Note: Cytochrome P450 is a family of proteins (enzymes) including several genes (CYPs). The letters that follow CYP indicate a subfamily of gene.

Cytochrome P450 2D6 (CYP2D6) genotyping to determine drug metabolizer status may be considered medically necessary for patients with either of the following conditions:

I. Gaucher disease being considered for treatment with eliglustat
II. Huntington disease being considered for treatment with tetrabenazine in a dosage greater than 50 mg per day

Cytochrome P450 (CYP450) genotyping for the purpose of aiding in the choice of clopidogrel (Plavix®) versus alternative antiplatelet agents, or in decisions on the optimal dosing for clopidogrel (Plavix®), is considered investigational.

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 investigational for all of the following (see Policy Guidelines):

I. Selection or dosage of codeine
II. Dosing of efavirenz and other antiretroviral therapies for HIV infection
III. Dosing of immunosuppressants for organ transplantation
IV. Selection or dosing of β-blockers (e.g., metoprolol)
V. Dosing and management of antitubercular medications

The use of genetic testing panels that include multiple CYP450 variants is considered investigational.

NOTE: Refer to Appendix A to see the policy statement changes (if any) from the previous version.

Policy Guidelines

This policy does not address the use of genetic or panel testing that include tests for genes other than CYP450-related genes (e.g., the Genecept Assay). Testing related to mental health drugs (see below) and the broader panel testing, which are discussed in Blue Shield of California Medical Policy: Genetic Testing for Mental Health Conditions:

- Selection or dosing of selective serotonin reuptake inhibitors (SSRIs)
- Selection or dosing of selective norepinephrine reuptake inhibitors and serotonin-norepinephrine reuptake inhibitors (SNRIs)
- Selection or dosing of tricyclic antidepressants
- Selection or dosing of antipsychotic drugs

Genetics Nomenclature Update

The Human Genome Variation Society (HGVS) nomenclature is used to report information on variants found in DNA and serves as an international standard in DNA diagnostics. It is being implemented for genetic testing medical evidence review updates starting in 2017 (see Table PG1). HGVS nomenclature is recommended by the Human Variome Project, the HUman Genome Organization (HUGO), and by the Human Genome Variation Society itself.

The American College of Medical Genetics and Genomics (ACMG) and the Association for Molecular Pathology (AMP) standards and guidelines for interpretation of sequence variants represent expert opinion from both organizations, in addition to the College of American
Pathologists. These recommendations primarily apply to genetic tests used in clinical laboratories, including genotyping, single genes, panels, exomes, and genomes. Table PG2 shows the recommended standard terminology—“pathogenic,” “likely pathogenic,” “uncertain significance,” “likely benign,” and “benign”—to describe variants identified that cause Mendelian disorders.

### Table PG1. Nomenclature to Report on Variants Found in DNA

<table>
<thead>
<tr>
<th>Previous</th>
<th>Updated</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mutation</td>
<td>Disease-associated variant</td>
<td>Disease-associated change in the DNA sequence</td>
</tr>
<tr>
<td>Variant</td>
<td>Change in the DNA sequence</td>
<td></td>
</tr>
<tr>
<td>Familial variant</td>
<td>Disease-associated variant identified in a proband for use in subsequent targeted genetic testing in first-degree relatives</td>
<td></td>
</tr>
</tbody>
</table>

### Table PG2. ACMG-AMP Standards and Guidelines for Variant Classification

<table>
<thead>
<tr>
<th>Variant Classification</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pathogenic</td>
<td>Disease-causing change in the DNA sequence</td>
</tr>
<tr>
<td>Likely pathogenic</td>
<td>Likely disease-causing change in the DNA sequence</td>
</tr>
<tr>
<td>Variant of uncertain significance</td>
<td>Change in DNA sequence with uncertain effects on disease</td>
</tr>
<tr>
<td>Likely benign</td>
<td>Likely benign change in the DNA sequence</td>
</tr>
<tr>
<td>Benign</td>
<td>Benign change in the DNA sequence</td>
</tr>
</tbody>
</table>

ACMG: American College of Medical Genetics and Genomics; AMP: Association for Molecular Pathology.

### Genetic Counseling

Experts recommend formal genetic counseling for patients who are at risk for inherited disorders and who wish to undergo genetic testing. Interpreting the results of genetic tests and understanding risk factors can be difficult for some patients; genetic counseling helps individuals understand the impact of genetic testing, including the possible effects the test results could have on the individual or their family members. It should be noted that genetic counseling may alter the utilization of genetic testing substantially and may reduce inappropriate testing; further, genetic counseling should be performed by an individual with experience and expertise in genetic medicine and genetic testing methods.

### Coding

The following are specific CPT coding for this testing:

- **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)
- **81227**: CYP2C9 (cytochrome P450, family 2, subfamily C, polypeptide 9) (e.g., drug metabolism), gene analysis, common variants (e.g., *2, *3, *5, *6)

**Effective January 1, 2018**, the following CPT codes are specific to CYP450 genotyping. CYP3A4 and CYP3A5 were previously reported under code 81401:

- **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)

**Effective January 1, 2021**, the following CPT codes has been revised: There following are tier 2 CPT codes that include cytochrome P450 testing:

- **81402**: Molecular pathology procedure, Level 3 (e.g., >10 SNPs, 2-10 methylated variants, or 2-10 somatic variants [typically using non-sequencing target variant analysis], immunoglobulin and T-cell receptor gene rearrangements, duplication/deletion variants of 1 exon, loss of heterozygosity [LOH], uniparental disomy [UPD]) includes –
- 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 (e.g., analysis of 2-5 exons by DNA sequence analysis, mutation scanning or duplication/deletion variants of 6-10 exons, or characterization of a dynamic mutation disorder/triplet repeat by Southern blot analysis) includes:
    - CYP1B1 (cytochrome P450, family 1, subfamily B, polypeptide 1) (e.g., primary congenital glaucoma), full gene sequence

- 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, polypeptide 2) (e.g., steroid 21-hydroxylase isoform, congenital adrenal hyperplasia), full gene sequence

**Effective October 1, 2018**, the following PLA code has been deleted:
- **0028U**: CYP2D6 (cytochrome P450, family 2, subfamily D, polypeptide 6) (e.g., drug metabolism) gene analysis, copy number variants, common variants with reflex to targeted sequence analysis (CYP2D6 Genotype Cascade)

PLA codes **effective January 1, 2018** include:
- **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) (Focused Pharmacogenomics Panel)
- **0031U**: CYP1A2 (cytochrome P450 family 1, subfamily A, member 2) (e.g., drug metabolism) gene analysis, common variants (i.e., *1F, *1K, *6, *7) (Cytochrome P450 1A2 Genotype)

PLA codes **effective October 1, 2018** include:
- **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)
- **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)
- **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)
- **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)
Description

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

Related Policies

- N/A

Benefit Application

Benefit determinations should be based in all cases on the applicable contract language. To the extent there are any conflicts between these guidelines and the contract language, the contract language will control. 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.

Some state or federal mandates (e.g., Federal Employee Program [FEP]) prohibits plans from denying Food and Drug Administration (FDA)-approved technologies as investigational. In these instances, plans may have to consider the coverage eligibility of FDA-approved technologies on the basis of medical necessity alone.

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: NTL) are summarized in Table 1.

Table 1. Selected Testing Kits for CYP450 Genotyping Cleared for Marketing by FDA

<table>
<thead>
<tr>
<th>Device Name</th>
<th>Manufacturer</th>
<th>Approval Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>xTAG Cyp2d6 Kit V3</td>
<td>Luminex Molecular Diagnostics</td>
<td>2017</td>
</tr>
<tr>
<td>xTAG Cyp2c19 Kit V3</td>
<td>Luminex Molecular Diagnostics</td>
<td>2013</td>
</tr>
<tr>
<td>Spartan Rx Cyp2c19 Test System</td>
<td>Spartan Bioscience</td>
<td>2013</td>
</tr>
<tr>
<td>xTAG Cyp2d6 Kit V3 (Including Tdas Cyp2d)</td>
<td>Luminex Molecular Diagnostics</td>
<td>2013</td>
</tr>
<tr>
<td>Verigene Cyp2c19 Nucleic Acid Test (2c19)</td>
<td>Nanosphere</td>
<td>2012</td>
</tr>
<tr>
<td>Infiniti Cyp2c19 Assay</td>
<td>Autogenomics</td>
<td>2010</td>
</tr>
<tr>
<td>xTAG Cyp2d6 Kit V3, Model I030c0300 (96)</td>
<td>Luminex Molecular Diagnostics</td>
<td>2010</td>
</tr>
<tr>
<td>Invader Ugt1a1 Molecular Assay</td>
<td>Third Wave Technologies</td>
<td>2005</td>
</tr>
<tr>
<td>Roche AmpliChip Cyp450 Test</td>
<td>Roche Molecular Systems</td>
<td>2005</td>
</tr>
</tbody>
</table>

FDA: Food and Drug Administration.

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 (AllBioTech). These tests are beyond the scope of this evidence review.

**FDA Labeling on CYP450 Genotyping**

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's 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.1,

**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/d 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.2,

**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 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.3,

**Rationale**

**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 one active and one inactive enzyme gene allele, may experience to a lesser degree some of the consequences of PMs. Ultrarapid metabolizers (UMs) are individuals with more than two 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 1 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.

**Literature Review**

The primary goal of pharmacogenomics testing and personalized medicine is to achieve better clinical outcomes in comparison 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.

**P450 genotype-guided Treatment strategy**

**Clinical Context and Therapy Purpose**

The purpose of a P450 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 P450 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.

**Patients**

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

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

Review of Evidence
Clopidogrel
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. 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. 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 vs aspirin alone was associated with statistical significant reduction in the risk of stroke (6.7% vs 12.4% hazard ratio, 0.51; 95% confidence interval, 0.35 to 0.75) but not among those who carried loss of function alleles (9.4% vs 10.8% hazard ratio, 0.93; 95% confidence interval, 0.69 to 1.26). 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. Among those who received prasugrel and clopidogrel based on genotyping test, 0% and 10%, respectively, exhibited high on-treatment reactivity while 17% patients who received standard treatment with clopidogrel without any genotypes testing exhibited high on-treatment 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/d for 6 days and subsequently 75 mg/d). 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) 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 (POPopular 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; hazard ratio, 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).

<table>
<thead>
<tr>
<th>Study; Trial</th>
<th>Countries</th>
<th>Sites</th>
<th>Dates</th>
<th>Participants</th>
<th>Interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>So et al</td>
<td>Canada</td>
<td>1</td>
<td>2011-2012</td>
<td>18-75 y who had PCI for STEMI who received POC testing for CYP2C19<em>2, ABCB1 TT, and CYP2C19</em>17 alleles (N=102)</td>
<td>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)</td>
</tr>
<tr>
<td>(2016)(^7); RAPID STEMI</td>
<td></td>
<td></td>
<td></td>
<td>Noncarriers given clopidogrel with dosing as per treating physician (n=43)</td>
<td></td>
</tr>
<tr>
<td>Roberts et al</td>
<td>Canada</td>
<td>1</td>
<td>2010-2011</td>
<td>18-75 y undergoing PCI for acute coronary syndrome or stable angina (n=200)</td>
<td>POC testing for CYP2C19*2 allele (n=102). Of these, 23 carriers were given prasugrel 10 mg/d,</td>
</tr>
<tr>
<td>(2012)(^7); RAPID GENE</td>
<td></td>
<td></td>
<td></td>
<td>No genetic testing and clopidogrel 75 mg/d</td>
<td></td>
</tr>
</tbody>
</table>
POC; point of care; PCI; Percutaneous coronary intervention; 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 RCT Results

<table>
<thead>
<tr>
<th>Study; Trial</th>
<th>Outcome</th>
<th>Interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>So et al (2016) RAPID STEMI Carriers</td>
<td>High Platelet Reactivitya</td>
<td>0%d</td>
</tr>
<tr>
<td>Prasugrel</td>
<td>0%d</td>
<td></td>
</tr>
<tr>
<td>Augmented clopidogrel</td>
<td>24%d</td>
<td></td>
</tr>
<tr>
<td>Noncarriers</td>
<td>Clopidogrel as per treating physician</td>
<td>5%d</td>
</tr>
<tr>
<td>Pr</td>
<td>0.0046b 0.507c</td>
<td></td>
</tr>
<tr>
<td>Roberts et al (2012) RAPID GENE Genotype-guided management</td>
<td>Prasugrel 10 mg/d</td>
<td>0%</td>
</tr>
<tr>
<td>Clopidogrel 75 mg/d</td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td>Entire cohort</td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td>Standard clinical management</td>
<td>Clopidogrel 75 mg/d</td>
<td>17%d</td>
</tr>
<tr>
<td>p</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>Claassens et al (2019) POPular Genetics Genotype-guided management (n=1242) Standard-treatment group (n=1246)</td>
<td>Primary Combined Outcomef</td>
<td>63 (5.1%)</td>
</tr>
<tr>
<td>Absolute difference (95% CI)</td>
<td>0.7 (−2.0 to 0.7); p&lt;0.001 for noninferiority</td>
<td></td>
</tr>
<tr>
<td>Primary Bleeding Outcomeg</td>
<td>122 (9.8%)</td>
<td></td>
</tr>
<tr>
<td>Hazard ratio (95% CI)</td>
<td>0.78 (0.61 to 0.98) p=0.04</td>
<td></td>
</tr>
</tbody>
</table>

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. 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%). In the absence of results from well-performed randomized trials designed to evaluate this issue, performing routine genetic testing or ex vivo tests of platelet reactivity to predict CYP2C19 metabolic state and identify poor metabolizers has not been shown to improve health clinical outcomes. The Tailored Antiplatelet Initiation to Lesson Outcomes Due to Decreased Clopidogrel Response After Percutaneous Coronary Intervention (TAILOR-PCI; NCT01742117) is a large ongoing RCT that will randomize 5270 patients undergoing PCI to clopidogrel without prospective genotyping guidance or a prospective CYP2C19 genotype-based antiplatelet therapy approach (ticagrelor 90 mg bid in CYP2C19*2 or CYP2C19*3 reduced function allele patients, clopidogrel 75 mg once daily in non-CYP2C19*2 or -CYP2C19*3 patients). The trial is expected to be completed in March 2020.

Table 5. Study Relevance Limitations

<table>
<thead>
<tr>
<th>Study</th>
<th>Populationa</th>
<th>Interventionb</th>
<th>Comparatorc</th>
<th>Outcomesd</th>
<th>Follow-Upd</th>
</tr>
</thead>
<tbody>
<tr>
<td>So et al (2016); RAPID STEMI</td>
<td>2. Platelet activity is an intermediate outcome measure</td>
<td>1, 2. Outcomes assessed at 1 mo</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roberts et al (2012); RAPID GENE</td>
<td>2. Platelet activity is an intermediate outcome measure</td>
<td>1, 2. Outcomes assessed at 1 wk</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Claassens et al (2019); POPular Genetics</td>
<td>2. Clinical context is unclear</td>
<td>2. Not standard or optimal</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

P0Pular 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 STEM: 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 Outcome 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.  

Table 6. Study Design and Conduct Limitations

<table>
<thead>
<tr>
<th>Study</th>
<th>Allocationa</th>
<th>Blindingb</th>
<th>Selective Reportingc</th>
<th>Data Completenessd</th>
<th>Powerd</th>
<th>Statisticalf</th>
</tr>
</thead>
<tbody>
<tr>
<td>So et al (2016)‡‡; RAPID STEMI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Claassens et al (2019); POPular Genetics</td>
<td>1. Not blinded to treatment assignment;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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 STEM: 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.

dData 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).  
ePower key: 1. Power calculations not reported; 2. Power not calculated for primary outcome; 3. Power not based on clinically important difference.  
fStatistical 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

Three 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 showed that 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 an ongoing RCT (TAILOR-PCI), assessing outcomes in 5270 patients randomized to genotype-based antiplatelet therapy approach or standard care, are expected in 2020 and likely to address this gap.
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.12 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.13,14 An increased early discontinuation rate with efavirenz has been reported in retrospective cohort studies evaluating including multiple CYP450 variants CYP2B6.15,16, 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.17 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)18 and Min et al (2018).19 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).18

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.20,21 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.22 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

Clopidogrel
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 randomized controlled trials (RCTs). Relevant outcomes are overall survival, medication use, and treatment-related morbidity. Three RCTs have evaluated the role of genetic testing for CYP2C19 for selecting an appropriate antplatelet 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 an ongoing RCT (TAILOR-PCI), assessing outcomes in 5270 patients randomized to genotype-based antiplatelet therapy approach or standard care, are expected in 2020 and likely to address this gap. The evidence is insufficient to determine the effects of the technology on health outcomes.

Other Drugs
For individuals who are undergoing or being considered for treatment with highly active antiretroviral agents, immunosuppressant therapy for organ transplantation, β-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 the effects of the technology on health outcomes.

Supplemental Information

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 from Blue Cross Blue Shield Association, input was received from 4 physician specialty societies and 4 academic medical centers 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
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 2010.23 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.

Medicare National Coverage
There is no national coverage determination. In the absence of a national coverage determination, coverage decisions are left to the discretion of local Medicare carriers.

Ongoing and Unpublished Clinical Trials
Some currently unpublished trials that might influence this review are listed in Table 7.

Table 7. Summary of Key Trials

<table>
<thead>
<tr>
<th>NCT No.</th>
<th>Trial Name</th>
<th>Planned Enrollment</th>
<th>Completion Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ongoing</td>
<td>Tailored Antiplatelet Initiation to Lesson Outcomes Due to Decreased Clopidogrel Response After Percutaneous Coronary Intervention (TAILOR-PCI)</td>
<td>5270</td>
<td>Mar 2020</td>
</tr>
</tbody>
</table>

NCT: national clinical trial.

Denotes industry-sponsored or cosponsored trial.

References
3. [3] FDA statement from Douglas Throckmorton, M.D., deputy center director for regulatory programs, Center for Drug Evaluation and Research, on new warnings about
the use of codeine and tramadol in children & nursing mothers. 2017;
https://www.fda.gov/NewsEvents/Newsroom/PressAnnouncements/ucm553285.htm.


   platelet function, and cardiovascular events: a systematic review and meta-analysis.
   JAMA. Dec 28 2011;306(24):2704-2714. PMID 22203539

   status and efficacy of clopidogrel for risk reduction among patients with minor stroke or
   transient ischemic attack. JAMA. Jul 5 2016;316(1):70-78. PMID 27348249

   pharmacogenomic approach to antplatelet therapy among patients with ST-elevation
   PMID 25850030

   personalisation of antplatelet treatment (RAPID GENE): a prospective, randomised,


    risk factor for secondary prevention after coronary stent revascularization: A landmark

    variation in efavirenz therapy. AIDS. Sep 12 2008;22(14):1709-1717. PMID 18753940

    patient with human immunodeficiency virus infection: case report and review of the

    Nov 1 2007;45(9):1230-1237. PMID 17918089

    constitutive androstane receptor (CAR) polymorphisms are associated with early
    discontinuation of efavirenz-containing regimens. J Antimicrob Chemother. Sep
    2011;66(9):2092-2098. PMID 21715435

    with premature discontinuation of first-line anti-HIV therapy: an observational cohort

    polymorphisms and Nevirapine-induced SJS/TEN: a pharmacogenetics study. Eur J


18. [18] Min SS, Papaz TT, Lafreniere-Roula MM, Nalll NN, Grasemann HH, Schwartz SS,
    Kamath BB, Ng VV, Parekh RR, Manlhiot CC, Mital SS. A randomized clinical trial of age
    and genotype-guided tacrolimus dosing after pediatric solid organ transplantation.
    Pediatr Transplant, 2018 Sep 5;22(7). PMID 30178515

    associated with a lower heart rate and blood pressure in beta-blocker users. Clin

    Nov-Dec 2008;36(6):1354-1362. PMID 19094446

Documentation for Clinical Review

Please provide the following documentation:

- History and physical and/or consultation notes including:
  - Reason for performing test
  - Signs/symptoms/test results related to reason for genetic testing
  - How test result will impact clinical decision making
  - Diagnosis being considered for treatment
- Physician order for genetic test
  - Name and description of genetic test
  - Name of laboratory that performed the test
  - Any available evidence supporting the clinical validity/utility of the specific test
  - CPT codes billed for the particular genetic test

Post Service (in addition to the above, please include the following):
- Laboratory report including: specific name and test requested

Coding

This Policy relates only to the services or supplies described herein. Benefits may vary according to product design; therefore, contract language should be reviewed before applying the terms of the Policy. Inclusion or exclusion of codes does not constitute or imply member coverage or provider reimbursement.

<table>
<thead>
<tr>
<th>Type</th>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPT®</td>
<td>0028U</td>
<td>CYP2D6 (cytochrome P450, family 2, subfamily D, polypeptide 6) (e.g., drug metabolism) gene analysis, copy number variants, common variants with reflex to targeted sequence analysis (Deleted code effective 10/1/2018)</td>
</tr>
<tr>
<td></td>
<td>0029U</td>
<td>Drug metabolism (adverse drug reactions and drug response), targeted sequence analysis (i.e., CYP1A2, CYP2C19, CYP2C9, CYP2D6, CYP3A4, CYP3A5, CYP4F2, SLCO1B1, VKORC1 and rs1277823) (Code effective 1/1/2018)</td>
</tr>
<tr>
<td></td>
<td>0031U</td>
<td>CYP1A2 (cytochrome P450 family 1, subfamily A, member 2) (e.g., drug metabolism) gene analysis, common variants (i.e., *1F, *1K, *6, *7) (Code effective 1/1/2018)</td>
</tr>
<tr>
<td></td>
<td>0071U</td>
<td>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) (Code effective 10/1/2018)</td>
</tr>
<tr>
<td>Type</td>
<td>Code</td>
<td>Description</td>
</tr>
<tr>
<td>------</td>
<td>------</td>
<td>-------------</td>
</tr>
<tr>
<td>0072U</td>
<td>CYP2D6 (cytochrome P450, family 2, subfamily D, polypeptide 6) (e.g., drug metabolism) gene analysis, targeted sequence analysis (i.e., CYP2D6-2D7 hybrid gene) (Code effective 10/1/2018)</td>
<td></td>
</tr>
<tr>
<td>0073U</td>
<td>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) (Code effective 10/1/2018)</td>
<td></td>
</tr>
<tr>
<td>0074U</td>
<td>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) (Code effective 10/1/2018)</td>
<td></td>
</tr>
<tr>
<td>0075U</td>
<td>CYP2D6 (cytochrome P450, family 2, subfamily D, polypeptide 6) (e.g., drug metabolism) gene analysis, targeted sequence analysis (i.e., 5' gene duplication/multiplication) (Code effective 10/1/2018)</td>
<td></td>
</tr>
<tr>
<td>0076U</td>
<td>CYP2D6 (cytochrome P450, family 2, subfamily D, polypeptide 6) (e.g., drug metabolism) gene analysis, targeted sequence analysis (i.e., 3' gene duplication/multiplication) (Code effective 10/1/2018)</td>
<td></td>
</tr>
<tr>
<td>81225</td>
<td>CYP2C19 (cytochrome P450, family 2, subfamily C, polypeptide 19) (e.g., drug metabolism), gene analysis, common variants (e.g., *2, *3, *4, *8, *17)</td>
<td></td>
</tr>
<tr>
<td>81227</td>
<td>CYP2C9 (cytochrome P450, family 2, subfamily C, polypeptide 9) (e.g., drug metabolism), gene analysis, common variants (e.g., *2, *3, *5, *6)</td>
<td></td>
</tr>
<tr>
<td>81230</td>
<td>CYP3A4 (cytochrome P450 family 3 subfamily A member 4) (e.g., drug metabolism), gene analysis, common variant(s) (e.g., *2, *22) (Code effective 1/1/2018)</td>
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<tr>
<td>81231</td>
<td>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) (Code effective 1/1/2018)</td>
<td></td>
</tr>
<tr>
<td>81402</td>
<td>Molecular Pathology Procedure Level 3 (Code revision effective 1/1/2021)</td>
<td></td>
</tr>
<tr>
<td>81404</td>
<td>Molecular Pathology Procedure Level 5 (Code revision effective 1/1/2021)</td>
<td></td>
</tr>
<tr>
<td>81405</td>
<td>Molecular Pathology Procedure Level 6 (Code revision effective 1/1/2021)</td>
<td></td>
</tr>
</tbody>
</table>

### Policy History

This section provides a chronological history of the activities, updates and changes that have occurred with this Medical Policy.

<table>
<thead>
<tr>
<th>Effective Date</th>
<th>Action</th>
</tr>
</thead>
</table>
| 10/01/2010     | New policy Combined the following BSC policies:  
                • Cytochrome P450 Genotyping  
                • Genetic Testing for Initial Warfarin Dose with BCBSA Medical Policy adoption |
| 03/12/2012     | Coding Update |
| 02/22/2013     | Coding Update |
| 04/04/2014     | Policy revision with position change |
Definitions of Decision Determinations

**Medically Necessary:** Services that are Medically Necessary include only those which have been established as safe and effective, are furnished under generally accepted professional standards to treat illness, injury or medical condition, and which, as determined by Blue Shield, are: (a) consistent with Blue Shield medical policy; (b) consistent with the symptoms or diagnosis; (c) not furnished primarily for the convenience of the patient, the attending Physician or other provider; (d) furnished at the most appropriate level which can be provided safely and effectively to the patient; and (e) not more costly than an alternative service or sequence of services at least as likely to produce equivalent therapeutic or diagnostic results as to the diagnosis or treatment of the Member’s illness, injury, or disease.

**Investigational/Experimental:** A treatment, procedure, or drug is investigational when it has not been recognized as safe and effective for use in treating the particular condition in accordance with generally accepted professional medical standards. This includes services where approval by the federal or state governmental is required prior to use, but has not yet been granted.

**Split Evaluation:** Blue Shield of California/Blue Shield of California Life & Health Insurance Company (Blue Shield) policy review can result in a split evaluation, where a treatment, procedure, or drug will be considered to be investigational for certain indications or conditions, but will be deemed safe and effective for other indications or conditions, and therefore potentially medically necessary in those instances.

**Prior Authorization Requirements (as applicable to your plan)**

Within five days before the actual date of service, the provider must confirm with Blue Shield that the member's health plan coverage is still in effect. Blue Shield reserves the right to revoke an authorization prior to services being rendered based on cancellation of the member's eligibility.

Final determination of benefits will be made after review of the claim for limitations or exclusions.

Questions regarding the applicability of this policy should be directed to the Prior Authorization Department at (800) 541-6652, or the Transplant Case Management Department at (800) 637-2066 ext. 3507708 or visit the provider portal at www.blueshieldca.com/provider.

Disclaimer: This medical policy is a guide in evaluating the medical necessity of a particular service or treatment. Blue Shield of California may consider published peer-reviewed scientific literature, national guidelines, and local standards of practice in developing its medical policy. Federal and state law, as well as contract language, including definitions and specific contract provisions/exclusions, take precedence.
over medical policy and must be considered first in determining covered services. Member contracts may differ in their benefits. Blue Shield reserves the right to review and update policies as appropriate.
### POLICY STATEMENT

<table>
<thead>
<tr>
<th>BEFORE</th>
<th>AFTER</th>
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<tbody>
<tr>
<td><strong>Cytochrome P450 Genotype-Guided Treatment Strategy 2.04.38</strong></td>
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<td><strong>Policy Statement:</strong></td>
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<td><strong>Note:</strong> Cytochrome P450 is a family of proteins (enzymes) including several genes (CYPs). The letters that follow CYP indicate a subfamily of gene.</td>
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<td>Cytochrome P450 2D6 (CYP2D6) genotyping to determine drug metabolizer status may be considered <strong>medically necessary</strong> for patients with either of the following conditions:</td>
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<td>I. Gaucher disease being considered for treatment with eliglustat</td>
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<td>Cytochrome P450 (CYP450) genotyping for the purpose of aiding in the choice of clopidogrel (Plavix®) versus alternative antiplatelet agents, or in decisions on the optimal dosing for clopidogrel (Plavix®), is considered <strong>investigational</strong>.</td>
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<td>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 <strong>investigational</strong> for all of the following (see Policy Guidelines):</td>
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<td>III. Dosing of immunosuppressants for organ transplantation</td>
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<td>V. Dosing and management of antitubercular medications</td>
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