patients and health care professionals.¹⁸

Several of these institutions were identified through the efforts of the ASHP Section of Clinical Specialists and Scientists Section Advisory Group on Emerging Sciences. The goal of this group is to identify and develop tools for health-system pharmacists to advance their knowledge and ability to use emerging sciences. Pharmacogenomics is clearly an emerging science that is in the implementation and adoption phase. If the profession of pharmacy is to

serve as a leader in the advancement of patient care delivery models such as the PAI and PPMI, then the implementation of personalized medicine incorporating the science of pharmacogenomics will need to be a fundamental part of that model.

Conclusion

Through prioritized efforts of the pharmacy profession and health care institutions, pharmacogenomics will be disseminated and implemented, and the goal of the Pharmacy Practice Model Initiative's consensus statements of improving health care using patients' genetic characteristics will be realized.

Disclosures

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