Medical Policy

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Title: Cytochrome p450 Genotype-Guided Treatment Strategy

Related Policies	▪ *Genotype-Guided Tamoxifen Treatment*

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Populations	Interventions	Comparators	Outcomes
Individuals: • With need for antiplatelet therapy who are undergoing or being considered for clopidogrel therapy	Interventions of interest are: • CYP2C19-guided treatment strategy	Comparators of interest are: • Clinically guided management	Relevant outcomes include: • Overall survival • Medication use • Treatment-related morbidity
Individuals: • Who are undergoing or	Interventions of interest are:	Comparators of interest are:	Relevant outcomes include: • Medication use

Populations	Interventions	Comparators	Outcomes
being considered for treatment with highly active antiretroviral agents	• CYP450-guided treatment strategy	• Clinically guided management	• Treatment-related morbidity
Individuals: • Who are undergoing or being considered for treatment with immunosuppressant therapy for organ transplantation	Interventions of interest are: • CYP450-guided treatment strategy	Comparators of interest are: • Clinically guided management	Relevant outcomes include: • Medication use • Treatment-related morbidity
Individuals: • Who are undergoing or being considered for treatment with beta-blockers	Interventions of interest are: • CYP450-guided treatment strategy	Comparators of interest are: • Clinically guided management	Relevant outcomes include: • Medication use • Treatment-related morbidity
Individuals: • Who are undergoing or being considered for treatment with antitubercular medications	Interventions of interest are: • CYP450-guided treatment strategy	Comparators of interest are: • Clinically guided management	Relevant outcomes include: • Medication use • Treatment-related morbidity

DESCRIPTION

The cytochrome P450 (CYP450) family is involved in the metabolism of many currently administered drugs, and genetic variants in CYP450 are associated with altered metabolism of many drugs. Testing for CYP450 variants may assist in selecting and dosing drugs affected by these genetic variants.

OBJECTIVE

The objective of this evidence review is to evaluate whether testing for cytochrome P450 variants improves the net health outcome by influencing the selection and dosing of drugs metabolized by cytochrome P450 enzymes.

BACKGROUND

Drug Efficacy and Toxicity

Drug efficacy and toxicity vary substantially across individuals. Because drugs and doses are typically adjusted, if needed, by trial-and-error, clinical consequences may include a prolonged time to optimal therapy. In some cases, serious adverse events may result.

Multiple factors may influence the variability of drug effects, including age, liver function, concomitant diseases, nutrition, smoking, and drug-drug interactions. Inherited (germline) DNA

sequence variation in genes coding for drug-metabolizing enzymes, drug receptors, drug transporters, and molecules involved in signal transduction pathways also may have major effects on the activity of those molecules and thus on the efficacy or toxicity of a drug.

Pharmacogenomics studies how an individual's genetic inheritance affects the body's response to drugs. It may be possible to predict therapeutic failures or severe adverse drug reactions in individual patients by testing for important DNA variants (genotyping) in genes related to the metabolic pathway (pharmacokinetics) or signal transduction pathway (pharmacodynamics) of the drug. Potentially, test results could be used to optimize drug choice and/or dose for more effective therapy, avoid serious adverse events, and decrease medical costs.

Cytochrome P450 System

The cytochrome P450 (CYP450) family is a major subset of all drug-metabolizing enzymes; several CYP450 enzymes are involved in the metabolism of a significant proportion of currently administered drugs. CYP2D6 metabolizes approximately 25% of all clinically used medications (e.g., dextromethorphan, β-blockers, antiarrhythmics, antidepressants, morphine derivatives), including most prescribed drugs. CYP2C19 metabolizes several important types of drugs, including proton pump inhibitors, diazepam, propranolol, imipramine, and amitriptyline.

Some CYP450 enzymes are highly polymorphic, resulting in some enzyme variants that have variable metabolic capacities among individuals, and some with little to no impact on activity. Thus, CYP450 enzymes constitute an important group of drug-gene interactions influencing the variability of the effect of some CYP450-metabolized drugs.

Individuals with 2 copies (alleles) of the most common (wild-type) DNA sequence of a particular CYP450 enzyme gene resulting in an active molecule are termed extensive metabolizers (EMs; normal). Poor metabolizers (PMs) lack active enzyme gene alleles, and intermediate metabolizers, who have 1 active and 1 inactive enzyme gene allele, may experience to a lesser degree some of the consequences of PMs. Ultrarapid metabolizers (UMs) are individuals with more than 2 alleles of an active enzyme gene. There is pronounced ethnic variability in the population distribution of metabolizer types for a given CYP enzyme.

UMs administered an active drug may not reach therapeutic concentrations at usual recommended doses of active drugs, while PMs may suffer more adverse events at usual doses due to reduced metabolism and increased concentrations. Conversely, for administered prodrugs that must be converted by CYP450 enzymes into active metabolites, UMs may suffer adverse events, and PMs may not respond.

Many drugs are metabolized to varying degrees by more than one enzyme, either within or outside of the CYP450 superfamily. Also, the interaction between different metabolizing genes, the interaction between genes and environment, and interactions among different nongenetic factors also influence CYP450-specific metabolizing functions. Thus, identification of a variant in a single gene in the metabolic pathway may be insufficient in all but a small proportion of drugs to explain interindividual differences in metabolism and consequent efficacy or toxicity.

Determining Genetic Variability in Drug Response

Genetically determined variability in drug response has been traditionally addressed using a trial-and-error approach to prescribing and dosing, along with therapeutic drug monitoring for drugs

with a very narrow therapeutic range and/or potentially serious adverse events outside that range. However, therapeutic drug monitoring is not available for all drugs of interest, and a cautious trial-and-error approach can lengthen the time to achieving an effective dose.

CYP450 enzyme phenotyping (identifying metabolizer status) can be accomplished by administering a test enzyme substrate to a patient and monitoring parent substrate and metabolite concentrations over time (e.g., in urine). However, testing and interpretation are time-consuming and inconvenient; as a result, phenotyping is seldom performed.

The clinical utility of *CYP450* genotyping (i.e., the likelihood that genotyping will significantly improve drug choice, dosing, and patient outcomes) may be favored when the drug under consideration has a narrow therapeutic dose range, when the consequences of treatment failure are severe, and/or when serious adverse reactions are more likely in patients with gene sequence variants. Under these circumstances, genotyping may direct early selection of the most effective drug or dose, and/or avoid drugs or doses likely to cause toxicity. For example, warfarin, some neuroleptics, and tricyclic antidepressants have narrow therapeutic windows and can cause serious adverse events when concentrations exceed certain limits, resulting in cautious dosing protocols. The potential severity of the disease condition may call for immediate and sufficient therapy; genotyping might speed up the process of achieving a therapeutic dose and avoiding significant adverse events.

REGULATORY STATUS

Clinical laboratories may develop and validate tests in-house and market them as a laboratory service; laboratory-developed tests must meet the general regulatory standards of the Clinical Laboratory Improvement Amendments. Diagnostic genotyping tests for certain CYP450 enzymes are available under the auspices of the Clinical Laboratory Improvement Amendments. Laboratories that offer laboratory-developed tests must be licensed by the Clinical Laboratory Improvement Amendments for high-complexity testing. To date, the U.S. Food and Drug Administration (FDA) has chosen not to require any regulatory review of this test.

Several testing kits for *CYP450* genotyping cleared for marketing by the FDA (FDA product code: NTI) are summarized in Table 1.

Table 1. Selected Testing Kits for *CYP450* Genotyping Cleared for Marketing by the Food and Drug Administration

Device Name	Manufacturer	Approval Date
xTAG Cyp2c19 Kit V3	Luminex Molecular Diagnostics	2013
Spartan Rx Cyp2c19 Test System	Spartan Bioscience	2013
Verigene Cyp2c19 Nucleic Acid Test (2c19)	Nanosphere	2012
Infiniti Cyp2c19 Assay	Autogenomics	2010
xTAG Cyp2d6 Kit V3, Model I030c0300 (96)		
Invader Ugt1a1 Molecular Assay	Third Wave Technologies	2005
Roche AmpliChip Cyp450 Test	Roche Molecular Systems	2005

Several manufacturers market diagnostic genotyping panel tests for *CYP450* genes, such as the YouScript Panel (Genelex Corp.), which includes *CYP2D6*, *CYP2C19*, *CYP2C9*, *VKORC1*, *CYP3A4*, and *CYP3A5*. Other panel tests include both *CYP450* and other non-*CYP450* genes involved in drug metabolism, such as the GeneSight Psychotropic panel (Assurex Health) and PersonaGene Genetic Panels (AIBioTech). These tests are beyond the scope of this evidence review.

Food and Drug Administration Labeling on *CYP450* Genotyping
The FDA maintains online compendia of pharmacogenetic associations online under 3 categories: 1. pharmacogenetic associations for which the data support therapeutic management recommendations; 2. pharmacogenetic associations for which the data indicate a potential impact on safety or response and 3. pharmacogenetic associations for which the data demonstrate a potential impact on pharmacokinetic properties only.[1,]

The FDA has included pharmacogenomics information in the physician prescribing information (drug labels) of multiple drugs. In most cases, this information is general and lacks specific directives for clinical decision making. In the following examples, the FDA has given clear and specific directives on either use of a specific dose (e.g., eliglustat, tetrabenazine) or when a drug may not be used at all (e.g., codeine) and therefore evidence in such cases is not reviewed in the Rationale section.

Eliglustat
The FDA has approved eliglustat for treatment of adults with Gaucher disease type 1 who are CYP2D6 EMs, intermediate metabolizers, or PMs as detected by an FDA-cleared test. Further, the label acknowledges the limitation of use among UMs because they may not achieve adequate concentrations and a specific dosage was not recommended for patients with indeterminate CYP2D6 metabolizer status. Further, the label states that the dosing strategy should be 84 mg orally, twice daily for CYP2D6 EMs or intermediate metabolizers and 84 mg orally, once daily for CYP2D6 PMs. The FDA has included a black box to warn about the reduced effectiveness in PMs and to advise healthcare professionals to consider alternative dosing or to use of other medications in patients identified as potential PMs.[2,]

Tetrabenazine
The FDA has approved tetrabenazine for the treatment of chorea associated with Huntington disease. According to the label, patients requiring doses above 50 mg per day should be genotyped for the drug-metabolizing enzyme CYP2D6 to determine if the patient is a PM or EM. For patients categorized as PMs using an FDA-approved test, the maximum daily dose should not exceed 50 mg, with a maximum single dose of 25 mg.[3,]

Codeine
The FDA does not recommend genotyping before prescribing codeine. The FDA has contraindicated codeine for treating pain or cough in children under 12 years of age and codeine is not recommended for use in adolescents ages 12 to 18 years who are obese or have conditions such as obstructive sleep apnea or severe lung disease. There is an additional warning to mothers not to breastfeed when taking codeine.[4,]

Siponimod
The FDA has approved siponimod for the treatment of relapsing forms of multiple sclerosis, to include clinically isolated syndrome, relapsing-remitting disease, and active secondary progressive

disease, in adults. The recommended maintenance dosage is 2 mg. The recommended maintenance dosage in patients with a *CYP2C9* 1/*3* or **2/*3* genotype is 1 mg. Siponimod is contraindicated in patients with a *CYP2C9*3/*3* genotype.[5,]

POLICY

A. CYP2D6 genotyping to determine drug metabolizer status may be considered **medically necessary** for individuals:

1. With Gaucher disease being considered for treatment with eliglustat, **OR**
2. With Huntington disease being considered for treatment with tetrabenazine in a dosage greater than 50 mg per day

B. CYP2C9 genotyping to determine drug metabolizer status may be considered **medically necessary** for individuals:

1. With relapsing forms of multiple sclerosis, to include clinically isolated syndrome, relapsing-remitting disease, and active secondary progressive disease, being considered for treatment with siponimod.

C. CYP450 genotyping for the purpose of aiding in the choice of drug or dose to increase efficacy and/or avoid toxicity for the following drugs is considered **experimental / investigational**, aside from determinations in the separate policies noted above:

1. dosing of efavirenz and other antiretroviral therapies for HIV infection
2. dosing of immunosuppressants for organ transplantation
3. selection or dosing of β-blockers (e.g., metoprolol)
4. dosing and management of antitubercular medications
5. selection or dosage of codeine

D. CYP450 genotyping for the purpose of aiding in the choice of clopidogrel versus alternative antiplatelet agents, or in decisions on the optimal dosing for clopidogrel, is considered **experimental / investigational**.

E. The use of genetic testing panels that include multiple CYP450 variants is considered **experimental / investigational**.

POLICY GUIDELINES

A. This policy does not address the use of genetic panel tests for genes other than CYP450-related genes (e.g., the Genecept Assay).

B. The Food and Drug Administration maintains a database of pharmacogenomic biomarkers in drug labeling. See section "Regulatory Status" for details.

Please refer to the member's contract benefits in effect at the time of service to determine coverage or non-coverage of these services as it applies to an individual member.

RATIONALE

This evidence review has been updated regularly with searches of the PubMed database. The most recent literature update was performed through April 25, 2022.

The primary goal of pharmacogenomics testing and personalized medicine is to achieve better clinical outcomes in compared with the standard of care. Drug response varies greatly between individuals, and genetic factors are known to play a role. However, in most cases, the genetic variation only explains a modest portion of the variance in the individual response because clinical outcomes are also affected by a wide variety of factors including alternate pathways of metabolism and patient- and disease-related factors that may affect absorption, distribution, and elimination of the drug. Therefore, assessment of clinical utility cannot be made by a chain of evidence from clinical validity data alone. In such cases, evidence evaluation requires studies that directly demonstrate that the pharmacogenomic test alters clinical outcomes; it is not sufficient to demonstrate that the test predicts a disorder or a phenotype.

Evidence reviews assess the clinical evidence to determine whether the use of technology improves the net health outcome. Broadly defined, health outcomes are the length of life, quality of life, and ability to function-including benefits and harms. Every clinical condition has specific outcomes that are important to patients and managing the course of that condition. Validated outcome measures are necessary to ascertain whether a condition improves or worsens; and whether the magnitude of that change is clinically significant. The net health outcome is a balance of benefits and harms.

To assess whether the evidence is sufficient to draw conclusions about the net health outcome of a technology, 2 domains are examined: the relevance, and quality and credibility. To be relevant, studies must represent one or more intended clinical use of the technology in the intended population and compare an effective and appropriate alternative at a comparable intensity. For some conditions, the alternative will be supportive care or surveillance. The quality and credibility of the evidence depend on study design and conduct, minimizing bias and confounding that can generate incorrect findings. The randomized controlled trial (RCT) is preferred to assess efficacy; however, in some circumstances, nonrandomized studies may be adequate. RCTs are rarely large enough or long enough to capture less common adverse events and long-term effects. Other types of studies can be used for these purposes and to assess generalizability to broader clinical populations and settings of clinical practice.

CYP450 GENOTYPE-GUIDED TREATMENT STRATEGY

Clinical Context and Therapy Purpose

The purpose of a cytochrome P450 (*CYP450*) genotype-guided strategy is to tailor selection and dosing of drugs based on gene composition for drug metabolism. In theory, this should lead to early selection and optimal dosing of the most effective drugs, while minimizing treatment failures or toxicities.

The question addressed in this evidence review is: Does *CYP450* genotype-guided strategy change patient management in a way that improves net health outcome?

The following PICO was used to select literature to inform this review.

Populations

The relevant populations of interest is patients being considered for treatment with clopidogrel, eliglustat, tetrabenazine, selective serotonin reuptake inhibitors, serotonin-norepinephrine reuptake inhibitors, tricyclic antidepressants, antipsychotic drugs, codeine, efavirenz and other

antiretroviral therapies for HIV infection, immunosuppressants for organ transplantation, β-blockers (e.g., metoprolol), and antitubercular medications.

Interventions
Commercial tests for individual genes or gene panels are available and are listed in the Regulatory Status section. Only those panels that include *CYP450* genes are listed in that section.

Comparators
The following practice is currently being used: standard clinical management without genetic testing.

Outcomes
Specific outcomes of interest are listed in Table 2.

Table 2. Outcomes of Interest for Individuals With Altered Drug Metabolism

Drug	Outcomes
Clopidogrel	• Initial and maintenance dose selection • Decrease in platelet reactivity • Myocardial infarction, cardiovascular or all-cause death, revascularization, fatal/nonfatal cerebrovascular accident, aortic event
Highly active antiretroviral agents	• Dose selection • Avoidance of treatment failure • Avoidance or reduction of adverse events
Immunosuppressant therapy for organ transplantation	• Dose selection • Avoidance of organ failure • Avoidance or reduction of adverse events
β-blocker(s)	• Dose selection • Superior control of blood pressure • Avoidance or reduction of adverse events due to overtreatment
Antitubercular medications	• Dose selection • Avoidance or reduction of hepatotoxicity due to overtreatment

REVIEW OF EVIDENCE

CLOPIDOGREL

Randomized Controlled Trials
Dual antiplatelet therapy with aspirin and a P2Y12 inhibitor (clopidogrel, prasugrel, ticagrelor) is the standard of care for the prevention of subsequent atherothrombotic events such as stent thrombosis or recurrent acute coronary syndrome in patients who undergo a percutaneous intervention or who have an acute coronary syndrome.

Clopidogrel is a prodrug that is converted to its active form by several CYP450 enzymes (particularly CYP2C19). Individuals with genetic variants that inactivate the CYP2C19 enzyme are associated with lack of response to clopidogrel. There are several variants of *CYP2C19* but the 2 most frequent variants associated with loss of function alleles are *CYP2C19*2* and *CYP2C19*3*. It

is hypothesized that such individuals may benefit from other drugs such as prasugrel or ticagrelor or a higher dose of clopidogrel. Approximately 30% of whites and blacks and 65% of Asians carry a nonfunctional *CYP2C19* gene variant.[6,] While CYP2C19 is the major enzyme involved in the generation of clopidogrel active metabolite, the variability in clinical response seen with clopidogrel may also result from other factors such as variable absorption, accelerated platelet turnover, reduced CYP3A metabolic activity, increased adenosine diphosphate exposure, or upregulation of P2Y12 pathways, drug-drug interactions, comorbidities (e.g., diabetes, obesity), and medication adherence.

Multiple observational studies in patients undergoing percutaneous coronary intervention (PCI) have reported associations between the presence of loss of function alleles and lower levels of active clopidogrel metabolites, high platelet reactivity, and increased risk of adverse cardiovascular events. However, evidence of publication bias has been reported in these studies where smaller studies have reported larger benefits than larger studies which have reported no effect or smaller effect.[7,] Wang et al (2016) reported post hoc analysis of the Clopidogrel in High-Risk Patients with Acute Nondisabling Cerebrovascular Events trial conducted in China; it randomized patients with a transient ischemic attack or minor stroke to clopidogrel plus aspirin or aspirin alone. In a subgroup analysis of patients who did not have the loss of function alleles, clopidogrel plus aspirin versus aspirin alone was associated with statistical significant reduction in the risk of stroke (6.7% vs. 12.4%; hazard ratio [HR], 0.51; 95% confidence interval [CI], 0.35 to 0.75) but not among those who carried loss of function alleles (9.4% vs. 10.8%; HR, 0.93; 95% CI, 0.69 to 1.26).[8,] Results of this analysis have contributed to the formulation of the hypothesis of a differential effect of clopidogrel in patients with and without loss of function alleles.

Trials are important to validate such hypotheses. However, only a few trials of genotype-directed dosing or drug choice have been conducted; they are summarized in Tables 3 and 4 and discussed next. It is important to note that these trials use "high on-treatment platelet reactivity" as the outcome measure. Patients who exhibit "high on-treatment platelet reactivity" are referred to as being nonresponsive, hyporesponsive, or resistant to clopidogrel in the published literature.

Roberts et al (2012) reported on the results of an RCT that allocated patients undergoing PCI for acute coronary syndrome or stable angina to genotype-guided management to select for treatment with prasugrel (carriers) or clopidogrel (noncarriers) or to standard treatment with clopidogrel.[9,] Among those who received prasugrel and clopidogrel based on genotyping test, 0% and 10%, respectively, exhibited high on-treatment platelet reactivity while 17% patients who received standard treatment with clopidogrel without any genotypes testing exhibited high on-treatment platelet reactivity. This difference was not statistically significant. So et al (2016) reported on the results of an RCT that randomized ST-elevation myocardial infarction patients who were carriers of *CYP2C19*2*, *ABCB1* TT, and *CYP2C19*17* alleles to prasugrel 10 mg daily or an augmented dosing strategy of clopidogrel (150 mg per day for 6 days and subsequently 75 mg per day).[10,] Results showed that (1) carriers did not respond to augmented clopidogrel as well as they did to prasugrel (24% patients with high platelet reactivity vs. 0%) and (2) among noncarriers, physician-directed clopidogrel was effective for most patients (95% did not have high platelet reactivity).

Claassens et al (2019) [11,] reported on the results of the CYP2C19 Genotype Guided Treatment With Antiplatelet Drugs in Patients With ST-segment-elevation Myocardial Infarction Undergoing

Immediate PCI With Stent Implantation: Optimization of Treatment (POPular Genetics) trial. In this non-inferiority trial, patients with acute coronary syndrome were randomly assigned to receive standard treatment (prasugrel or ticagrelor) or genotype-guided treatment (clopidogrel in those without *CYP2C19* loss of-function variants; standard treatment otherwise). Results of the primary combined endpoint met the P value for non-inferiority. Thus, one can conclude that a genotype guided strategy led to outcomes that were at least as good as, if not better than, outcomes with the standard approach of prescribing prasugrel or ticagrelor to all patients. However, the trial results do not inform whether using genotype based strategy for prescribing clopidogrel results in any incremental net health benefit versus standard treatment with clopidogrel. Furthermore, there was no difference in the incidence of PLATO major bleeding between the genotype-guided group and the standard-treatment group (2.3% in both groups; HR, 0.97; 95% CI, 0.58 to 1.63). The statistically significant difference observed in the primary bleeding outcome was primarily driven by PLATO minor bleeding events in the genotype-guided group versus standard-treatment group (7.6% vs. 10.5%; HR , 0.72; 95% CI, 0.55 to 0.94).

Pereira et al (2021) reported the results of the open-label randomized TAILOR-PCI trial of 5302 patients undergoing PCI for acute coronary syndromes or stable coronary artery disease.[12,] The genotype-guided group underwent point-of-care genotyping for detection of *CYP2C19* carriers and were prescribed ticagrelor (prasugrel was recommended as an alternative for patients who did not tolerate ticagrelor) and noncarriers were prescribed clopidogrel. Patients randomized to the conventional group were prescribed clopidogrel and underwent genotyping after 12 months. Among 5302 patients randomized (median age, 62 years; 25% women), 94% completed the trial. Of 1849 *CYP2C19* carriers, 764 of 903 (85%) assigned to genotype-guided therapy received ticagrelor, and 932 of 946 (99%) assigned to conventional therapy received clopidogrel. The primary end point (a composite of cardiovascular death, myocardial infarction, stroke, stent thrombosis, and severe recurrent ischemia at 12 months) occurred in 35 of 903 *CYP2C19* carriers (4.0%) in the genotype-guided therapy group and 54 of 946 (5.9%) in the conventional therapy group at 12 months (HR , 0.66; 95% CI, 0.43 to 1.02; p=.06). None of the 11 prespecified secondary end points showed significant differences, including major or minor bleeding in *CYP2C19* carriers in the genotype-guided group (1.9%) versus the conventional therapy group (1.6%) at 12 months (HR , 1.22; 95% CI , 0.60 to 2.51; p=.58). Among all randomized patients, the primary end point occurred in 113 of 2641 (4.4%) in the genotype-guided group and 135 of 2635 (5.3%) in the conventional group (HR , 0.84; 95% CI , 0.65 to 1.07; p=.16). The trial failed to meet the pre-specified end point and the authors contend that the trial was underpowered to detect an effect size less than the 50% relative risk after a revised sample calculation. Despite the occurrence of 89 ischemic events observed in this trial, which exceeded the 76 events anticipated to provide adequate power, the observed relative risk reduction was 34% instead of the estimated 50%, hence a borderline p value of.056 was observed. Further, the authors also comment that the potential benefit of genotype-guided oral P2Y12 inhibitor therapy may be important early after PCI rather than 12 months after PCI. A post-hoc analysis of the data from the trial showed that a nearly 80% reduction in the rate of adverse events occurred in the first three months of treatment among patients who received genetically guided therapy compared with those who did not.

Table 3. Summary of Key Randomized Controlled Trial Characteristics

Study; Trial	Countries	Sites	Dates	Participants	Interventions	
					Active	**Comparator**
So et al (2016)[10]; RAPID STEMI	Canada	1	2011 - 2012	18-75 y who had PCI for STEMI who received POC testing for *CYP2C19*2*, *ABC B1* TT, and *CYP2C19*17* alleles (N=102)	Carriers randomized to prasugrel 10 mg/d (n=30) or augmented clopidogrel (150 mg/d for 6 d and then 75 mg/d) (n=29)	Noncarriers given clopidogrel with dosing as per treating physician (n=43)
Roberts et al (2012)[9]; RAPID GENE	Canada	1	2010 - 2011	18-75 y undergoing PCI for acute coronary syndrome or stable angina (n=200)	POC testing for *CYP2C19*2* allele (n=102). Of these, 23 carriers were given prasugrel 10 mg/d, and 74 noncarriers were given clopidogrel 75 mg/d.	No genetic testing and clopidogrel 75 mg/d
Claassens et al (2019);[11] POPular Genetics	Europe	10	2011 - 2018	21 y or older with signs and symptoms of STEMI undergoing PCI (n=2488)	Genotype-guided group: Individuals received clopidogrel (non-carriers) or prasugrel/ticagrelor (carriers) for one year	Prasugrel/ticagrelor for one year
Pereira et al (2021)[12]; TAILOR PCI	US, Canada, South Korea, and Mexico	40	2013 - 2018	Adult undergoing PCI for ACS or stable CAD (n=5302).	Genotype-guided therapy group using POC genotyping. *CYP2C19* carriers were prescribed ticagrelor for maintenance therapy, and noncarriers or those with inconclusive results were prescribed clopidogrel. Prasugrel was recommended as an alternative for patients who did not tolerate ticagrelor (n=2653 randomized; n=2641eligible for analysis; n=903 *CYP2C19* carriers identified and included in primary analysis).	Conventional therapy group without prospective genotyping. All were prescribed clopidogrel according to drug label (n=2650 randomized; n=2635 eligible for analysis; n=946 *CYP2C19* carriers identified and included in primary analysis).

PCI; Percutaneous coronary intervention; POC; point of care; STEMI; ST-elevation myocardial infarction
POPular Genetics: Cost-effectiveness of CYP2C19 Genotype Guided Treatment With Antiplatelet Drugs in Patients With ST-segment-elevation Myocardial Infarction Undergoing Immediate PCI With Stent Implantation: Optimization of

Treatment; RAPID GENE: ReAssessment of Anti-Platelet Therapy Using an InDividualized Strategy Based on GENetic Evaluation; RAPID STEMI: ReAssessment of Anti-Platelet Therapy Using an InDividualized Strategy in Patients With ST-segment Elevation Myocardial Infarction.

Table 4. Summary of Key Randomized Controlled Trial Results

Study; Trial	**Outcome**
	High Platelet Reactivity[a]
So et al (2016)[10,]; RAPID STEMI	102
Carriers	
Prasugrel	0%[d]
Augmented clopidogrel	24%[d]
Noncarriers	
Clopidogrel as per treating physician	5%[d]
p	.0046[b];.507[c]
Roberts et al (2012)[9,]; RAPID GENE	187
Genotype-guided management	
Prasugrel 10 mg/d	0%
Clopidogrel 75 mg/d	10%
Entire cohort	10%
Standard clinical management	
Clopidogrel 75 mg/d	17%[e]
p	*NS*
Claassens et al (2019);[11,]; POPular Genetics	Primary Combined Outcome[f]
Genotype-guided management (n=1242)	63 (5.1%)
Standard-treatment group (n=1246)	73 (5.9%)
Absolute difference (95% CI); p	0.7 (−2.0 to 0.7); <.001 for noninferiority
	Primary Bleeding Outcome[g]
Genotype-guided management (n=1242)	*122 (9.8%)*
Standard-treatment group (n=1246)	156 (12.5%)
Hazard ratio (95% CI); p	0.78 (0.61 to 0.98);.04
Pereira et al (2021)[12,]; TAILOR PC	Primary Combined Outcome[h]
Genotype-guided management (n=903)	35 (4%)
Conventional therapy (n=946)	54 (5.9%)
Difference in 12-month event rates, % (95% CI)	−1.8 (−3.9 to 0.1)
Hazard ratio (95% CI) ; p	0.66 (0.43 to 1.02) ;.06

Study; Trial	Outcome
	High Platelet Reactivity[a]
	Secondary Combined Outcome[i]
Genotype-guided management (n=903)	16 (1.9%)
Conventional therapy (n=946)	14 (1.6%)
Difference in 12-month event rates, % (95% CI)	0.3 (−0.9 to 1.6)
Hazard ratio (95% CI) ; p	1.22 (0.60 to 2.51) ;.58

POPular Genetics: Cost-effectiveness of CYP2C19 Genotype Guided Treatment With Antiplatelet Drugs in Patients With ST-segment-elevation Myocardial Infarction Undergoing Immediate PCI With Stent Implantation: Optimization of Treatment; RAPID GENE: ReAssessment of Anti-Platelet Therapy Using an InDividualized Strategy Based on GENetic Evaluation; RAPID STEMI: ReAssessment of Anti-Platelet Therapy Using an InDividualized Strategy in Patients With ST-segment Elevation Myocardial Infarction.
CI: confidence interval; NS: not significant.
[a] P2Y12 reaction unit >234 (a measure of high on-treatment platelet reactivity).
[b] Prasugrel vs. augmented clopidogrel.
[c] Prasugrel vs. physician-directed clopidogrel.
[d]At 30 days.
[e] At 1 week.
[f] Death from any cause, myocardial infarction, definite stent thrombosis, stroke, or major bleeding as defined by Platelet Inhibition and Patient Outcomes (PLATO) criteria at 12 months
[g] PLATO major bleeding (coronary artery bypass graft [CABG]-related and non–CABG-related) or minor bleeding at 12 months (primary bleeding outcome)
[h] Cardiovascular death, myocardial infarction, stroke, severe recurrent ischemia, stent thrombosis
[i] Major or minor bleeding as defined by the Thrombolysis in Myocardial Infarction (TIMI) criteria

The purpose of the limitation tables (see Tables 5 and 6) is to display notable limitations identified in each study. This information is synthesized as a summary of the body of evidence following each table and provides the conclusions on the sufficiency of the evidence supporting the position statement. The studies were, in general, well-designed and conducted, the major limitation being the use of platelet activity, which is an intermediate outcome measure, and lack of reporting on health endpoints over a longer follow-up. Platelet reactivity during treatment is an intermediate endpoint that has been shown to have a limited value in guiding therapeutic decisions based on results of the large Assessment by a Double Randomization of a Conventional Antiplatelet Strategy Versus a Monitoring-Guided Strategy for Drug-Eluting Stent Implantation and of Treatment Interruption Versus Continuation One Year After Stenting (ARCTIC) RCT.[13,14,] Briefly, the ARCTIC trial randomized 2440 patients scheduled for coronary stenting to platelet-function monitoring or no monitoring. Platelet-function testing was performed in the monitored group both before and 14 to 30 days after PCI. Multiple therapeutic changes, including an additional loading dose of clopidogrel (at a dose ≥600 mg) or a loading dose of prasugrel (at a dose of 60 mg) before the procedure, followed by a daily maintenance dose of clopidogrel 150 mg or prasugrel 10 mg, were made according to a predefined protocol. There was no difference in the rate of the primary composite endpoint (death, myocardial infarction, stent thrombosis, stroke, or urgent revascularization) at 1 year between the monitoring (34.6%) and no monitoring groups (31.1%). Further, an adequately powered TAILOR-PCI RCT reported no statistically significant difference in a composite end point of cardiovascular death, myocardial infarction, stroke, stent thrombosis, and severe recurrent ischemia among patients with *CYP2C19* loss-of-function alleles who underwent PCI, genotype-guided selection of an oral P2Y12 inhibitor compared with conventional clopidogrel therapy. Limitations of this trial included the possibility of

being underpowered when sample size calculations were revised, some patients not receiving designated antiplatelet therapy and the open-label nature of the trial. However, the adjudication of all events was blinded.

Table 5. Study Relevance Limitations

Study	Population[a]	Intervention[b]	Comparator[c]	Outcomes[d]	Follow-Up[e]
So et al (2016)[10]; RAPID STEMI				2. Platelet activity is an intermediate outcome measure 3. CONSORT harms not reported	1, 2. Outcomes assessed at 1 mo
Roberts et al (2012)[9]; RAPID GENE				2. Platelet activity is an intermediate outcome measure 3. CONSORT harms no reported	1, 2. Outcomes assessed at 1wk
Claassens et al (2019); [11]; POPular Genetics	2. Clinical context is unclear	2. Not standard or optimal			
Pereira et al (2021)[12]; TAILOR PC		2. Version used unclear (some patients not receiving designated antiplatelet therapy)			

POPular Genetics: Cost-effectiveness of CYP2C19 Genotype Guided Treatment With Antiplatelet Drugs in Patients With ST-segment-elevation Myocardial Infarction Undergoing Immediate PCI With Stent Implantation: Optimization of Treatment; RAPID GENE: ReAssessment of Anti-Platelet Therapy Using an InDividualized Strategy Based on GENetic Evaluation; RAPID STEMI: ReAssessment of Anti-Platelet Therapy Using an InDividualized Strategy in Patients With ST-segment Elevation Myocardial Infarction.
The evidence limitations stated in this table are those notable in the current review; this is not a comprehensive gaps assessment.
[a] Population key: 1. Intended use population unclear; 2. Clinical context is unclear; 3. Study population is unclear; 4. Study population not representative of intended use.
[b] Intervention key: 1. Not clearly defined; 2. Version used unclear; 3. Delivery not similar intensity as comparator; 4.Not the intervention of interest.
[c] Comparator key: 1. Not clearly defined; 2. Not standard or optimal; 3. Delivery not similar intensity as intervention; 4. Not delivered effectively.
[d] Outcomes key: 1. Key health outcomes not addressed; 2. Physiologic measures, not validated surrogates; 3. No CONSORT reporting of harms; 4. Not establish and validated measurements; 5. Clinical significant difference not prespecified; 6. Clinical significant difference not supported.
[e] Follow-Up key: 1. Not sufficient duration for benefit; 2. Not sufficient duration for harms.

Table 6. Study Design and Conduct Limitations

Study	Allocation[a]	Blinding[b]	Selective Reporting[d]	Data Completeness[e]	Power[d]	Statistical[f]
So et al (2016)[10,]; RAPID STEMI						
Roberts et al (2012)[9,]; RAPID GENE	3. Allocation concealment unclear					
Claassens et al (2019); [11,]; POPular Genetics		1. Not blinded to treatment assignment;				
Pereira et al (2021)[12,]; TAILOR PC		1. Not blinded to treatment assignment				

POPular Genetics: Cost-effectiveness of CYP2C19 Genotype Guided Treatment With Antiplatelet Drugs in Patients With ST-segment-elevation Myocardial Infarction Undergoing Immediate PCI With Stent Implantation: Optimization of Treatment; RAPID GENE: ReAssessment of Anti-Platelet Therapy Using an InDividualized Strategy Based on GENetic Evaluation; RAPID STEMI: ReAssessment of Anti-Platelet Therapy Using an InDividualized Strategy in Patients With ST-segment Elevation Myocardial Infarction.
The evidence limitations stated in this table are those notable in the current review; this is not a comprehensive gaps assessment.
[a] Allocation key: 1. Participants not randomly allocated; 2. Allocation not concealed; 3. Allocation concealment unclear; 4. Inadequate control for selection bias.
[b] Blinding key: 1. Not blinded to treatment assignment; 2. Not blinded outcome assessment; 3. Outcome assessed by treating physician.
[c] Selective Reporting key: 1. Not registered; 2. Evidence of selective reporting; 3. Evidence of selective publication.
[d] Data Completeness key: 1. High loss to follow-up or missing data; 2. Inadequate handling of missing data; 3. High number of crossovers; 4. Inadequate handling of crossovers; 5. Inappropriate exclusions; 6. Not intent to treat analysis (per protocol for noninferiority trials).
[e] Power key: 1. Power calculations not reported; 2. Power not calculated for primary outcome; 3. Power not based on clinically important difference.
[f] Statistical key: 1. Intervention is not appropriate for outcome type: (a) continuous; (b) binary; (c) time to event; 2. Intervention is not appropriate for multiple observations per patient; 3. Confidence intervals and/or p values not reported; 4.Comparative treatment effects not calculated.

Section Summary: Clopidogrel

Four RCTs have evaluated the role of genetic testing for *CYP2C19* for selecting appropriate antiplatelet treatment and/or amplified dosing of clopidogrel using an intermediate outcome measure of platelet reactivity to predict CYP2C19 metabolic state. One RCT has shown there was no statistical difference in patients with "on-treatment high platelet reactivity" who received genotype-guided management or standard treatment with clopidogrel. The second RCT showed that carriers of loss of function alleles did not respond to augmented clopidogrel as well as they did to prasugrel, while physician-directed clopidogrel was effective for most noncarriers. However, routine testing using platelet reactivity as an outcome measure to predict CYP2C19 metabolic state has not been shown to improve health outcomes. The third non-inferiority RCT compared showed that genotype guided strategy led to outcomes that were at least as good as, if not better than, outcomes with the standard approach of prescribing prasugrel or ticagrelor to all patients. Results of this trial do not inform whether using genotype based strategy for

prescribing clopidogrel results in any incremental net health benefit versus standard treatment with clopidogrel. Furthermore, the statistical significant difference observed in favor of genotype guided strategy for bleeding outcome was primarily driven by minor bleeding events. There was no difference in the incidence of major bleeding between the 2 groups. Results of TAILOR-PCI reported no statistically significant difference in a composite end point of cardiovascular death, myocardial infarction, stroke, stent thrombosis, and severe recurrent ischemia among patients with *CYP2C19* loss-of-function alleles who underwent PCI, genotype-guided selection of an oral P2Y12 inhibitor compared with conventional clopidogrel therapy.

SELECTION AND DOSING OF OTHER DRUGS

Antiretroviral Agents

Efavirenz is a widely used non-nucleoside reverse transcriptase inhibitor component of highly active antiretroviral therapy for patients with HIV infection. However, unpredictable interindividual variability in efficacy and toxicity remain important limitations associated with its use. Forty percent to 70% of patients have reported adverse central nervous system events. While most resolve in the first few weeks of treatment, about 6% of patients discontinue efavirenz due to adverse events.[15,] Efavirenz is primarily metabolized by the CYP2B6 enzyme, and inactivating variants such as *CYP2B6*6* are associated with higher efavirenz exposure, although plasma levels appear not to correlate with adverse events. On the other hand, *CYP2B6* poor metabolizers have markedly reduced adverse events while maintaining viral immunosuppression at substantially lower doses.[16,17,] An increased early discontinuation rate with efavirenz has been reported in retrospective cohort studies evaluating multiple *CYP450* variants including *CYP2B6.*[18,19,] *CYP2B6 G516T* and *T983C* single nucleotide variants were reported by Ciccacci et al (2013) to be associated with susceptibility to Stevens-Johnson syndrome in a case-control study of 27 patients who received nevirapine-containing antiretroviral treatment.[20,] The current evidence documenting the usefulness of *CYP450* variant genotyping to prospectively guide antiretroviral medications and assess its impact on clinical outcomes is lacking.

Immunosuppressants for Therapy for Organ Transplantation

Tacrolimus is the mainstay immunosuppressant drug and multiple studies have shown that individuals who express *CYP3A5* (extensive and intermediate metabolizers) generally have decreased dose-adjusted trough concentrations of tacrolimus, possibly delaying achievement of target blood concentrations compared with those who are *CYP3A5* nonexpressers (poor metabolizers) in whom drug levels may be elevated and possibly result in nephrotoxicity. The current evidence demonstrating the impact of *CYP3A5* genotyping to guide tacrolimus dosing and its impact on clinical outcomes includes RCTs by Thervet et al (2010)[21,] and Min et al (2018).[22,] Both RCTs compared the impact of *CYP3A5* genotype-informed dosing with standard dosing strategies on tacrolimus drug levels. The trials were not powered to assess any clinical outcomes such as graft function or survival, which otherwise were similar between groups in Thervet et al (2010).[21,]

b-Blockers

Several reports have indicated that lipophilic b-blockers (e.g., metoprolol), used in treating hypertension, may exhibit impaired elimination in patients with *CYP2D6* variants.[23,24,] The current evidence documenting the usefulness of *CYP2D6* genotyping to prospectively guide antitubercular medications and assess its impact on clinical outcomes is lacking.

Antitubercular Medications
A number of studies, summarized in a systematic review by Wang et al (2016), have reported an association between *CYP2E1* status and the risk of liver toxicity from antitubercular medications.[25,] The current evidence documenting the usefulness of *CYP2E1* genotyping to prospectively guide antitubercular medications and assess its impact on clinical outcomes is lacking.

Section Summary: Selection and Dosing of Other Drugs
In general, most published *CYP450* pharmacogenomic studies for highly active antiretroviral agents, b-blockers, and antitubercular medications are retrospective evaluations of *CYP450* genotype associations, reporting intermediate outcomes (e.g., circulating drug concentrations) or less often, final outcomes (e.g., adverse events or efficacy). Many of these studies are small, underpowered, and hypothesis generating. Prospective intervention studies, including RCTs documenting clinical usefulness of *CYP450* genotyping to improve existing clinical decision-making to guide dose or drug selection, which will then translate into improvement in patient outcomes, were not identified.

Summary of Evidence
For individuals with a need for antiplatelet therapy who are undergoing or being considered for clopidogrel therapy who receive a *CYP2C19*-guided treatment strategy, the evidence includes 3 RCTs. Relevant outcomes are overall survival, medication use, and treatment-related morbidity. Four RCTs have evaluated the role of genetic testing for *CYP2C19* for selecting appropriate antiplatelet treatment and/or amplified dosing of clopidogrel using an intermediate outcome measure of platelet reactivity to predict CYP2C19 metabolic state. One RCT has shown there was no statistical difference in patients with "on-treatment high platelet reactivity" who received genotype-guided management or standard treatment with clopidogrel. The second RCT showed that carriers of loss of function alleles did not respond to augmented clopidogrel as well as they did to prasugrel, while physician-directed clopidogrel was effective for most noncarriers. However, routine testing using platelet reactivity as an outcome measure to predict CYP2C19 metabolic state has not been shown to improve health outcomes. The third non-inferiority RCT compared showed that genotype guided strategy led to outcomes that were at least as good as, if not better than, outcomes with the standard approach of prescribing prasugrel or ticagrelor to all patients. Results of this trial do not inform whether using genotype based strategy for prescribing clopidogrel results in any incremental net health benefit versus standard treatment with clopidogrel. Furthermore, the statistical significant difference observed in favor of genotype guided strategy for bleeding outcome was primarily driven by minor bleeding events. There was no difference in the incidence of major bleeding between the 2 groups. Results of TAILOR-PCI reported no statistically significant difference in a composite end point of cardiovascular death, myocardial infarction, stroke, stent thrombosis, and severe recurrent ischemia among patients with *CYP2C19* loss-of-function alleles who underwent PCI, genotype-guided selection of an oral P2Y12 inhibitor compared with conventional clopidogrel therapy. A meta-analysis that included 7 RCTs (15,949 patients) comparing clopidogrel versus alternative (prasugrel or ticagrelor) demonstrated that ticagrelor or prasugrel compared with clopidogrel significantly reduced ischemic events in *CYP2C19* carriers but not in noncarrier patients with coronary artery disease after PCI. The evidence is insufficient to determine that the technology results in an improvement in the net health outcome.

For individuals who are undergoing or being considered for treatment with highly active antiretroviral agents, immunosuppressant therapy for organ transplantation, beta-blockers, or antitubercular medications who receive a *CYP2C19*-guided treatment strategy, the evidence includes retrospective studies. Relevant outcomes are medication use and treatment-related morbidity. In general, most published *CYP450* pharmacogenomic studies for these drugs consist of retrospective evaluations of *CYP450* genotype associations, reporting intermediate outcomes (e.g., circulating drug concentrations) or less often, final outcomes (e.g., adverse events or efficacy). Many of these studies are small, underpowered and hypothesis generating. Prospective intervention studies, including RCTs documenting the clinical usefulness of *CYP450* genotyping to improve existing clinical decision making to guide dose or drug selection, which may then translate into improvement in patient outcomes, were not identified. The evidence is insufficient to determine that the technology results in an improvement in the net health outcome.

SUPPLEMENTAL INFORMATION

The purpose of the following information is to provide reference material. Inclusion does not imply endorsement or alignment with the evidence review conclusions.

Clinical Input From Physician Specialty Societies and Academic Medical Centers

While the various physician specialty societies and academic medical centers may collaborate with and make recommendations during this process, through the provision of appropriate reviewers, input received does not represent an endorsement or position statement by the physician specialty societies or academic medical centers, unless otherwise noted.

In response to requests, input was received from 4 physician specialty societies and 4 academic medical centers while this policy was under review in 2012. Opinions on use of genotype testing of patients being considered for clopidogrel treatment were mixed, with 5 suggesting the test be considered investigational and 3 suggesting it be considered medically necessary.

Practice Guidelines and Position Statements

Guidelines or position statements will be considered for inclusion in 'Supplemental Information' if they were issued by, or jointly by, a US professional society, an international society with US representation, or National Institute for Health and Care Excellence (NICE). Priority will be given to guidelines that are informed by a systematic review, include strength of evidence ratings, and include a description of management of conflict of interest.

American College of Cardiology Foundation

A consensus statement by the American College of Cardiology Foundation (ACCF) and the American Heart Association (AHA) on genetic testing for the selection and dosing of clopidogrel was published in 2010.[26,] The recommendations for practice included the following statements:

1. "Adherence to existing ACCF/AHA guidelines for the use of antiplatelet therapy should remain the foundation for therapy. Careful clinical judgment is required to assess the importance of the variability in response to clopidogrel for an individual patient and its associated risk to the patient…
2. Clinicians must be aware that genetic variability in CYP enzymes alter clopidogrel metabolism, which in turn can affect its inhibition of platelet function. Diminished responsiveness to clopidogrel has been associated with adverse patient outcomes in registry experiences and clinical trials.

3. The specific impact of the individual genetic polymorphisms on clinical outcome remains to be determined....
4. Information regarding the predictive value of pharmacogenomic testing is very limited at this time; resolution of this issue is the focus of multiple ongoing studies. The selection of the specific test, as well as the issue of reimbursement, is both important additional considerations.
5. The evidence base is insufficient to recommend either routine genetic or platelet function testing at the present time….
6. There are several possible therapeutic options for patients who experience an adverse event while taking clopidogrel in the absence of any concern about medication compliance."

U.S. Preventive Services Task Force Recommendations
No U.S. Preventive Services Task Force recommendations for cytochrome P450 have been identified.

Ongoing and Unpublished Clinical Trials
No relevant ongoing or unpublished studies that might influence this review were identified.

CODING

The following codes for treatment and procedures applicable to this policy are included below for informational purposes. This may not be a comprehensive list of procedure codes applicable to this policy.

Inclusion or exclusion of a procedure, diagnosis or device code(s) does not constitute or imply member coverage or provider reimbursement. Please refer to the member's contract benefits in effect at the time of service to determine coverage or non-coverage of these services as it applies to an individual member.

The code(s) listed below are medically necessary ONLY if the procedure is performed according to the "Policy" section of this document.

CPT/HCPCS	
81225	CYP2C19 (cytochrome P450, family 2, subfamily C, polypeptide 19 (e.g., drug metabolism), gene analysis, common variants (e.g., *2, *3, *4, *8, *17)
81226	CYP2D6 (cytochrome P450, family 2, subfamily D, polypeptide 6) (e.g., drug metabolism), gene analysis, common variants (e.g., *2, *3, *4, *5, *6, *9, *10, *17, *19, *29, *35, *41, *1XN, *2XN, *4XN)
81227	CYP2C9 (cytochrome P450, family 2, subfamily C, polypeptide 9) (e.g., drug metabolism), gene analysis, common variants (e.g., *2, *3, *5, *6)
81230	CYP3A4 (cytochrome P450 family 3 subfamily A member 4) (e.g., drug metabolism), gene analysis, common variant(s) (e.g., *2, *22)
81231	CYP3A5 (cytochrome P450 family 3 subfamily A member 5) (e.g., drug metabolism), gene analysis, common variants (e.g., *2, *3, *4, *5, *6, *7)
81402	Molecular Pathology Procedure Level 3 ▪ CYP21A2 (cytochrome P450, family 21, subfamily A, polypeptide 2) (e.g., congenital adrenal hyperplasia, 21-hydroxylase deficiency), common variants (e.g., IVS2-13G, P30L, I172N, exon 6 mutation cluster [I235N, V236E, M238K], V281L, L307FfsX6, Q318X, R356W, P453S, G110VfsX21, 30-kb deletion variant)
81404	Molecular Pathology Procedure Level 5 ▪ CYP1B1 (cytochrome P450, family 1, subfamily B, polypeptide 1) (e.g., primary congenital glaucoma), full gene sequence
81405	Molecular Pathology Procedure Level 7 ▪ CYP11B1 (cytochrome P450, family 11, subfamily B, polypeptide 1) (e.g., congenital adrenal hyperplasia), full gene sequence ▪ CYP17A1 (cytochrome P450, family 17, subfamily A, polypeptide 1) (e.g., congenital adrenal hyperplasia), full gene sequence ▪ CYP21A2 (cytochrome P450, family 21, subfamily A, polypeptide2) (e.g., steroid 21-hydroxylase isoform, congenital adrenal hyperplasia), full gene sequence
0029U	Drug metabolism (adverse drug reactions and drug response), targeted sequence analysis (i.e., CYP1A2, CYP2C19, CYP2C9, CYP2D6, CYP3A4, CYP3A5, CYP4F2, SLCO1B1, VKORC1 and rs12777823)
0031U	CYP1A2 (cytochrome P450 family 1, subfamily A, member 2)(e.g., drug metabolism) gene analysis, common variants (i.e., *1F, *1K, *6, *7)
0070U	CYP2D6 (cytochrome P450, family 2, subfamily D, polypeptide 6) (e.g., drug metabolism) gene analysis, common and select rare variants (i.e., *2, *3, *4, *4N,

CPT/HCPCS	
	*5, *6, *7, *8, *9, *10, *11, *12, *13, *14A, *14B, *15, *17, *29, *35, *36, *41, *57, *61, *63, *68, *83, *xN)
0071U	CYP2D6 (cytochrome P450, family 2, subfamily D, polypeptide 6) (e.g., drug metabolism) gene analysis, full gene sequence (List separately in addition to code for primary procedure)
0072U	CYP2D6 (cytochrome P450, family 2, subfamily D, polypeptide 6) (e.g., drug metabolism) gene analysis, targeted sequence analysis (i.e., CYP2D6-2D7 hybrid gene) (List separately in addition to code for primary procedure)
0073U	CYP2D6 (cytochrome P450, family 2, subfamily D, polypeptide 6) (e.g., drug metabolism) gene analysis, targeted sequence analysis (i.e., CYP2D7-2D6 hybrid gene) (List separately in addition to code for primary procedure)
0074U	CYP2D6 (cytochrome P450, family 2, subfamily D, polypeptide 6) (e.g., drug metabolism) gene analysis, targeted sequence analysis (i.e., non-duplicated gene when duplication/multiplication is trans) (list separately in addition to code for primary procedure)
0075U	CYP2D6 (cytochrome P450, family 2, subfamily D, polypeptide 6) (e.g., drug metabolism) gene analysis, targeted sequence analysis (i.e., 5 gene duplication/multiplication) (list separately in addition to code for primary procedure)
0076U	CYP2D6 (cytochrome P450, family 2, subfamily D, polypeptide 6) (e.g., drug metabolism) gene analysis, targeted sequence analysis (i.e., 3 gene duplication/ multiplication) (list separately in addition to code for primary procedure)

ICD-10 DIAGNOSES	
I20.0	Unstable angina
I21.01-I22.9	Acute myocardial infarction code range
I24.1	Dressler's syndrome
I25.110	Atherosclerotic heart disease of native coronary artery with unstable angina pectoris
I63.50-I63.549	Occlusion and stenosis of cerebral arteries, resulting in cerebral infarction, code range
I66.01-I66.9	Occlusion and stenosis of cerebral arteries, not resulting in cerebral infarction, code range
I73.9	Peripheral vascular disease, unspecified

REVISIONS	
10-26-2010	Policy added to the bcbsks.com web site.
08-12-2011	Rationale section updated.
	In Coding section: Updated nomenclature for CPT codes: 88385, 88386
	Reference section updated.
02-14-2012	In Coding section: ▪ Added CPT codes: 81225, 81226, 81227 (effective 01-01-2012) ▪ Added the following notations: ▪ "Use 81225, 81226, 81227 when indicated, otherwise use 88384, 88385, 88386.

REVISIONS	
	▪ See the policies below for genetic testing related to these items: ○ Genetic Testing for Helicobacter pylori Treatment medical policy ○ Genetic Testing for Tamoxifen Treatment medical policy ○ Genetic Testing for Warfarin Dose medical policy"
01-01-2013	In Coding section: ▪ Removed CPT codes: 88384, 88385, 88386 (effective 12-31-2012)
03-31-2014	Description section updated
	In Policy section: ▪ In Item A revised wording from: "CYP450 phenotyping for CYP2C19 *2 and *3 alleles may be considered medically necessary in patients with cardiovascular disease undergoing treatment with clopidogrel (Plavix®) in order to identify those who are poor metabolizers of the drug (patients with CYP2C19*2/2,*3/3, and *2/3 genotypes) and who are, therefore, likely to exhibit poor response to the drug." To: "CYP450 genotyping for the purpose of aiding in the choice of clopidogrel versus alternative antiplatelet agents, or in decisions on the optimal dosing for clopidogrel, may be considered medically necessary." ▪ In Item B revised the wording from: "Aside from the use with clopidogrel treatment noted above, genotyping to determine specific cytochrome p450 (CYP450) genetic polymorphisms for the purpose of aiding in the choice of drug or dose increase efficacy and/or avoid toxicity is considered experimental / investigational. This includes, but is not limited to, CYP450 genotyping for the following applications:" To: "CYP450 genotyping for the purpose of aiding in the choice of drug or dose to increase efficacy and/or avoid toxicity for all other drugs is considered experimental / investigational. This includes, but is not limited to, CYP450 genotyping for the following applications:" ▪ In Item B removed E/I indication, "dose of atomoxetine HCl (approved for treatment of attention-deficit/hyperactivity disorder)" ▪ In Item B added E/I indications: "4. selection and dosing of selective norepinephrine reuptake inhibitors", "5. selection and dosing of tricyclic antidepressants", and "9. dosing and management of antituberculosis medications"
	Rationale section updated
	In Coding section: ▪ CPT Coding Instructions added ▪ Added ICD-10 Diagnoses Codes: P91.821, P91.822, P91.823 (Effective 10-01-2020)
	References updated
10-01-2016	In Coding section: ▪ ICD-10 Codes Added Effective 10-01-2016: I63.413, I63.423, I63.433, I63.443, I63513, I63.523, I63.533, I63.543
03-10-2021	Title revised to "Cytochrome p450 Genotype-Guided Treatment Strategy" from "Cytochrome p450 Genotyping"
	Description section updated
	In Policy section: ▪ Added "CYP2D6 genotyping to determine drug metabolizer status may be considered medically necessary for patients: 1. With Gaucher disease being considered for treatment with eliglustat 2. With Huntington disease being considered for treatment with tetrabenazine in a dosage greater than 50 mg per day" ▪ In Item B removed "This includes, but is not limited to, CYP450 genotyping for the following applications" and added "aside from the determinations in the separate policy statements above" to read "CYP450 genotyping for the purpose of aiding in the choice of drug or dose to increase efficacy and/or avoid toxicity for all other drugs is considered

REVISIONS	
	experimental / investigational. aside from determinations in the separate policy statements above:" ▪ In Item B 1 removed "deciding whether to prescribe" and "for nursing mother" and added "selection or dosage of" to read "selection or dosage of codeine" ▪ In Item B 2 removed "common component of highlight active" and added "and other" to read "dosing of efavirenz and other antiretroviral therapies for HIV infection" ▪ Removed the following as they are no longer pertinent to this policy: "6. selection or dose of selective serotonin reuptake inhibitor (SSRI) 7. selection or dose of antipsychotic drugs 8. selection and dosing of selective norepinephrine reuptake inhibitors 9. selection and dosing of tricyclic antidepressants" ▪ In Item C revised "may be considered medically necessary" to "is considered **experimental / investigational**" to read "CYP450 genotyping for the purpose of aiding in the choice of clopidogrel versus alternative antiplatelet agents, or in decisions on the optimal dosing for clopidogrel, is considered experimental / investigational." ▪ Added Item D "The use of genetic testing panels that include multiple CYP450 variants is considered experimental / investigational."
	Rationale section updated
	In Coding section: ▪ Added the following CPT and PLA codes: 81230, 81231, 0029U, 0031U, 0070U, 0071U, 0072U, 0073U ▪ Added the following ICD-10 codes: P91.821, P91.822, P91.823
	References updated
08-28-2021	Description section updated.
	In Policy section: ▪ Added Item B.5.
	Rationale section updated.
	Reference section updated.
09-08-2022	Updated Description Section
	Updated Policy Section ▪ Added Section B: CYP2C9 genotyping to determine drug metabolizer status may be considered medically necessary for individuals: 1. With relapsing forms of multiple sclerosis, to include clinically isolated syndrome, relapsing-remitting disease, and active secondary progressive disease, being considered for treatment with siponimod.
	Updated Policy Guideline Section ▪ Added Section B: "The Food and Drug Administration maintains a database of pharmacogenomic biomarkers in drug labeling. See section "Regulatory Status" for details."
	Updated Rationale Section
	Updated Coding Section ▪ Converted ICD-10 codes to ranges
	Updated References Section

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