Clinical Pharmacogenomics: Opportunities for Expanding Pharmacy Practice

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Cleveland Clinic Department of Pharmacy
Pharmacogenomics Clinical Specialist
Director, Personalized Medication Program

UAN: 0048-0000-15-035-L04-P/T
Objectives

• Pharmacist Objectives:
  — Describe the principles of pharmacogenomics
  — Provide examples of pharmacist managed pharmacogenomic programs
  — Identify resources that may assist with the integration of pharmacogenomics into clinical practice

• Technician Objectives:
  — Describe the principles of pharmacogenomics
Clinical Case

JK is a 38 year old male diagnosed with Crohn’s Disease. Medications are as follows:
- Mesalamine 375 mg TID
- Infliximab 5 mg/kg every 8 weeks
- Mercaptopurine 50 mg daily (0.5 mg/kg)

4 weeks prior to infliximab infusion mercaptopurine dosage increased to 100 mg daily (1 mg/kg). Labs performed at time of infliximab infusion significant for:
- WBC – 1.16 (3.7-11.0)
- RBC – 2.60 (3.9-5.2)
- Hemoglobin – 7 (11.5-15.5)
- Hematocrit – 20.0 (36.0-46.0)
- Platelet Count – 35 (150-400)

Could pharmacogenomic testing predict myelosuppression?
Pharmacogenomics is the study of how genetic variations affect drug response

- Drug metabolizing enzymes
- Drug receptors
- Drug transporters
- Drug targets

Pharmacogenomics

Same Concept as Drug-Drug Interactions

- Disruption of PK or PD by
  - Drug-drug interactions
  - Gene-drug interactions
- Drug-Drug interaction
  - PPI & clopidogrel
- Gene-Drug interaction
  - CYP2C19 poor metabolizer & clopidogrel

Cleveland Clinic

Sangkuhl et al. *Pharmacogenet Genomics* 20(7): 463-5; 2010
Benefits of Pharmacogenomics

Incorporating pharmacogenomics into the medical decision-making process can help identify those

- At risk of an adverse reaction
- At risk of non-response
Clinical Utility of Pharmacogenomics

- Genetic profile predictive of favorable response
  - Treat with conventional drug dosing

- Genetic profile predictive of toxicity
  - Treat with alternative drug or dose

- Genetic profile predictive of non-response
  - Treat with alternate drug
**TPMT** and Thiopurines

*An Example of Applied Pharmacogenomics*

- **TPMT** metabolizes thiopurines to less active compounds

- In the absence of **TPMT** activity greater concentrations of thioguanine nucleotides (TGNs) are present
TPMT and Mercaptopurine

Patient Population

Conventional Dosing

TGN Exposure

Myelosuppression

Adapted from Evans and Relling
TPMT and Mercaptopurine

Conventional Dosing

TGN Exposure

Myelosuppression

Low/absent

Intermediate

Normal

Individualized Dosing

Adapted from Evans and Relling
# Modifying Thiopurine Doses Based on TPMT Activity May Prevent Myelosuppression

<table>
<thead>
<tr>
<th></th>
<th>Normal TPMT activity</th>
<th>Intermediate TPMT activity</th>
<th>Low/Absent TPMT activity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Azathioprine</strong></td>
<td>Conventional dosages</td>
<td>↓ by 30-60%</td>
<td>Avoid drug or ↓ by 90% 3x/week</td>
</tr>
<tr>
<td></td>
<td>e.g., 2-3 mg/kg/day</td>
<td>e.g., 1-1.5 mg/kg/day</td>
<td></td>
</tr>
<tr>
<td><strong>Mercaptopurine</strong></td>
<td>Conventional dosages</td>
<td>↓ by 30-60%</td>
<td>Avoid drug or ↓ by 90% 3x/week</td>
</tr>
<tr>
<td></td>
<td>e.g., 1.5 mg/kg/day</td>
<td>e.g., 0.75 mg/kg/day</td>
<td></td>
</tr>
<tr>
<td><strong>Thioguanine</strong></td>
<td>Conventional dosages</td>
<td>↓ by 30-60%</td>
<td>↓ by 90% 3x/week</td>
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</tbody>
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Clinical Case

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- Platelet Count – 35 (150-400)

Could pharmacogenomics testing predict myelosuppression?

TPMT Intermediate Activity
WHY NOW?

Why is there a growing emphasis on pharmacogenomics and precision/personalized medicine?
Changing medicine: Liggett with DNA sequence

Prescription for Disaster
Every year, more than 100,000 people die in the U.S. because they carry “misspelled” genes that make medications either ineffective or deadly. Now doctors can test for the genes before prescribing.

<table>
<thead>
<tr>
<th>DRUG</th>
<th>USE</th>
<th>EFFECT OF MISSPELLED GENE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albuterol</td>
<td>Asthma</td>
<td>Makes medication ineffective, leading to gasping, wheezing</td>
</tr>
<tr>
<td>Ventolin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thiopurines</td>
<td>Childhood</td>
<td>Drug is not metabolized; its buildup kills bone marrow</td>
</tr>
<tr>
<td></td>
<td>leukemia</td>
<td></td>
</tr>
<tr>
<td>Codeine</td>
<td>Pain</td>
<td>Body can’t convert drug to its active form; no pain relief</td>
</tr>
<tr>
<td>Isoniazid</td>
<td>Tuberculosis</td>
<td>Body metabolizes drug so fast it isn’t absorbed</td>
</tr>
<tr>
<td>Prozac</td>
<td>Depression</td>
<td>Drug is metabolized so slowly it can reach toxic levels</td>
</tr>
<tr>
<td>Proca...</td>
<td>Heart</td>
<td>Drug isn’t cleared from body, leading to fatal liver disease</td>
</tr>
</tbody>
</table>

NEWSWEEK FEBRUARY 8, 1999
Incorporating Pharmacogenomics Into Patient Care

WHY NOW?

• Change in how healthcare is provided
  – Greater emphasis on outcomes
  – Greater emphasis on preventative care

• Advances in technology
  – Adoption of electronic health records (EHR)
  – Genomic testing capabilities

• Greater guidance on how to provide personalized care
What Changes are Occurring?

- Transitioning away from a volume incentive model
  - Amount of reimbursement largely based on volume
  - Reimbursement did not consider outcomes
  - Focused on ‘sick-care’

- Transitioning towards a value-based care model
  - Considers both costs AND outcomes
  - Amount of reimbursement influenced by outcomes
  - Greater focus on preventative care
  - Population health & Personalized healthcare
Population Health and Personalized Medicine

The health outcomes of a group of individuals (e.g., Healthcare System), including the distribution of such outcomes within the group.

**OUTCOMES**
- Mortality
- Morbidity
- Quality of Life

**Factors Influencing Outcomes**
- Environment
- Behavior
- Socio-economics
- Patient Characteristics
  - Lab tests
  - Drug interactions
- Genomics
  - Disease risk
  - Pharmacogenomics

Identify at risk sub-groups and intervene before problems arise

Adverse Drug Events
Potential for Pharmacogenomics to Decrease Risk

• An estimated 2 to 4 million persons suffer from a serious, disabling, or fatal adverse drug event each year

• In the United States, adverse drug events cause over 700,000 emergency room visits each year

• Over 120,000 of those emergency room visits result in further hospitalization

• Approximately 100,000 deaths per year attributed to adverse drug events
Estimated that ~ 90,000 patients visit ED each year due to psychiatric drug-induced adverse events

<table>
<thead>
<tr>
<th>Medication Category and Class</th>
<th>No. of Cases</th>
<th>Estimated Annual No. of Visits</th>
<th>Proportion of Category Visits</th>
<th>Hospitalization Rate</th>
<th>Estimated Annual ED Visits per 10,000 Outpatient Prescription Visits, No. (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedatives and anxiolytics</td>
<td>1371</td>
<td>30,707</td>
<td>NA</td>
<td>23.5</td>
<td>3.6 (3.2-4.1)</td>
</tr>
<tr>
<td>Antidepressants</td>
<td>1076</td>
<td>25,377</td>
<td>NA</td>
<td>12.4</td>
<td>2.4 (2.1-2.7)</td>
</tr>
<tr>
<td>Antipsychotics</td>
<td>1055</td>
<td>21,578</td>
<td>NA</td>
<td>15.3</td>
<td>11.7 (10.1-13.2)</td>
</tr>
<tr>
<td>Lithium salts</td>
<td>197</td>
<td>3,620</td>
<td>NA</td>
<td>53.6</td>
<td>16.4 (13.0-19.9)</td>
</tr>
</tbody>
</table>
Pharmacoresistance
Potential for Pharmacogenomics to Help Guide Drug Selection

• Improve treatment response
  – Approximately 30-50% of psychiatric patients fail initial pharmacotherapy regimen
  – About 20-60% of epilepsy patients may fail initial treatment

• Genetic variants may dictate initial drug selection

Barak et al, Progress in neuro-psychopharmacology & biological psychiatry 35;1744-1747, 2011
Patients Becoming More Educated About Pharmacogenomics & Personalized Therapy

• Patients are becoming more educated about pharmacogenomics
  – Direct to consumer marketing
  – Government initiatives
  – Health system advertisements

• Genetic testing is becoming affordable
  – A $500 pharmacogenomic test provides results for 225 genes
  – $1000 dollars will buy genome sequencing
Adoption of Electronic Health Records

Pharmacogenomics at the Point of Care


- **Search:**

- **ALL TOPICS**
  - LAB GENERAL
  - CHEMISTRY
  - HEMATOLOGY
  - MOLECULAR GENETICS
  - RADIOLOGY

- **MOLECULAR GENETICS**
  - **TPMT Genotype:** TPMT*1/TPMT*1

- **BestPractice Advisory - Zzzleapfrog,FourteenA**

- **RISK OF SEVERE MYELOSUPPRESSION:** TPMT genotype or phenotype is recommended prior to initiation of thiopurine therapy. Please order a genotype or phenotype test below OR select a reason for not ordering a test.

- **Click here for additional information about TPMT-Thiopurines**

- **Acknowledge reason:**
  - Test ordered and result pending
  - Not indicated for current medical problem...
  - Already on stable dose of medication
  - External result noted by clinician
  - External result requested
  - Patient declined test
  - Other - Document in note
  - Med Update

- **Open order:**
  - PRO-PREDICTR ENZACT (phenotype)
  - PRO-PREDICTR TPMT BL (genotype)
Clinical Pharmacogenetics Implementation Consortium Guideline for CYP2D6 and CYP2C19 Genotypes and Dosing of Tricyclic Antidepressants

Guidelines that inform clinicians how to integrate pharmacogenomics into patient care
Where Does This Leave Pharmacy in the New Healthcare Landscape?

• Keep doing what we have been doing

• Identify ways to participate in:
  — Value based care (control costs, improve outcomes)
  — Population health (preventative care)
  — Personalized medicine (pharmacogenomics)

• Be prepared to lead
Examples of Pharmacist Managed Pharmacogenomic Programs
ASHP POSITION: Pharmacogenomics (PGx) can improve medication-related outcomes across the continuum of care

ASHP recommendations for all pharmacists’ functions

• Recommend PGx testing when appropriate
• Design patient-specific medication regimens based on patient characteristics including PGx
• Educate patients and clinicians about PGx
• Communicate PGx-specific drug therapy recommendations to the health care team
Examples of Pharmacist Managed Pharmacogenomic Programs

• Northshore University Healthsystem, Chicago
  – Mark Dunnenberger, PharmD

• Moffitt Cancer Center, Florida
  – Gillian Bell, PharmD

• Cleveland Clinic
NorthShore University Healthsystem

• Center for Personalized Medicine
  —Pharmacogenomics initiative
    ○ Pharmacogenomics Clinic
    ○ EHR implementation

Mark Dunnenberger
PharmD, BCPS
NorthShore Pharmacogenomics Clinic

- Launched a Pharmacogenomics Clinic
  - Expect 15-25 patients per month

- Consult Example:
  - Family and medication history
  - Analysis of current pharmacotherapy
  - PGx recommendations for current medication therapy
  - Patient will receive report to take home
  - Results may be placed into the EHR

- Clinicians can order a “Pharmacogenomics Clinic Referral” via EHR
Moffitt Cancer Center

- Optimize treatment of each patient through utilization of all clinically relevant methods of personalization
- Pharmacogenetic analysis (e.g., TPMT, CYP2C19)
- Formal consult note in patient’s chart and availability to discuss results and implications for therapy with patients

Attendings: Gillian Bell, PharmD  
Christine Walko, PharmD  
Todd Knepper, PharmD
Personalized Medicine Consultation

07/02/2014 7:15  Kelly, Kerry - Personalized Medicine Consult

Result type: Personalized Medicine Consultation
Result date: 02 July 2014 7:16
Result status: Auth (Valid)
Result title: Personalized Medicine Consult
Performed by: Kelly, Kerry on 02 July 2014 7:16
Verified by: Kelly, Kerry on 02 July 2014 7:16
Encounter info: 6369245, HLM, Routine Outpatient, 06/16/2014

Personalized Medicine Consult Entered On: 07/02/2014 7:17
Performed On: 07/02/2014 7:16 by Kelly, Kerry

Personalized Medicine Consult Details
Personalized Medicine Consult performed by: Kelly, Kerry
Date / Time of Consult: 07/02/2014 7:16
Type of Consultation Performed: TPMT Activity

TPMT Activity Consultation
TPMT Phenotype Result: TPMT*1/*3B
TPMT Predicted phenotype: Low or absent activity
TPMT activity consult: TPMT predicted phenotype: Low or absent activity

This result signifies that this patient has two copies of a non-functional (low activity) allele. This patient is predicted to have low or absent TPMT activity and is at high risk for life-threatening myelosuppression with normal doses of drugs in the thiopurine class (mercaptopurine, thioguanine or azathioprine). For malignancy, reduce dose and frequency of mercaptopurine or thioguanine drastically. Recommend starting with 10% of the target dose for mercaptopurine and administering three times a week. For thioguanine, consider an alternative agent such as mercaptopurine or start with 10% of the target dose and administer three times a week. Azathioprine should be avoided or if azathioprine is given, start with 10% of the target dose and administer three times a week instead of daily. Adjust subsequent thiopurine doses based on degree of myelosuppression and disease specific guidelines. In the setting of myelosuppression, and depending on other therapy, emphasis should be on reducing thiopurine doses over other agents. Allow 4-6 weeks to reach steady state after each dose adjustment.

Kelly, Kerry - 07/02/2014 7:16
Personalized Medicine Consultation
Tumor Profiling

- Somatic profiling test ordered
- Personalized Medicine Consult Service discussion and review
- Consult report generated and documented in EHR
- Referral to Clinical Genomic Action Committee
- Discussion of genetic results with treating clinician
- Patient and oncologist discussion

Tumor genetic results where treatment implications not clearly dictated by available practice guidelines or standards of care
Cleveland Clinic Personalized Medication Program

• Personalized Medication Program established to incorporate evidence-based pharmacogenomics into patient care.

• The goal of the Personalized Medication Program is to
  – Improve patient safety by identifying those at risk of an adverse drug reaction
  – Improve treatment outcomes by helping to guide the selection of the most effective drug and dosage
Cleveland Clinic Personalized Medication Program

• Pharmacy Department manages the Personalized Medication Program

• Collaborations with
  — Center for Clinical Genomics
  — Genomic Medicine Institute
  — Pathology and Lab Medicine
Personalized Medication Program Initiatives

• Integrate clinical decision support into our EHR
  – Takes into consideration patients’ genome at the point of drug prescribing and verification

• Clinical pharmacogenomic services
  – Pharmacogenomic consultation service
  – Cleveland Clinic’s MyConsult®

• Education
Integrating Personalized Medicine into the EHR Pharmacogenomic Clinical Decision Support

**TPMT - thiopurines**
Patients with low TPMT activity are at an increased risk of severe life-threatening myelosuppression

**HLA-B*57:01 - abacavir**
FDA boxed warning. Patients who are positive for HLA-B*57:01 are at a high risk of experiencing a serious and sometimes fatal hypersensitivity reaction

**HLA-B*15:02 - anticonvulsants**
FDA boxed warning. Patients who are positive for HLA-B*15:02 are at an increased risk of Stevens-Johnson syndrome/epidermal necrolysis
Workflow for Integrating Pharmacogenomic CDS into the EHR

Pharm IT builds and curates PGx CDS

Dave Stowe, RPh
Marc Willner, PharmD

Jeff Chalmers, PharmD

Personalized Medication Program Identifies Possible Gene-Drug Pairs
Pharmacogenomic Workgroup Formed

Informatics
- Inpatient
- Outpatient
- ED
- Enterprise
- Disease mgt. task force
Workflow for Integrating Pharmacogenomic CDS into the EHR

- Personalized Medication Program Identifies Possible Gene-Drug Pairs
- Pharmacogenomic Workgroup Formed
- P & T
- Informatics
  - Inpatient
  - Outpatient
  - ED
  - Enterprise
  - Disease mgt. task force

Mandy Leonard, PharmD BCPS

PGx CDS presented to P & T Committee
Integrating Pharmacogenomic CDS into EHR Discrete Data Entry

Collaboration with Lab Medicine to enter results into data-minable field

Tom Daly, MD
Example of Pharmacogenomic CDS

**HLA-B*57:01 – Abacavir**

**FDA BLACK BOX WARNING:** RISK OF A SERIOUS FATAL HYPERSENSITIVITY REACTION. A HLA-B*57:01 genotype test is recommended before prescribing abacavir or reinitiating abacavir therapy, including for those who previously tolerated abacavir therapy. Please click 'accept' below to order the HLA-B*57:01 genotype test or a reason for not ordering the test.

Click here for additional information regarding HLA-B*57:01 - Abacavir

- Test drawn and pending in lab
- External result noted by clinician
- External test result records requested a...
- Other - Document in note
- Med Update
- Patient declined test

Open order: HLA B5701

Accept  Cancel
Example of Pharmacogenomic CDS

HLA-B*57:01 – Abacavir Patient Safety Alerts

U.S. BOXED WARNING FOR ABACAVIR: Serious and sometimes fatal hypersensitivity reactions have occurred for patients testing positive for the presence of the HLA B5701 allele. Therapy is not recommended in patients testing positive for the HLA B5701 allele.

Click here for additional information regarding HLA-B*57:01 - Abacavir

Last HB5701=Positive on 2/25/2014

Acknowledge reason: [Text input field]

Med Update

Accept  |  Cancel
Only 7.8% of clinicians state alerts difficult to interpret
CDS Formative Evaluation

Only 13% of clinicians state alerts are negatively disruptive
**Pharmacogenomic Test Reporting in Order Composer**

### Place orders

<table>
<thead>
<tr>
<th>New order:</th>
<th>Search</th>
</tr>
</thead>
<tbody>
<tr>
<td>Order mode:</td>
<td>Not using defaults</td>
</tr>
</tbody>
</table>

**During visit (1 Order)**

**abacavir 300 mg - lamivUDine 150 mg - zidovudine 300 mg tablet (TRIZIVIR)**

1 tablet, ORAL, 2 TIMES DAILY, First Dose Today at 2100, Until Discontinued

<table>
<thead>
<tr>
<th>Priority:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Report: Lab Test Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component</td>
</tr>
<tr>
<td>HLA B5701</td>
</tr>
</tbody>
</table>

**Reference Links:**

1. Drug Info - Adult
2. Drug Info - Peds
3. HLA-B*57:01 CPIC Guidelines

**Dose:**

| 1 tablet |

**Administer Dose:**

1 tablet

**Administer Amount:**

1 tablet

**Route:**

ORAL

**Frequency:**

2 TIMES DAILY

**For:** 1 tablet

**Starting:** 4/6/2015 Today Tomorrow

**First Dose:** Today 2100 Until Discontinued
EHR Stage 2 Meaningful Use

- Evidence-based consensus guidelines linked to decision support meets CMS Stage 2 meaningful use criteria
  - Allows Cleveland Clinic to receive incentives and avoid Medicare payment adjustments

Clinical Pharmacogenetics Implementation Consortium Guidelines for *HLA-B* Genotype and Abacavir Dosing

MA Martin¹, TE Klein², BJ Dong³, M Pirmohamed⁴, DW Haas⁵⁻⁷ and DL Kroetz¹
Pharmacogenomic Guidelines

CLEVELAND CLINIC PERSONALIZED MEDICATION PROGRAM

**HLA-B*15:02 – ANTICONVULSANTS CONSENSUS GUIDELINES**

PURPOSE OF DOCUMENT: Individuals who carry the HLA-B*15:02 allele are approximately 100-fold more susceptible to carbamazepine-induced Stevens-Johnson syndrome (SJS) and toxic epidermal necrolysis (TEN) than those who are non-carriers of the

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**CLEVELAND CLINIC PERSONALIZED MEDICATION PROGRAM**

**CYP2D6 – PIMOZIDE CONSENSUS GUIDELINES**

PURPOSE OF DOCUMENT: There is an increased risk of pimozide-induced arrhythmias in those who are CYP2D6 poor metabolizers due to elevated drug concentrations. CYP2D6 genotyping is offered at Cleveland Clinic (test name P450 2D6 GENOTYPE) to help

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**CLEVELAND CLINIC PERSONALIZED MEDICATION PROGRAM**

**TPMT – AZATHIOPRINE/MERCAPTOPURINE/THIOGUANINE CONSENSUS GUIDELINES**

PURPOSE OF DOCUMENT: There is an increased risk of severe life-threatening myelosuppression in those with intermediate or low/absent thiopurine methyltransferase (TPMT) activity that are prescribed normal doses of drugs in the thiopurine class

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**CLEVELAND CLINIC PERSONALIZED MEDICATION PROGRAM**

**G6PD – DAPSONE CONSENSUS GUIDELINES**

PURPOSE OF DOCUMENT: Individuals with glucose-6-phosphate dehydrogenase (G6PD) deficiency are more susceptible to orally administered dapsone-induced acute hemolytic anemia. G6PD phenotyping is offered at Cleveland Clinic (test name G6PD Screen) to

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**CLEVELAND CLINIC PERSONALIZED MEDICATION PROGRAM**

**CYP2D6 – TETRABENAZINE CONSENSUS GUIDELINES**

PURPOSE OF DOCUMENT: There is an increased risk of tetrabenazine-induced side effects (e.g., parkinsonism and depression/suicidality) in those who are CYP2D6 poor metabolizers due to elevated drug and drug metabolite concentrations. CYP2D6 genotyping is
Pharmacogenomic Guidelines

1. Has the patient previously taken carbamazepine? 
   - Yes
   - No

2. Patient consistently taking carbamazepine for >3 months?
   - Yes
   - No

3. Is the patient at high-risk of carrying the HLA-B*15:02 allele based on ancestry?
   - No
   - Yes

   - Less evidence for HLA-B*15:02 genotyping
   - HLA-B*15:02 genotyping recommended

4. Patient positive for HLA-B*15:02 allele?
   - Yes
   - No

   - Carbamazepine use is not recommended
   - Prescribe carbamazepine per standard dosing guidelines
Pharmacogenomic Decision Support Supporting Documents
CYP2D6 - pimozide
CYP2D6 poor metabolizers are at an increased risk of pimozide-induced QT prolongation. The FDA and drug manufacturer recommends limiting dosages

CYP2D6 – tetrabenazine
CYP2D6 poor metabolizers are at an increased risk of parkinsonism and depression/suicidality. The FDA and drug manufacturer recommends limiting dosages

G6PD - dapsone
Patients with G6PD deficiency are at an increased risk of acute hemolytic anemia when prescribed oral dapsone
# Personalized Medication Program

**EHR Pharmacogenomic Consult Request**

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**CONSULT CLINICAL PHARMACOGENOMICS**

Routine, ONCE First occurrence Today at 1545, For emergent questions, contact the pharmacogenomics clinical pharmacist at pager 22924.

## Questions:

<table>
<thead>
<tr>
<th>Prompt</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Is the consult for clinical interpretation and drug dosing recommendations for a pharmacogenomic test result?</td>
<td>Yes, indicate which test result and which drug</td>
</tr>
<tr>
<td>2. Is the consult for an opinion on whether pharmacogenomics may help explain drug intolerances?</td>
<td>Yes, indicate which drug(s) and the observed adverse drug effect</td>
</tr>
<tr>
<td>3. Is the consult for an opinion on whether pharmacogenomics may help explain non-response to a drug?</td>
<td>Yes, indicate which drug(s)</td>
</tr>
<tr>
<td>4. What other information is being requested (if applicable)?</td>
<td></td>
</tr>
</tbody>
</table>

## Priority:

- **Routine**

## Frequency:

- **ONCE**
Cleveland Clinic’s MyConsult® Online Medical Second Opinion offers consultations for individuals who are seeking an expert second opinion regarding clinical pharmacogenomics. Clinical pharmacogenomics is the study of how genes affect an individual’s response to medication.
Clinicin Education

- An American Medical Association and Medco Health Solutions survey of 10,000 physicians found that:
  - 98% of respondents acknowledged that genetics may influence drug therapy
  - 29% received formal training in pharmacogenetics
  - 90% NOT adequately informed about pharmacogenetic testing

- A survey of 303 pharmacists found that:
  - 85% agreed that pharmacists should be required to be knowledgeable about pharmacogenomics
  - 63% COULD NOT accurately apply pharmacogenetic test results
Personalized Medication Program

Pharmacogenomic Education

• Education Initiatives
  – PGY1 & PGY2 pharmacogenomics rotation
  – Pharmacogenomics Journal Club
  – Medical resident teaching
  – Department talks
  – Grand Rounds

• Patient education documents
Resources
Training Opportunities

• PGY2 Pharmacogenetics - St. Jude Children’s Research Hospital
• PGY2 Pharmacogenetics - University of Florida
• PGY2 Translational Pharmacogenetics - University of Illinois at Chicago
• PGY2 Pharmacogenetics – San Diego VA Healthsystem
• PGY2 HIV Ambulatory Care/Clinical Pharmacogenetics Residency Program - University of Houston College of Pharmacy
• PGY2 Specialty Pharmacy and Pharmacogenomics - Indiana University Health
Pharmacogenomic Resources

• Clinical Pharmacogenetics Implementation Consortium (CPIC)

• Pharmacogenomics Knowledgebase (http://www.pharmgkb.org)

• FDA Drug Insert (http://www.fda.gov/drugs/scienceresearch/researchareas/pharmacogenetics/ucm083378.htm)

• Genetic Testing Registry (http://www.ncbi.nlm.nih.gov/gtr/)

• National Guideline Clearinghouse (http://www.guideline.gov/)
CPIC: Clinical Pharmacogenetics Implementation Consortium

- The Clinical Pharmacogenetics Implementation Consortium (CPIC) is a shared project between PharmGKB and the Pharmacogenomics Research Network.
- CPIC guidelines are designed to help clinicians understand HOW genetic test results should be used to optimize drug therapy.
- Once published the guidelines are updated periodically.

http://www.pharmgkb.org

<table>
<thead>
<tr>
<th>Drug</th>
<th>Guidelines</th>
</tr>
</thead>
<tbody>
<tr>
<td>abacavir</td>
<td>CPIC Dosing Guideline for abacavir and HLA-B</td>
</tr>
<tr>
<td>allopurinol</td>
<td>CPIC Dosing Guideline for allopurinol and HLA-B</td>
</tr>
<tr>
<td>amitriptyline</td>
<td>CPIC Dosing Guideline for amitriptyline and CYP2C19, CYP2D6</td>
</tr>
<tr>
<td>azathioprine</td>
<td>CPIC Dosing Guideline for azathioprine and TPMT</td>
</tr>
<tr>
<td>capecitabine</td>
<td>CPIC Dosing Guideline for capecitabine, fluorouracil, tegafur and DPYD</td>
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<td>warfarin</td>
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Conclusions

• Personalized healthcare and pharmacogenomics increasingly integrated into patient care

• Opportunities for expanding pharmacy practice in pharmacogenomics
  – Build EHR genomic infrastructure
  – Provide pharmacogenomic clinical services
  – Education
Patients ARE going to start coming to you with genetic information that they EXPECT you to incorporate into their care.

"Here's my sequence..."