Continuing Education

PHARMACIST CE:

Pharmacists as Champions of Pharmacogenomics: Bringing Precision Medicine into Clinical Practice

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CE FOR **PHARMACISTS**

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Learning Objectives

- Define the purpose of pharmacogenetic testing in clinical practice
- Identify differences in preemptive, reactive, and prospective testing and situations where each test strategy may be beneficial
- Explain the pharmacist's unique role as a pharmacogenomics resource for both provider and patient
- Describe current opportunities and challenges in the implementation of pharmacogenomic testing
- Identify appropriate resources for further information

Pharmacogenetics (PGx) focuses on explaining how an individual's genetic polymorphisms in drug metabolic pathways can cause variation in medication response.[1-3] These genetic variations have been estimated to account for 20 to 95 percent of the difference in individual responses to drugs.[3] In healthcare settings, this genetic information is linked together with clinical data to guide providers in selecting safer and more effective medication therapies for patients.[1,2,4] Integrating pharmacogenomics into current healthcare models aims to improve the patient experience, reduce cost, and improve population health.[4,5] Currently, more than 26 million people have taken an at-home ancestry test, which showcases the surging public interest surrounding genetic information.[6] In April, 2019 the American Journal of Managed Care estimated that by 2021, over 100 million people will have used a direct-to-consumer genetic test.[7] As healthcare systems continue to be more consumer-driven, today's healthcare professionals must possess knowledge and skills desired by patients who see the importance and value in personal genetics as well as applications of pharmacogenomics.[1,5]

Similarly, pharmacists are changing roles as well, evolving from the image of a drug reference and medication dispenser, and transitioning to a critical member of the patient care team. However, many practicing pharmacists feel unprepared to assume responsibility for interpreting results of pharmacogenetic tests and using results to make changes to pharmacotherapy plans.[8-10] Therefore, it is critical for both currently practicing and future pharmacists to develop a fundamental understanding of basic genetic concepts underlying pharmacogenomics and remain engaged with its application in patient care.[1,8] As clinical evidence supporting the use of pharmacogenomic testing continues to grow, the importance of expanding the knowledge and infrastructure to utilize PGx data in medication therapy and delivery of healthcare to patients will continue to gain momentum.[11,12]

Fortunately for pharmacists and prescribers, guidelines published online by the Clinical Pharmacogenetics Implementation Consortium (CPIC) are freely available to aid in translating genetic laboratory test results into actionable prescribing decisions for established gene-drug pairs.[2,6] Clinicians can utilize CPIC for assistance in making medication dose adjustments or suggesting treatment alternatives, as well as providing direction for safe prescribing practices.

Physicians and pharmacists alike have first-hand, clinical experience witnessing that standard doses of drugs do not produce the same response in all patients. PGx testing can help to identify patients more likely to benefit from a particular drug or class of drugs, and provide insight to dosing adjustments, both of which help to limit the enormous costs of "trial and error" approaches to prescribing.[13,14] In 2016 in the United States, the estimated annual cost of prescription drug-related morbidity and mortality resulting from drug therapy problems was $528.4 billion dollars.[4] This data directs to the significant economic impact associated with the underlying variability in treatment response as well as risk of adverse events. While many factors contribute to these phenomena, genetic factors might contribute in part to the observed variability and the occurrence of adverse events for a subset of the overall medication-associated costs. There is growing evidence that PGx testing can reduce health care cost. Using pharmacogenomic testing may help predict and limit adverse drug reactions to ultimately reduce the financial burden caused by hospitalizations and deaths resulting from these adverse drug events.

Pharmacogenomic testing is relevant to the majority of patients and is quickly becoming the standard of care when prescribing medications with established drug-gene interactions.[5] The US Food and Drug Administration (FDA) now includes pharmacogenomic labeling information for over 200 medications, including some that warn of potential life threatening situations via "Black Box warnings." Relevant genomic information on drug labels is anticipated to increase in the future, as pharmacogenomic data is incorporated into drug development studies.[1,12]

Currently, there are many guidelines and resources available to help pharmacists and other providers translate genetic laboratory test results into actionable prescribing decisions for affected drugs.[11,15,16] Pharmacists have the requisite knowledge (e.g., pharmacokinetics, pharmacodynamics, and pharmacology) and possess the training to educate patients and providers regarding the use of pharmacogenetic information. The profession is well-positioned to increase safe medication use by prescribers, monitor adverse drug reaction occurrences, and perform adherence assessments of patients with respect to their medication use.[17,18]

Why Provide PGx Testing?

There is growing interest from patients as well as healthcare providers in understanding the role of pharmacogenetic testing to improve outcomes and lower healthcare costs.[19] In the US, 18% of all prescriptions are influenced by actionable PGx genes, with 90-99% of the population having at least one high-risk variant for established genes.[2,15,20,21] Common reasons why providers refer patients to PGx services

TABLE 1. Drug-Gene Pairs with Actionable CPIC Guidelines

Gene(s)	Drug
CFTR	ivacaftor
CYP2D6	atomoxetine, codeine, ondansetron, SSRIs, tamoxifen, TCAs
CYP2C9, HLA-B	phenytoin
CYP2C9, VKORC1, CYP4F2	warfarin
CYP2C19	clopidogrel, SSRIs, TCAs, voriconazole
CYP3A5	tacrolimus
G6PD	rasburicase
HLA-B	abacavir, allopurinol, carbamazepine
SLCO1B1	simvastatin
TPMT/NUDT15	azathioprine, mercaptopurine, thioguanine

Established drug-gene pairs with actionable CPIC guidelines. CPIC = Clinical Pharmacogenetic Implementation Consortioum; TCAs = tricyclic antidepressants; SSRIs = selective serotonin reuptake inhibitors.
Source: cpicpgx.org/genes-drugs/

include: toxicity concerns, side effects, medication non-responders (e.g., lack of efficacy), family history of significant variants, preemptive to treatment, or incidental research findings.[15] As of 2019, there were 23 published pharmacogenomic-based CPIC guidelines covering 19 genes and 46 drugs across a variety of therapeutic categories. A selection of commonly known gene-drugs pairs pharmacists should be familiar with are shown in Table 1.

Pharmacogenomic testing provides an ideal opportunity for collaboration between physician and pharmacist to provide comprehensive, personalized patient care (Figure 1). Previous studies have reported patient perspectives of PGx testing to be overall very positive and supportive of future integration into healthcare.[22,23] Historically, patients view pharmacists as accessible, trustworthy sources of medical information. Furthermore, PGx testing helps give patients an opportunity to be proactive in their plan of care which may help to increase medication compliance.[17,22,24] Pharmacists will continue to hold a very critical role in bringing pharmacogenomic testing to the frontlines of patient care to help promote more informed medication decision making among providers.

Pharmacogenomics & Precision Medicine Algorithm

The 4 "I's" of PGx Testing

The four key elements encompassing pharmacogenomic testing, which providers should be familiar with, include: indication, investigation, interpretation, and implementation. Each of these four areas contributes to the desired final result which is the provision of an actionable recommendation based on pharmacogenomics that positively influences patient care. The pharmacist should have an understanding of the necessary patient information, sample type (saliva, blood, buccal), cost of testing, amount of data generated by the test, turnaround time of results, and presumed actionability, prior to selecting a particular pharmacogenomic test. Testing efforts should focus on established drug-gene pairs that have evidence-based guidelines and clinical recommendations for action by the clinician.[2,21,25] While understanding the complex sequencing techniques is not required to understand the clinical application of PGx testing, the pharmacist should know the strengths and weaknesses of the intended test.[2]

Indication: Reactive, Preemptive, or Prospective

Presently, the majority of testing done is reactive, which occurs after a patient experiences an adverse effect or has a history of non-response to drug therapy.[5] Reactive tests are ordered on an "as needed" basis for pharmacogenetically actionable drugs, which requires clinicians to have foundational pharmacogenomic knowledge and be aware of important gene-drug pairs to prompt ordering of the genetic test.[2,20] If the PGx test is not comprehensive, covering a broad range of genes, changes to a patient's medication therapy or onset of additional medical issues may require ordering an additional PGx test. This reactive method requires added time for testing and reporting of results, thereby limiting provider access to valuable PGx information for prescribing decisions.[20] A retrospective pharmacogenetic study which used a 3-gene panel to test patients found that 34% of all potential major adverse drug reactions were due to a patient's individual genetics and not drug-drug interactions.[26] This finding highlights the need for PGx testing within the clinical environment with engagement by pharmacists to assist in individualizing therapies for patients to achieve desired health outcomes.

Preemptive testing aims to proactively test patients prior to medication use to help avoid adverse drug reactions and improve medication efficacy.[20,27,28] Testing can be customized to fit the needs of the patient, such as testing one specific gene or testing a select group of genes using a limited gene panel. The preemptive method of testing can also be utilized for dosing information for certain high risk medications with a narrow therapeutic index, where the risk of adverse drug reaction could be extremely harmful or result in costly hospitalization.[14,18,27] For example, the drug mercaptopurine can cause severe myelosuppression in certain patients that are unable to metabolize the drug efficiently, therefore, preemptive testing prior to using the drug helps providers make more informed treatment decisions, avoid adverse drug reactions, and improve the patient experience.[18,29] Preemptive testing can also provide information that may be relevant at a later

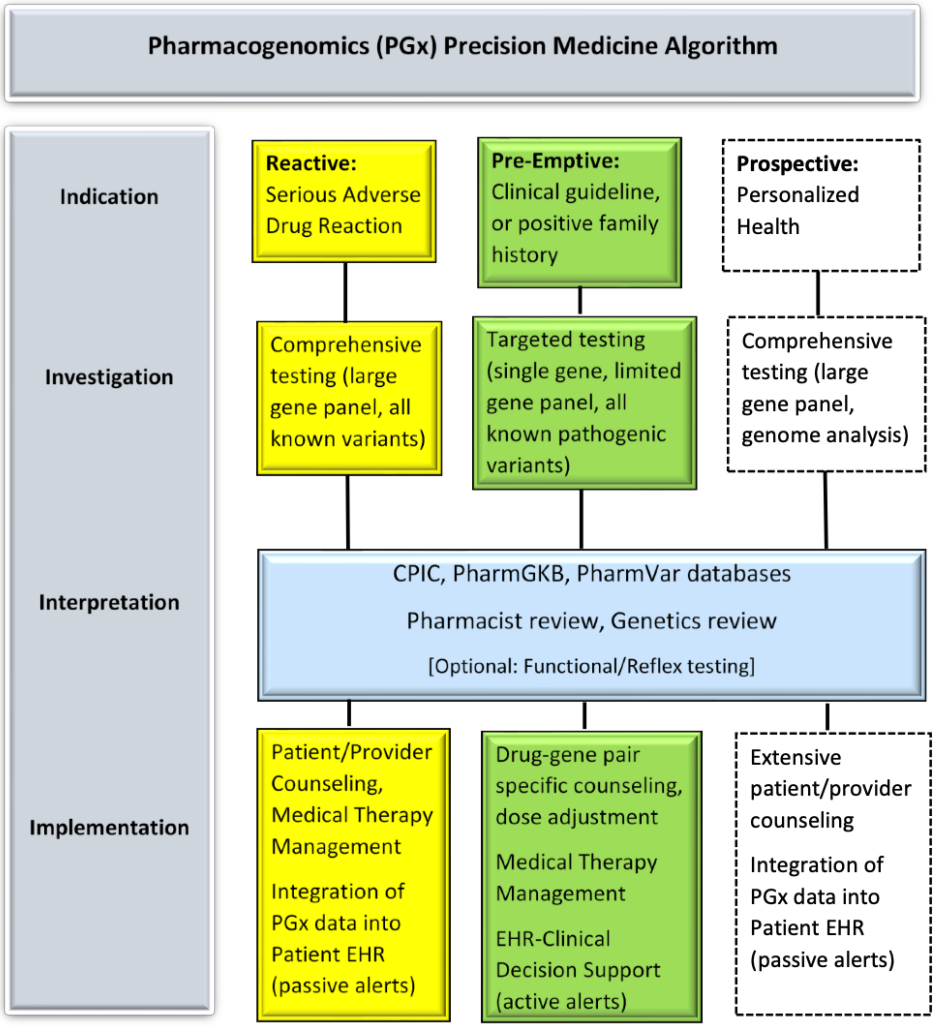
time, as health conditions and medication needs of the patient change, yet their genotype will likely remain the same.[27,30] As pharmacogenomic testing continues to decrease in cost, there will be a greater push for preemptive testing as a more comprehensive and cost-effective approach to patient care.[2,5]

Prospective testing is another option in the expanding realm of personalized healthcare. A large gene panel or even whole genome sequencing can be done to gather the most complete picture of a patient's genetic information. Conducting PGx testing on a prospective basis in younger patients may have great utility as the patient grows older and matures, providing metabolic drug information over a lifetime. Yet at this current time, most prospective testing is done primarily in the research setting, as this testing option comes at a greater cost and generates the largest amount of data, often with limited actionability.

Investigation: Comprehensive vs Targeted

Pharmacogenomic testing can also be performed at various levels of specificity. If there is a specific gene-drug pair in question, a single gene assay could be sufficient to offer prescribing guidance to the clinician.[31] A well-known example would be the interrogation of cytochrome P450 2C19 (CYP 2C19) metabolizer status prior to utilization of clopidogrel after stent placement.[11,32,33] However, many medications are metabolized by more than one enzyme (Table 1), and it may be necessary to screen multiple genes for variation.[2] In this case a broader, more comprehensive testing approach is needed, in order to interrogate a variety of genes at one time. This may be accomplished through various targeted gene panels, which can identify common variant sequences using a reference database.[31] Gene panels can be customized to fit the needs of the user in order to maximize currently known variant information with guideline supported actionability. Some multi-gene panels may be targeted, limited to ten or fifteen genes, while others can cover hundreds of genes and thousands of possible single nucleotide polymorphisms (SNPs).[34]

FIGURE 1. The 4 "I's" of Pharmacogenomics (PGx) Precision Medicine Algorithm



EHR = electronic health record, CPIC = Clinical Pharmacogenetic Implementation Consortioum
Dashed lines indicate the practice is not yet standard of care

Interpretation: Using Evidence-based Guidelines & Clinical Expertise

Collecting pharmacogenomic data is only the first step. The next critical step is interpreting the data in an evidence-based manner to impact patient care. The Clinical Pharmacogenetics Implementation Consortium (CPIC) is an international consortium of experts in the field of PGx, curating published scientific evidence to facilitate clinical implementation of pharmacogenetic tests.[15] CPIC provides freely available, evidence-based and peer-reviewed pharmacogenetic clinical practice guidelines.[15,35] The purpose of CPIC is to help clinicians understand how available genetic test results should be used to optimize drug therapy and improve patient care.

Levels of evidence are systematically assigned to each drug-gene association, along with the strength of each prescribing recommendation.[15,27,35] CPIC guidelines are divided into four tiers (A, B, C, and D). Levels A and B recommend at least one "change in prescribing" action, based on the patient's genotype.[15,27,35,36] These guidelines are exceptional resources for determining the clinical relevance of gene-drug pairs.[15,37] Of note, the CPIC guidelines are intended to guide clinicians in understanding how to use available genetic test results to improve drug therapy, not to provide guidance on whether these tests should be ordered.[25,36]

For many PGx relevant genes, variation in alleles are described using a haplotype-based star nomenclature (i.e.

*1/*2).[25,38] Collectively both haplotypes represent the patient's genotype, which correlates to an assigned phenotype and subsequent variability in medication response.[25] It should be noted that star allele designations are unique to each gene and were assigned in the order of discovery, leading to a lack of standardization in genetic variation definitions.[38] Thus, it is imperative for pharmacists to refer to credible resources, such as CPIC, when interpreting results of PGx tests. Functional classification of phenotypes can be broadly divided into four categories of normal metabolizers (NM), poor metabolizers (PM), intermediate metabolizers (IM), and ultra-rapid metabolizers (UM).[25,38] Pharmacists can use this patient-specific metabolic information, along with known pharmacokinetic and pharmacodynamic data, to generate a more complete picture of drug therapy in patient care.

Currently, CPIC has 23 published guidelines, covering 19 genes and 46 drugs in several therapeutic areas.[27] CPIC also provides additional resources to facilitate the implementation of pharmacogenomics into routine clinical practice, including adapting the electronic health record (EHR).[15,27]

Additional resources are also available for clinicians wishing to dive further into pharmacogenomics. The Dutch Pharmacogenetics Working Group (DPWG) is similar to CPIC, and consists of a multidisciplinary team of healthcare professionals which aid in the development of PGx guidelines and application of PGx in patient care.[39] The Pharmacogenomics Knowledge Base (PharmGKB), funded by the National Institute of Health (NIH), is an online resource that provides information about how variations within human genetics affects patient's response to medications.[40] Additionally, the FDA maintains a list of tables organizing PGx information which is mentioned on drug labels.[41] These can include patient variability to drugs, risk of adverse effects, and genotype specific dosing recommendations.[12,41]

Depending on the scope of the PGx test and amount of data generated, the pharmacist may collaborate with a medical geneticist to gain a deeper understanding of test results and discuss possible impacts on medication therapy plans or patient care in the future. In some cases, reflex testing may be done to provide further clarification if there is ambiguity from the results of the initial PGx test. If incidental findings are discovered during the evaluation of a patient's PGx test results, the medical geneticist or genetic counselor is an excellent resource for communicating these findings to patients.

Implementation: Data Integration & Clinical Decision Support

The clinical significance of PGx testing stems from using evidence-based guidelines linking genotype to phenotype and relating that phenotype to proper medication selection, avoidance, or dose adjustment.[21,42] The pharmacist can be invaluable in bringing PGx into patient care through translating PGx test results into clinically relevant action. Once results are received, the pharmacist can work with the physician to adjust, discontinue, or change medications to better suit the patient's unique genetic profile and health needs. These medication therapy recommendations can also be built into the EHR to fire as alerts to warn providers at the time of medication prescribing and are known as Clinical Decision Support tools (CDS).

Examples of PGx Testing in Clinical Care

Pain Management

The metabolism of codeine into morphine is mediated by the enzyme CYP2D6, which governs both the efficacy and safety of the drug.[43-45] The various metabolic phenotypes associated with of CYP2D6 have been well defined.[46] Patients with non-functional CYP2D6 alleles will not convert codeine to morphine and will not experience analgesia from treatment with codeine.[43] Those patients are still at risk for adverse reactions due to codeine therapy, but will not receive any medical benefit (i.e., pain relief) from therapy.[43,46] Patients who are CYP2D6 ultra-rapid metabolizers can be exposed to toxic concentrations of morphine even when administered only small codeine doses.[44,46] Reports have shown based on CYP2D6, 12% of the population should not take codeine due to either poor metabolic activity or ultra-rapid metabolic activity.[45]

Cardiology

The anticoagulant agent clopidogrel is a widely prescribed cardiovascular drug with a narrow therapeutic index. Clopidogrel is a prodrug which requires metabolic activation by CYP2C19, to be effective.[3,28,32] Genetic polymorphisms in the CYP2C19 gene influence the metabolism and subsequent efficacy of clopidogrel.[32,33] CYP2C19*2 and CYP2C19*3 alleles are categorized as nonfunctional and lack enzyme activity, which results in reduced activation of clopidogrel, diminished platelet inhibition, and greater likelihood of a cardiovascular event.[3,45] Clinical implementation of CYP2C19 genotyping to guide antiplatelet therapy has shown success in avoiding prescribing clopidogrel to patients who are intermediate and poor metabolizers of the drug.[32,47] For example, *2 is the most common CYP2C19 loss-of-function allele which has a frequency around 15% in Caucasians and Africans, and as great as 35% in Asians. These patients who have the *2 allele cannot metabolize clopidogrel properly and thus will not achieve therapeutic drug levels.[35]

Psychology

Many commonly used psychiatric medications, including various tricyclic antidepressants (TCAs) and selective serotonin receptor inhibitors (SSRIs), are metabolized via CYP2D6 and CYP2C19 enzymes.[42] The metabolism and activation of nearly 25% of antidepressants, antipsychotics, and opioids takes place via CYP2D6, which is a highly polymorphic gene.[48] The Sequenced Treatment Alternatives to Relieve Depression (STAR*D) trial, funded by National Institutes of Health, was a landmark pharmacogenetic study of mood disorders.[49] Participants from the study showed that allele variation among different ethnicities impacted effectiveness of antidepressant treatment.[49,50]

However, determining the impact of multiple variants within these key genes remains complex.[51] In practice, a substantial proportion of depressed patients will fail to respond to the first-line antidepressant treatment.[49,52] This style of "trial and error" prescribing with a high likelihood of treatment failure can be frustrating to patients, especially those with behavioral-related conditions. Pharmacogenomic testing can be done to estimate a patient's drug-metabolism phenotype to aid in the selection of psychiatric medications that are predicted to maintain therapeutic drug levels to minimize adverse effects and increase the likelihood of favorable patient response.[48,51,52] For example, a patient that is a CYP2C19 poor metabolizer of escitalopram may be at an increased risk of an adverse reaction due to elevated escitalopram plasma concentrations, therefore the clinical pharmacist may consider a 50% starting dose reduction for these patients.[16]

Oncology

One of the largest areas utilizing the benefits PGx testing is within the field of oncology. For some anticancer drugs, pharmacogenomic testing is considered part of routine oncologic care.[3] Patients with acute lymphoblastic leukemia (ALL) can be preemptively tested for genetic variants in two critical genes, thiopurine methyltransferase (TPMT) and nudix (nucleoside diphosphate linked moiety X)-type motif 15 (NUDT15).[3,29] These two genes, TPMT and NUDT15, are responsible for the metabolism of a class of commonly used chemotherapy agents, the thiopurines, which includes mercaptopurine and thioguanine.[53] Patients with variants in either TPMT or NUDT15 resulting in reduced thiopurine metabolism are significantly more likely to experience toxicity and severe myelosuppression during treatment.[29,53] Recent additions to CPIC guidelines highlight the importance of testing for NUDT15 especially in non-Caucasian ethnicities.[29,53] Preemptive PGx testing of TPMT and NUDT15 allows providers to proactively make chemotherapy dosing adjustments, based on each patient's specific drug metabolism, to minimize adverse effects and optimize treatment outcomes for patients with ALL.[29,36,53]

Supporting Pharmacist-driven Implementation

Pharmacists are essential in the effective application of all medical therapeutics and are particularly valuable in interpreting pharmacogenetic variants and their impact on drug response.[8,54] Pharmacists are also uniquely positioned throughout the health care system to responsibly advise both providers and patients on the benefits and risks of medications.

Many physicians have experience in genetics but may not understand how to best use pharmacogenomic testing to improve their patient's response to medications, including the avoidance of side effects.[28,54] In 2018, the IGNITE-Network Survey asked physicians about barriers to the clinical implementation of genomic medicine and found that only one-third of respondents felt that their training prepared them to work with patients who were genetically "high-risk."[54] Furthermore, only 23% of physician respondents stated they could find and use reliable resources to understand and communicate genetic risk in the care of their patients.[54]

Holding a pivotal role as both point-of-care providers and recognized medication experts, pharmacists are perfectly positioned to bring PGx testing to the forefront of clinical practice.[55] Throughout the country there are many established,

pharmacist-run clinical pharmacogenetic testing services. One well-known example is the "PG4KDS: Clinical Implementation of Pharmacogenetics" Program at St. Jude Children's Research Hospital, headed by Mary Relling, PharmD.[45] Through this program, every child is offered PGx testing at the time they establish care and this information is incorporated into the EHR. Clinical pharmacogenomic testing programs showcase both the leadership roles pharmacists hold and the impact of their actions on entire healthsystems.[18] Pharmacists have the most experience dealing with medication pharmacodynamics, pharmacokinetics, and medication adherence assessments, thus integrating this valuable gene-drug information is the next skill added to the pharmacist's tool box.[17]

Opportunities for Growth

One of the most critical steps in bringing PGx to the mainstream is to develop "Clinical Champions" of PGx who reach out to grow community involvement and support, as well as provide education to other pharmacists and physicians.[37,56] This will require healthcare institutions to provide PGx-focused education and maintain engagement within the clinical and community settings.[10,17] Pharmacists have the therapeutic knowledge and required clinical skills needed to bring PGx into the clinical setting. Additionally, pharmacists are also widely accessible, making them essential team members in moving personalized healthcare forward.

Access to Electronic Health Record (EHR)

Improving provider access to pharmacogenomic data in the EHR remains a vital part of bringing the clinical implementation into practice.[20,23] The proposed idea of right drug, right dose, right patient, is only possible with the right information, available at the right time as well.[37,45] Informatics, especially in the development of clinical decision support (CDS) within the EHR, is a critical tool for the integration of pharmacogenomics into routine patient care.[30,36] Challenges include storing pharmacogenomic data, which is valuable over a patient's lifetime, presenting recommendations to clinicians in a timely manner that is seamlessly integrated with clinical workflows, and updating CDS recommendations as the knowledge base changes.[20,30,36] Likewise, having universal access to patient PGx data across multiple pharmacy platforms will be essential (e.g., community to long-term care to hospital pharmacy).

Education

Pharmacogenomic education within pharmacy schools is a greatly underutilized opportunity to further promote its implementation into clinical practice. Though the Accreditation Counsel for Pharmacy Education requires that colleges of pharmacy include PGx in their standard coursework, guidance on the extent of the integration of PGx is minimal. As a result, PGx education is incorporated at varying degrees and rarely available as a rotation experience. Future healthcare providers, both pharmacy and medical students, need to have a sufficient amount of opportunities to practice applying pharmacogenomic data in patient care. This should be done within the classroom, in skills laboratories, and on clinical rotations, to prepare learners for the transition into real practice settings as healthcare professionals.

Currently, many pharmacists believe pharmacogenomics is important, but a vast majority lack the knowledge and confidence to act on results of a PGx test.[9,10,30,54] Pharmacy schools need to teach future pharmacists how to apply pharmacogenomic knowledge to make better informed decisions regarding medication therapies for patients.[8,11] Practicing pharmacists have educational opportunities available to earn a PGx certificate, while graduating pharmacy students may consider pharmacogenomic-focused fellowships and residencies.[8] Given the speed at which science and information advance, clinical pharmacogenomics testing programs will be steadily growing and evolving.[13,18,36] Sites will need to develop a process to keep providers educated on new guidelines through events such as interprofessional PGx meetings, continuing education opportunities, and PGx-focused workshops.[2,8,13,25]

Reimbursement

Financial reimbursement for preventive medicine services and pre-emptive screening services is rarely provided to healthcare systems, and even more rarely reimbursed by health insurers which creates a major problem in moving PGx testing forward.[27] Finding a way to differentiate the cost savings of PGx testing, compared to the accepted or reimbursed standard of care and current interventions, also remains difficult. There is a great need to develop a model which could predict the cost savings of preemptive testing and measure long term impacts of PGx test results that impact prescribing decisions.[2,13,36] Without payers seeing the value in routine use of PGx testing, reimbursement will remain limited for the majority of patients.[3,27]

Developing studies to model cost-benefit analysis are extremely difficult and complex, as life-long studies would be needed to show the overall benefit of having genetic information available for prescribers to make informed decisions throughout a patient's lifetime.[5] Additionally, randomized clinical studies of genetically-based prescribing outcomes versus current standards of care are rarely done in pharmacogenomics because the most important variants are rare and sample sizes are often too small to generate significant results.[5,45] In certain high-risk genotypes, avoiding genetically based prescribing could be considered unethical.[36,37]

However, there were promising developments in 2019. In October of 2019, United Healthcare announced they would offer reimbursement for PGx testing in patients diagnosed with major depressive disorder or anxiety and experienced treatment failure with at least one medication.[52] The reimbursement covers the use of a pharmacogenetic multi-gene panel of up to 15 relevant genes to help guide therapy decisions.[52] As one of the top providers of health insurance in the United States, there is hope that this coverage decision will encourage other large healthcare payers to reimburse for PGx testing reimbursement as well.

In Summary

As a significant building block to precision medicine, pharmacogenomics has the opportunity to advance individualized medication therapy and improve patient

outcomes across many populations and conditions. Other healthcare providers can depend more on pharmacists, the medication experts equipped with this new armamentarium, to ensure that patients meet healthcare goals while avoiding adverse drug reactions, thus reducing total costs of care. With the proper education, guidance, and accessibility, pharmacists are well positioned to make contributions to precision medicine and facilitate its delivery into patient care.

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PR *This article has been peer-reviewed. The contribution in reviewing is greatly appreciated!*

Disclosure: Gunter Scharer and Ulrich Broeckel are employed in part by and hold equity in RPRD Diagnostics LLC. The remaining authors declare no real or potential conflicts or financial interest in any product or service mentioned in the manuscript, including grants, equipment, medications, employment, gifts and honoraria.

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Assessment Questions

1. The purpose of utilizing pharmacogenomic testing in clinical practice aims to provide patients:
   a. Improved outcomes
   b. More personalized care
   c. Less risk of ineffective medication selection
   d. All of the above

2. **True or False:** Genetic variations have been estimated to account for 20 to 95 percent of the difference in individual responses to drugs.
   a. True
   b. False

3. Which PGx testing type occurs prior to drug administration in order to proactively making dosing adjustments based on a patient's unique metabolic phenotype?
   a. Reactive
   b. Preemptive
   c. Prospective

4. Reactive pharmacogenetic testing may be useful in situations where:
   a. Prior to giving a highly toxic drug, with a narrow therapeutic window
   b. Patient is not responding to repeated medication dose increases
   c. Results of the test would not change prescriber course of action
   d. Patient wants to know their metabolic phenotype before taking codeine

5. **True or False:** CPIC guidelines are available to help providers decide when to order PGx tests
   a. True
   b. False

6. Which of the following drugs has an actionable CPIC published guideline?
   a. Tramadol
   b. Oxycodone
   c. Aspirin
   d. Clopidogrel

7. Challenges facing the implementation progress of PGx testing in clinical settings include:
   a. EHR functionality to include PGx results
   b. Lack of provider understanding and education
   c. Buy-in and reimbursement from payers
   d. All the above

8. Some key PGx resources include all of the following EXCEPT:
   a. PharmGKB
   b. CPIC
   c. LexiPGx
   d. FDA website

9. Did the activity meet the stated learning objectives? (if you answer no, please email sarahs@pswi.org to explain)
   a. Yes
   b. No

10. On a scale of 1 – 10 (1-no impact; 10-strong impact), please rate how this program will impact the medication therapy management outcomes or safety of your patients.

11. On a scale of 1 – 10 (1-did not enhance; 10-greatly enhanced), please rate how this program enhanced your competence in the clinical areas covered.

12. On a scale of 1 – 10 (1-did not help; 10-great help), please rate how this program helped to build your management and leadership skills.

13. How useful was the educational material?
   a. Very useful
   b. Somewhat useful
   c. Not useful

14. How effective were the learning methods used for this activity?
   a. Very effective
   b. Somewhat effective
   c. Not effective

15. Learning assessment questions were appropriate.
   a. Yes
   b. No

16. Were the authors free from bias?
   a. Yes
   b. No

17. If you answered "no" to question 16, please comment (email info@pswi.org).

18. Please indicate the amount of time it took you to read the article and complete the assessment questions.

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10) a b
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