



BlueCross BlueShield of Louisiana

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Cytochrome p450 Genotyping

Policy # 00169

Original Effective Date: 07/15/2005

Current Effective Date: 05/21/2014

Applies to all products administered or underwritten by Blue Cross and Blue Shield of Louisiana and its subsidiary, HMO Louisiana, Inc. (collectively referred to as the "Company"), unless otherwise provided in the applicable contract. Medical technology is constantly evolving, and we reserve the right to review and update Medical Policy periodically.

Note:

Imuran is addressed separately in medical policy 00237 Pharmacogenomic and Metabolite Markers for Patients Treated with Thiopurines.

Warfarin is addressed separately in medical policy 00245 Genetic Testing for Warfarin Dose.

Tamoxifen is addressed separately in medical policy 00269 Genetic Testing for Tamoxifen Treatment.

When Services Are Eligible for Coverage

Coverage for eligible medical treatments or procedures, drugs, devices or biological products may be provided only if:

- *Benefits are available in the member's contract/certificate, and*
- *Medical necessity criteria and guidelines are met.*

Based on review of available data, the Company may consider cytochrome p450 (CYP450) genotyping for the purpose of aiding in the choice of clopidogrel versus alternative anti-platelet agents, or in decisions on the optimal dosing for clopidogrel, to be **eligible for coverage**.

When Services Are Considered Investigational

Coverage is not available for investigational medical treatments or procedures, drugs, devices or biological products.

Based on review of available data, the Company considers genotyping to determine cytochrome p450 (CYP450) genetic polymorphisms for the purpose of aiding in the choice of drug or dose to increase efficacy and/or avoid toxicity to be **investigational**.*

This includes, but is not limited to, cytochrome p450 (CYP450) genotyping for the following applications:

- Selection or dose of selective serotonin reuptake inhibitor (SSRI)
- Selection or dose of antipsychotics
- Deciding whether to prescribe codeine for nursing mothers
- Selection and dosing of selective norepinephrine reuptake inhibitors
- Selection and dosing of tricyclic antidepressants (TCA)
- Dose of efavirenz (common component of highly active antiretroviral therapy for human immunodeficiency virus [HIV] infection)
- Dose of immunosuppressant for organ transplantation
- Selection or dose of beta blockers (e.g., metoprolol)
- Dosing and management of antituberculosis medications



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Background/Overview

The CYP450 family is involved in the metabolism of a significant proportion of currently administered drugs, and genetic variants in CYP450 are associated with altered metabolism of many drugs. Genetic testing for CYP450 variants may assist in selecting and dosing drugs that are impacted by these genetic variants.

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.

Various factors may influence the variability of drug effects, including age, liver function, concomitant diseases, nutrition, smoking, and drug-drug interactions. Inherited (germline) deoxyribonucleic acid (DNA) sequence variation (polymorphisms) 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 is the study of 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 polymorphisms (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 effects, and decrease medical costs. Pharmacogenomic and Metabolite Markers for Patients Treated with Azathioprine (6-MP).

The 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. Some CYP450 enzyme genes 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 enzyme variants constitute one important group of drug-gene interactions influencing the variability of 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 (IMs), 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 2 alleles of an active enzyme gene. There is pronounced ethnic variability in the population distribution of metabolizer types for a given CYP enzyme.

Ultrarapid metabolizers 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 effects and PMs may not respond.

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However, it is very important to realize that many drugs are metabolized to varying degrees by more than one enzyme, either within or outside of the CYP450 superfamily. In addition, interaction between different metabolizing genes, interaction of genes and environment, and interactions among different non-genetic 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 inter-individual differences in metabolism and consequent efficacy or toxicity.

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 (TDM) for drugs with a very narrow therapeutic range and/or potential serious adverse effects outside that range. However, TDM is not available for all drugs of interest, and a cautious trial and error approach can lengthen the time to achieving an effective dose.

Cytochrome p450 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 consequent patient outcomes, is favored when the drug under consideration has a narrow therapeutic dose range (window), 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 TCA have narrow therapeutic windows and can cause serious adverse events when concentrations exceed certain limits, resulting in cautious dosing protocols. Yet, the potential severity of the disease condition may call for immediate and sufficient therapy; genotyping might speed the process of achieving a therapeutic dose and avoiding significant adverse events.

FDA or Other Governmental Regulatory Approval

U.S. Food and Drug Administration (FDA)

Diagnostic genotyping tests for certain CYP450 enzymes are now available. Some tests are offered as in-house laboratory-developed test services, which do not require U.S. FDA approval but which must meet Clinical Laboratory Improvement Act (CLIA) quality standards for high-complexity testing. The AmpliChip^{®‡} (Roche Molecular Systems, Inc.) is the only FDA-cleared test for CYP450 genotyping. The AmpliChip is a microarray consisting of many DNA sequences complementary to 2 CYP450 genes and applied in microscopic quantities at ordered locations on a solid surface (chip). The AmpliChip tests the DNA from a patient's white blood cells collected in a standard anticoagulated blood sample for 29 polymorphisms and mutations for the *CYP2D6* gene and 2 polymorphisms for the *CYP2C19* gene. CYP2D6 metabolizes approximately 25% of all clinically used medications (e.g., dextromethorphan, beta-blockers, antiarrhythmics, antidepressants, and morphine derivatives), including many of the most prescribed drugs. CYP2C19 metabolizes several important types of drugs, including proton-pump inhibitors, diazepam, propranolol, imipramine, and amitriptyline. The FDA cleared the test "based on results of a study conducted

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by the manufacturers of hundreds of DNA samples as well as on a broad range of supporting peer-reviewed literature." According to FDA labeling, "Information about CYP2D6 genotype may be used as an aid to clinicians in determining therapeutic strategy and treatment doses for therapeutics that are metabolized by the CYP2D6 product."

Centers for Medicare and Medicaid Services (CMS)

None

Rationale/Source

Validation of genotyping to improve pharmacologic treatment outcomes is a multistep process. In general, major suggested steps in the validation process are as follows:

- Establish the specific genotyping test performance characteristics, i.e., does the test accurately and reproducibly detect the gene markers of interest (**analytic validity**).
- For each drug of interest, conduct preliminary performance study(ies) in relevant populations or population subsets as appropriate to evaluate the strength of the associations between the selected genetic markers and dose, therapeutic efficacy, and/or adverse events; may be retrospective (**clinical validity**).
- Conduct prospective trial(s) in relevant patient populations to compare the use of genotyping for specific genetic markers to guide prescribing and dosing to standard treatment without genotyping. Determine whether genotyping improves patient outcomes such as therapeutic effect, time to effective dose, and adverse event rate (**clinical utility**).

Further discussion of the validation process is provided in a 2004 Technology Evaluation Center (TEC) Special Report, Genotyping for Cytochrome P450 Polymorphisms to Determine Drug-Metabolizer Status, on which this policy is based. The purpose of the Report was to provide background information on CYP450 enzymes; genotyping applications for currently available drugs; examples of companies and products; evaluation of clinical utility; examples and the current state of evidence, regulatory issues, and cost-effectiveness analysis. The Report, along with updated literature, offered the following general observations and conclusions:

- Although a genotyping assay may be designed to determine metabolizer status for a variety of enzymes and need only be performed once per patient to generate results relevant to a variety of drugs, whether or not the information is relevant for a particular drug must be validated for each drug of interest.
- The analytical validity of pharmacogenomic testing is likely to be high but should be evaluated for each marker of interest. A recent publication suggests that the Roche AmpliChip may have a low sensitivity for the CYP2D6 UM genotype.
- Data suggest a strong association between specific variant alleles and increased adverse events related to specific drugs or between specific variant alleles and final doses for specific drugs (clinical validity). Such associations, however, may not explain the majority of interindividual variability in drug response. For example, although CYP2C9 genotype is an independent predictor of final warfarin dose, CYP2C9 genotype in combination with other known genetic and nongenetic significant confounders statistically explains up to 60% of the variation in final dose. Whether or not



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that is sufficient to improve patient outcomes after genotype-directed dosing is, at present, unknown.

- Reduced activity in a particular CYP450 enzyme because of genotype may not affect outcomes when other metabolic pathways are available and when other confounders influence drug metabolism. Therefore, prospective studies of clinical utility are important to validate hypotheses generated by associational studies. However, few prospective studies of genotype-directed dosing or drug choice have been conducted, and none support genotype-directed decision making.
- Without prospective evidence defining the effect of genotyping on such outcomes, there are few dosing recommendations based on genotype. In one example, Kirchheiner et al. reviewed CYP2D6 and CYP2C19 polymorphisms and pharmacokinetic data for several antidepressants and antipsychotic drugs to provide dose recommendations. However, these recommendations were largely extrapolated from data on genotype-dependent pharmacokinetics for use in future clinical trials; efficacy of the recommendations in routine clinical use has not been established.

Below are brief synopses of the application and evidence for clinical topic areas of particular interest in the literature.

Selection or dose of SSRI. CYP2D6 and CYP2C19 are primary CYP450 enzymes involved in the metabolism of SSRIs. Thus, understanding a patient's metabolizer status might be helpful in choosing an initial SSRI and/or dose that is most likely to be effective. In January 2007, an Agency for Healthcare Research and Quality (AHRQ) Evidence-based Practice Center systematically reviewed the evidence on CYP450 testing for adults treated with SSRIs for nonpsychotic depression. Following this commissioned report, the Evaluation of Genomic Applications in Practice and Prevention (EGAPP) Working Group published the following recommendation: "The EGAPP Working Group found insufficient evidence to support a recommendation for or against use of CYP450 testing in adults beginning SSRI treatment for nonpsychotic depression. In the absence of supporting evidence, and with consideration of other contextual issues, EGAPP discourages use of CYP450 testing for patients beginning SSRI treatment until further clinical trials are completed."

Two recent reports have focused on use of genotyping in patients treated with paroxetine. Gex-Fabry et al. studied paroxetine levels and clinical response in 71 patients with depression who had been genotyped for CYP2D6 and ABCBA polymorphisms. In this prospective observational study, CYP2D6 heterozygous extensive metabolizer phenotype showed a marginal impact on paroxetine levels and no impact on treatment response.

Ververs et al., in a cohort study of 74 pregnant women, demonstrated that differences in CYP2D6 genotype caused differential effects on paroxetine plasma concentrations. Extensive metabolizers and UMs showed steady decreases in concentrations during the course of pregnancy, with increase in depressive symptoms. Intermediate metabolizers and PMs showed an increase in concentrations with no change in symptoms. It was suggested that knowledge about CYP2D6 genotype would be indispensable in this setting. However, no information on the use or outcome of use of such information was provided.



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Serretti et al., in a retrospective study of 287 patients on antidepressants, demonstrated no association between response and allelic variations for p450 CYP1A2, CYP2C9, CYP2C19 and CYP2D6.

Tsai et al. recently evaluated 100 patients diagnosed with major depressive disorder in an Asian population treated with escitalopram. These investigators evaluated 10 alleles involving CYP2D6, CYP2C19, and CYP3A4 and concluded genetic polymorphisms of CYP450 enzymes appeared to influence drug metabolism and treatment response. However, results were variable, and they were unable to provide a confident estimate of the ability of various allelic combinations to predict drug levels or treatment outcomes.

Finally Sim et al. retrospectively studied 1,472 Swedish subjects looking for associations between CYP2C19 polymorphisms and depressive symptoms. They concluded that PMs exhibited a significantly lower level of depressive symptoms than EMs. In the absence of drug-specific treatment outcomes or data related to drug levels, they suggested the need for further investigation of the functional link between CYP2C19 and depressive symptoms to further evaluate this observation.

Conclusions: Individuals with variants in multiple p450 genes have altered metabolism of SSRI drugs. However, the impact of genetic variants on clinical response and clinical outcomes is less clear, and the evidence is not sufficient to conclude that patients with genetic variants have reduced efficacy of SSRIs. Therefore, the clinical utility of testing for SSRI dose is uncertain.

Selection or dose of antipsychotic drugs. Classical antipsychotic agents (e.g., haloperidol, perphenazine, and risperidone) have therapeutic ranges that are often narrow, adverse effects that can be severe, and highly variable clinical responses. Case reports and small studies have reported associations between clinically significant adverse reactions or clinical responsiveness and specific CYP450 genotypes (e.g. CYP2D6, CYP3A4 variants), but most studies are small and results are inconsistent. Moreover, plasma concentration of antipsychotic drugs may not be correlated with treatment outcome or adverse effects. Because most patients with schizophrenia take combinations of psychoactive agents for extended periods of time, drug-drug and drug-environmental interactions may influence the CYP450 metabolic phenotype in addition to genotype. For example, carbamazepine, phenytoin, smoking, and alcohol consumption can induce CYP450 activity, whereas caffeine and fluvoxamine are inhibitors of CYP1A2. Some antipsychotic medications are metabolized by multiple CYP450 enzymes, and dominant pathways may vary. Several classical antipsychotic drugs inhibit the CYP450 enzyme required for their metabolism and may render the patient a phenotypic PM despite an EM genotype. Thus, initial dosing algorithms need to accommodate both genetic influences and other interactions; TDM will probably continue to be needed to reflect the metabolic phenotype during ongoing treatment.

Fleeman et al., in a 2010 health technology assessment, reviewed 51 articles on clinical validity of testing for CYP450 in patients with schizophrenia treated with antipsychotic medications. The authors concluded that patients with heterozygous or homozygous mutations for CYP2D6 were at increased risk for tardive dyskinesia (odds ratio, respectively, [OR]: 2.08 and 1.83) and patients with homozygous mutations at increased risk for Parkinsonism (OR: 1.64). However, no published reports on clinical utility were identified. The authors concluded "further evidence is required to link phenotype to genotype." This assessment has recently been published in the medical literature.

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Two additional reports on use of risperidone have been published since the last policy update. Jovanovic et al. evaluated the role of CYP2D6 in 83 drug-naïve patients undergoing a first episode of psychosis and treated with risperidone. While significant improvements were observed in positive and general symptoms using this drug, the investigators were unable to identify an association between treatment response and variations in either genetic or drug concentration findings. Locatelli et al. evaluated CYP2D6 genotypes in 50 patients hospitalized for acute schizophrenia and also treated with risperidone. They found elevations in risperidone plasma levels in patients classified as PMs or IMs based on genotyping. Drug efficacy is not reported, but these authors observed an association between genotype, levels of risperidone, and the occurrence of extrapyramidal syndromes. They were uncertain whether these observations were strong enough to support routine testing as an aid to assessment of drug toxicity and suggested further study was needed.

In 2011 Fleeman et al. published a systematic review and meta-analyses of CYP450 testing for use in prescribing antipsychotics in adults with schizophrenia. After search of 2,841 papers, they identified 47 papers that described clinical validity but no published papers on clinical utility of testing. They found no convincing evidence of an association between test results and either drug efficacy or toxicity. Differences when seen (an association, for example, with tardive dyskinesia) were considered too small to be clinically meaningful.

Conclusions: Individuals with genetic variants in the CYP2D6 gene may be at increased risk for adverse effects of antipsychotic drugs, particularly extrapyramidal effects such as tardive dyskinesia. However, the clinical utility of testing is uncertain, since management changes as a result of genetic testing have not been evaluated.

Deciding whether to prescribe codeine for nursing mothers. Codeine is metabolized by CYP2D6 to morphine. Enhanced CYP2D6 activity (i.e., in CYP2D6 UMs) predisposes to opioid intoxication. On August 17, 2007, the U.S. FDA issued a warning regarding codeine use by nursing mothers. Nursing infants “may be at increased risk of morphine overdose if their mothers are taking codeine and are ultra-rapid metabolizers of codeine.” Information about genetic variation and risk of accelerated codeine metabolism is now included in package insert information. The warning was prompted by a 2006 case report concerning an infant who died of morphine overdose. The mother, prescribed codeine for episiotomy pain, was a CYP2D6 UM, with high levels of circulating morphine. Not mentioned in the original case report, but noted in a later publication, is the fact that the mother was also homozygous for the UGT2B7*2 metabolizing enzyme variant, which is believed to also contribute to higher than normal production of active opioids from codeine. Currently, the FDA is not recommending genotyping for any population prior to prescribing codeine because “there is only limited information about using this test for codeine metabolism.” Information is limited to associations of genotype with morphine exposure and adverse effects such as sedation in adults, and association of mothers’ genotype with morphine exposure in mothers and with infant central nervous system (CNS) depression. Studies have been small, with correspondingly few PMs and UMs for drawing conclusions. Madadi et al. have recently described the use of a pedigree approach to aid in diagnosis, identification of other at-risk family members and simplification of pharmacogenomic analysis. However, they note that for most medical centers, the framework for performing this work may not exist, and its applicability and relevance to general use remain unestablished.

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A prospective clinical trial (NCT010504000) "CYP2D6 Screening for Adverse Drug Reactions to Codeine in Breast Milk" is currently actively recruiting patients. This trial will include a pharmacogenetically directed study of pain therapy in women undergoing cesarean sections. The target study completion date is December 2012.

Conclusions: The relationship between genetic variants of cytochrome p450, codeine metabolism, and nursing mothers is not certain. A clinical trial is underway to test dosing based on genotype.

Selection and dosing of clopidogrel. Dual antiplatelet therapy with aspirin and clopidogrel is currently recommended for the prevention of atherothrombotic events after acute myocardial infarction (MI). However, a substantial number of subsequent ischemic events still occur, which may be at least partly due to interindividual variability in the response to clopidogrel. Clopidogrel is a prodrug, which is converted by several CYP450 enzymes, CYP2C19 in particular, to an active metabolite. For this reason, genetic polymorphisms that inactivate the CYP2C19 enzyme are associated with impaired pharmacodynamic response in healthy individuals. Previous studies have shown that persistent high platelet reactivity, despite clopidogrel treatment at standard dosing is associated with CYP2C19 variants that code for inactive enzymes; higher loading and/or maintenance doses decrease reactivity even in initial nonresponders, presumed to be CYP2C19 PMs. Higher platelet reactivity has also been associated with a higher rate of subsequent thrombotic events. However, the intrinsic variability of platelet monitoring is a known limitation of all tests measuring platelet aggregation, making it difficult to use these tests for treatment modulation.

A number of publications have evaluated outcomes in patients treated with clopidogrel according to their CYP2C19 genetic status. . These studies showed that patients with genetic variants have worse outcomes than those without genetic variants. These data raised the possibility that the efficacy of clopidogrel was reduced in patients with genetic variants. A summary of some of these studies follows.

Simon et al. and Mega et al. found significant, although modest, increases in risk of subsequent thrombotic events for CYP2C19 variant carriers in unselected patient populations; Collet et al. found a stronger risk in a highly selected population of younger patients with family history.

Shuldiner et al. demonstrated platelet response to clopidogrel was highly heritable in a population of 429 healthy Amish patients matching genotype results for p450 (CYP) 2C19*2 variant with platelet aggregometry. The relation between genotype and platelet aggregation was replicated. Patients with *2 genotypes were found to have an increased cardiovascular (CV) ischemic event or death rate during 1 year of follow-up (hazard ratio [HR]: 2.42). Sibbing et al. reported that in a study of 2,485 patients pretreated with clopidogrel as part of coronary stent placement, those carrying *2 mutations had an increased 30 days' likelihood of stent thrombosis (HR: 3.81).

Mega et al. performed a meta-analysis of 9 studies (n=9,685 patients) comparing CYP2C19 genotype to clinical outcomes in patients treated with clopidogrel. Most patients (91.3%) had undergone percutaneous coronary intervention (PCI), and 54.5% had an acute coronary syndrome. They observed a significantly increased risk of CV death, MI, stroke, or stent thrombosis in patients with 1 and 2 reduced function CYP2C19 alleles as compared with non-carriers.



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In 2009, the FDA expanded the pharmacogenetics section of the clopidogrel label to include information on the metabolic impact of polymorphic CYP450 enzymes. However, no dosing or drug selection recommendations were made. In March 2010, based on the available data at that time, the FDA issued a safety communication indicating it was adding a boxed warning to the label of Plavix^{®†}. This warning includes information to:

- Warn about reduced effectiveness in PMs of Plavix (patients with CYP2C19 *2/2, *3/3, or *2/3 genotypes)
- Indicate tests are available to identify genetic differences in CYP2C19 function that will help identify Poor metabolizers
- Advise healthcare professionals to consider alternative dosing or use of other medications in patients identified as potential poor metabolizers.

More direct information on whether the efficacy of clopidogrel is reduced in patients with genetic variants can be obtained by genotyping both the treatment and control groups in RCTs to determine whether patients with genetic variants have the same response to treatment relative to placebo. In one such study, Pare et al. retrospectively genotyped 5,059 patients from 2 large randomized trials (the Clopidogrel in Unstable Angina to Prevent Recurrent Events or “CURE” trial and the Atrial Fibrillation Clopidogrel Trial with Irbesartan for Prevention of Vascular Events or “Active” trial) that showed clopidogrel reducing the rate of CV events when compared to placebo in patients with acute coronary syndromes and atrial fibrillation. Genotyping was performed for *2, *3, and *17 of the CYP2C19 allele. These investigators observed that the efficacy and safety of clopidogrel as compared with placebo was not affected by CYP2C19 loss of function alleles. Even when data were restricted to evaluation of patients homozygous for loss of function, no increased risk of CV events was observed. Although the reason for these divergent findings remains unclear, it was noted that in the populations studied, use of stents was substantially less than in previous reports (19% of patients with acute coronary syndromes and only 14.5% in patients with atrial fibrillation).

Variation in clopidogrel response is an extremely complicated process impacted by a wide range of both genetic and environmental factors (including patient compliance, metabolic state, and drug and food intake). For example, Sibbing et al., in a recent study (n=1,524) noted the presence of the CYP2C19*17 allele appears to result in decreased platelet aggregation when compared to wild-type homozygotes with an increased 30-day risk of bleeding but no change in the occurrence of stent thrombosis. Tiroch et al., in a study of 928 patients with acute MI, found that patients treated with continuous clopidogrel therapy exhibited improved outcomes (the need for target lesion revascularization and major adverse CV events) in carriers of increased function alleles CYP2C19*17). Over time, more information about gene drug associations may refine both testing needs and our ability to use results to optimize choice or dosing of drugs.

Two systematic reviews and a meta-analysis were reported in 2011 that review both the observational evidence and the clinical trial evidence. Both of these reviews suggest that CYP2C19 gene polymorphisms do not have a substantial or consistent influence on the clinical efficacy of clopidogrel.

Bauer et al. performed extensive searches of MEDLINE, EMBASE, and the Cochrane Library for relevant peer-reviewed reports of observational studies and clinical trials on genotyping. Out of 4203 reports in their



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initial search, they identified 15 studies for detailed analysis. They reported that on comparison of carriers of at least one reduced function allele of CYP2C19 with non-carriers; the unadjusted ORs of major adverse events were higher in 3 studies, lower in 1, and not significantly different in 8. For stent thrombosis the OR associated with reduced function allele carrier status was reduced in 4 studies but showed no significant difference in 5. No studies showed a significant positive or negative impact on outcomes as a result of CYP2C19*17 testing.

Holmes et al. searched online sites PubMed and EMBASE for studies linking CYP2C19 testing to treatment with clopidogrel. They identified 32 studies including 42,106 participants. Twenty-one studies included patients with acute coronary syndromes, and 8 studies included patients with stable coronary heart disease—the latter is usually associated with coronary stent placement. While the authors observed a decrease in the measurable concentration of clopidogrel metabolite in patients with a loss-of-function gene on 75 mg of clopidogrel, they were unable to show that this resulted in a clinically meaningful change in outcomes. Of particular note was the observation that when studies were stratified by numbers of outcome events, there was a clear trend toward the null in larger studies, consistent with small-study bias. The strongest data supporting use of testing was to predict stent thrombosis with a risk ratio of 1.75 (confidence interval [CI]: 1.50 to 2.03) for fixed effects and 1.88 (CI: 1.46 to 2.41) for random effects modeling. But again a trend toward the null was observed in larger studies. Assuming an event risk of 18 per 1,000 in the control group, they calculated that this corresponded to an absolute increase of 14 stent thromboses per 1,000 patients. Holmes et al. noted a trade-off between decreased risk of bleeding with loss of function that in part appeared to mitigate increased susceptibility to thrombosis. They cautioned that efforts to personalize treatment in the loss of function setting should be considered carefully because efforts to improve efficacy might be offset by risks of harms such as bleeding. In a recent editorial, Beitelshes notes that the results of this analysis may have been compromised by the fact that patients who did not undergo PCI were included. They concluded that the association between CYP2C19 genotype and adverse outcomes with clopidogrel treatment may not be present in all settings and may be strongest for clopidogrel indications with the greatest effects, such as patients undergoing PCI. This observation is supported by observations in the CHARISMA genetics study reported by Bhatt. A total of 4,819 patients were genotyped in this study, and no relationship between CYP2C19 status and ischemic outcomes in stable patients was observed. Bhatt also observed significantly less bleeding in this subgroup.

Roberts et al. reported on 200 patients randomized to compare use of a point-of-care test for the CYP2C19*2C to determine treatment versus standard treatment. In the tested group, carriers were given 10 mg of prasugrel daily. Non-carriers and all patients in the control group were given 75 mg of clopidogrel per day. The primary endpoint was high on-treatment platelet reactivity. In the group with genotyping, none of the 23 carriers had high on-treatment platelet reactivity; in the group receiving standard treatment 30% of 23 carriers had high on-treatment platelet reactivity. These authors concluded that rapid genotyping with subsequent personalized treatment reduces the number of carriers treated who exhibit high on-treatment reactivity. The authors do note that alternative approaches using either phenotyping or a combination of both phenotyping and genotyping might optimize treatment decision making.

Conclusions: Individuals with genetic variants of CYP450 have a decreased ability to metabolize clopidogrel, but the impact on clinically meaningful outcomes is uncertain. Some observational studies have



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reported increased rates of CV events in patients with genetic variants, but others have not. Systematic reviews of observational studies report that genetic variants may be associated with a modest increase in the rate of stent thrombosis.

The FDA has required the package insert for clopidogrel carry a black box warning concerning possible worse outcomes with clopidogrel treatment in patients with genetic variants. While genotyping appears in some studies to be helpful in identifying patients at higher risk of treatment failure and may be very useful in selected patients, more information is needed to refine optimal use of testing and to better understand the relative merit of management options. The FDA warning suggests changes in doses or changes in drug. Recent studies have suggested that changes in platelet reactivity in carriers may be dose-dependent and that in PCI patients, heterozygous carriers might require up to triple dosing of clopidogrel to reach a desired target platelet reactivity level. In homozygous carriers, it has been reported that even with higher clopidogrel doses, platelet reactivity cannot be raised to the level of clopidogrel treatment in non-carriers. In these patients other drugs such as prasugrel or ticagrelor may be used as treatment alternatives.

Selection and Dosing of Selective Norepinephrine Reuptake Inhibitors. SNRIs are used most commonly as antidepressants. Available agents in the U.S. include venlafaxine, duloxetine, and nefazodone. All of these drugs are metabolized by the CYP450 system, and medication levels vary according to CYP450 status. Some of these agents, for example venlafaxine, are metabolized to an active metabolite by the CYP2D6 enzyme, and other agents such as duloxetine are inhibitors of CYP450 activity. Lobello et al. tested patients from 4 randomized controlled trials (RCTs) of venlafaxine versus placebo for CYP2D6 status and correlated genetic status, defined as either EM or PM, with response to treatment. There were no significant differences in dose of the drug according to genetic status. In 4 of 5 comparisons, patients who were EMs had a better response to treatment as determined by depression rating scales. There was also a significantly greater percent of responders in the EM group compared to the PM. There were no differences in discontinuation of therapy or adverse event rates between the EM and PM group.

For duloxetine, the inhibitory effects on CYP450 activity are manifested by higher drug concentrations for other medications metabolized by CYP450, such as TCAs and/or SSRIs. Similarly, other inhibitors of CYP450 such as paroxetine, will increase levels of duloxetine.

Atomoxetine HCl is a SNRI that is approved to treat attention-deficit/hyperactivity disorder (ADHD). Atomoxetine, the active moiety, is primarily metabolized by CYP2D6. The therapeutic window for atomoxetine is wide, and dosing is weight-based, initiated at a standard dose per kg and adjusted thereafter according to clinical response and adverse effects. At steady state dosing, CYP2D6 PMs have substantially higher atomoxetine plasma concentrations than EMs, although because it is generally well-tolerated across a wide range, adverse effects do not appear to be significantly associated with PMs. After titration, mean doses for EMs and PMs also do not differ significantly. However, more EM patients discontinued in one trial due to lack of efficacy, and PMs improved inattention scores more than EMs in another, perhaps suggesting a need to re-examine recommended dosing limits. The FDA decided not to include a recommendation to perform genotyping prior to prescribing atomoxetine. Dosing directions recommend a low starting dose to be increased to the target dose if well-tolerated. Thus, genotyping for CYP2D6 PMs of atomoxetine is not



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recommended because the margin of safety is not exceeded and evidence to support guidelines for dosing such that patient outcomes are improved has not been collected.

Indeed, Ramoz et al. recently reported on 2 independent cohorts of 160 and 105 ADHD children treated for 6 weeks with atomoxetine. Interindividual response to the drug appeared independent of the genetic variants of CYP2D6. The authors did observe drug treatment and genomic associations, but these were found between drug response and a haplotype of the norepinephrine transporter (NET) gene—Slc6a2. It was suggested further study be applied to assessment of this region to better manage patients being treated with this drug.

Most recently ter Laak et al. evaluated 100 patients treated for ADHD with standard doses of atomoxetine. A neurologist identified 10 of these who, based on late response or adverse effects, were subject to CYP P450 testing. Eight of the 10 were found to have a nonfunctional or less functional 2D6 allele. Four of these children showed improved responses on decreased atomoxetine; 4 were taken off treatment because of initial adverse events. While it is plausible that pretreatment testing could yield improved results, the study was not designed to evaluate the actual effect of testing on treatment outcomes.

Conclusions: Serotonin-norepinephrine reuptake inhibitor (SNRI) metabolism is affected by genetic status of cytochrome p450, with the greatest potential clinical effect seen for venlafaxine. For this agent, EMs of CYP2D6 have higher levels of the active metabolite, and genetic status may have an impact on treatment response. A post-hoc re-analysis of data from multiple RCTs has correlated treatment response to venlafaxine with genetic status. No studies have yet established that outcomes are improved as a result of genetic testing prior to initiating venlafaxine or other SNRIs.

Atomoxetine is a SNRI that is used for attention-deficit disorder (ADD). It has a narrow therapeutic window, and there is potential for PMs to reach serum levels that may be toxic. However, current recommendations for starting atomoxetine at a low dose and watching closely for adverse effects while titrating higher should minimize the risk of toxicity for PMs.

Selection and dosing of tricyclic antidepressants. Nortriptyline and other TCAs are metabolized by the CYP2D6 enzyme. Patients who are PMs will develop serum concentrations of nortriptyline that are 3-10-fold higher than patients who are (EMs. de Vos et al. studied 678 patients treated with TCAs and reported that EMs had increased metabolism and lower serum levels of amitriptyline and citalopram, but not clomipramine. However, these authors reported that the differences observed were not likely to have clinically important effects.

It has been reported that patients with TCA overdose may have different risk depending on CYP450 genetic status. Simulations and case reports have reported that PMs may be at higher risk for toxic levels of nortriptyline and that toxic levels are maintained for longer periods of time. There are no clinical studies that demonstrate that measuring genetic status improves outcomes for patients who have had a TCA overdose.

Conclusions. Cytochrome p450 genetic status affects the metabolism and serum levels of multiple TCAs, including nortriptyline, but the clinical impact of these differences in metabolism are not clear. There is some



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evidence to suggest that patients who are PMs are more prone to toxic levels in the setting of a TCA overdose. There is no evidence available to support that prospective testing of patients treated with TCAs improves outcomes.

Dose of efavirenz. Current guidelines recommend efavirenz as the preferred non-nucleoside reverse transcriptase inhibitor component of highly active antiretroviral therapy for HIV-infected patients. Forty to 70% of patients report adverse CNS effects. While most resolve in the first few weeks of treatment, about 6% of patients discontinue efavirenz due to adverse effects. Efavirenz is primarily metabolized by CYP2B6, and inactivating polymorphisms are associated with higher efavirenz exposure, although plasma levels appear not to correlate with adverse effects. Limited reports suggest that CYP2B6 PMs have markedly reduced side effects while maintaining viral immunosuppression at substantially lower doses. Simulations of such dose adjustments support this position.

Cabrera et al. have recently reported on an evaluation in 32 patients of the relationship between CYP2B6 polymorphisms and efavirenz clearance. Although they reported that CYP2B6 polymorphisms could be used to account for only 27% of interindividual variability, they noted decreased clearance of 50% in the patient group with the G/T genotype and 75% with the T/T genotype. Based on this observation, they suggested a gradual reduction in dose of efavirenz be considered in patients with these phenotypes. They proposed use of a model to incorporate factors that affect drug levels. However, based on the complexity of factors involved in dosing, they concluded drug treatment should be carefully evaluated using TDM and assessment of clinical efficacy.

Two recent studies have been published, one evaluating 373 patients for polymorphisms in CYP2B6 and constitutive androstane receptor (CAR), and one evaluating genotyping for 23 markers in 15 genes. Both demonstrated an association between markers and early efavirenz discontinuation. Both articles recommended further study to determine the clinical utility of these associations.

Conclusions: Genetic variants in CYP2B6 are associated with increased side effects for patients treated with efavirenz, leading to some recommendations to reduce dosing based on genotype results. The impact of this strategy on health outcomes has yet to be evaluated; therefore the clinical utility of genotyping for efavirenz dose is uncertain.

Dose of immunosuppressant for organ transplantation. Immunosuppressive drugs administered to organ transplant patients have a narrow therapeutic index with the consequences of rejection or toxicity on either side. In addition, there is variability in patient response, requiring close clinical follow-up and routine TDM to maintain safety and efficacy. Tacrolimus blood levels are related to CYP3A5 genetic variants, with an approximately 2.3-fold difference in daily dose required to maintain target concentration between CYP3A5*3 and CYP3A5*1 homozygous variants. CYP3A5*1 carriers have been reported to have a significant delay in reaching target tacrolimus concentrations compared to noncarriers; although the overall rate of acute rejection episodes was not higher in CYP3A5*1 carriers, their rejection episodes did occur earlier. Zhao et al. recently developed a population pharmacokinetic model of tacrolimus in pediatric kidney transplant patients using 50 de novo pediatric kidney transplant patients. They found oral clearance of tacrolimus was higher in patients with low hematocrit and lower in patients with CYP3A5*3/*3

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polymorphisms. Although they applied a number of bootstrap techniques to validate their model, they did not perform an independent clinical validation of their model and concluded "a prospective study in a larger number of patients is warranted to evaluate the clinical benefits of individualizing tacrolimus dosage in the immediate post-transplantation period on the basis of a pretransplant determination of CYP3A5 polymorphism." Randomized trials are currently underway to test genotype-directed initial tacrolimus dose versus standard dose. While pharmacogenetic applications for sirolimus and cyclosporine have been investigated, results are far less clear that genotyping is likely to have a significant clinical influence.

Conclusions: There is currently limited evidence on the impact of genotype on dosing on immunosuppressant medications. Clinical utility for this test is lacking at the current time.

Selection and management of patients on beta blockers. Several recent reports have indicated that lipophilic beta selective adrenergic receptor antagonists such as metoprolol, used in treating hypertension, may exhibit impaired elimination in patients with CYP2D6 polymorphisms. Bijl et al., in a population-based cohort study of 1,553 patients, noted increased risk of bradycardia in patients found to be PMs (CYP2D6 *4/*4). Recently, Baudhuin et al. studied the relationship between CYP2D6, ADRB1, and UGT1A1 and response in 93 patients with congestive heart failure treated with metoprolol or carvedilol and observed no differences according to genotype.

Dosing and management of antituberculosis medications. A number of studies have reported an association between CYP2E1 status and the risk of liver toxicity from antituberculosis medications. A meta-analysis of available trials was reported by Deng et al. in 2013. Compared with wild type genotype, patients with any variant genotype had an increased risk of liver toxicity (OR: 1.36, 95% CI: 1.09-1.69). Patients who were slow metabolizers had the highest risk of toxicity (OR: 1.88, 95% CI: 1.14-3.09), and this overall risk was also increased in Asian patients. This study does not address the question of whether genetic testing can reduce liver damage from antituberculosis medications, compared to the usual strategy of monitoring liver enzymes and adjusting medications based on enzyme levels.

Clinical Input Received through 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 genotyping for testing in patients being considered for clopidogrel treatment were mixed, with 5 suggesting the test be considered investigational and 3 suggesting it be considered medically necessary.

Summary

Cytochrome p450 genotyping has been demonstrated in a number of studies to identify increased risk of thrombosis in patients with coronary disease or cardiac interventions being considered as candidates for clopidogrel treatment. This observation is most pronounced for stent thrombosis in patients undergoing PCI.



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Genotyping may be used to consider treatment alternatives, e.g., higher doses of clopidogrel or alternative drug choices. The FDA has created a black box warning indicating testing should be considered. Clinical input from academic medical centers and specialty societies was mixed concerning the benefit of genetic testing, but there was not consensus that the medically necessary determination be changed. As a result, genetic testing for selection and dosing of clopidogrel may be considered medically necessary.

For other medications, most published CYP450 pharmacogenomic studies are retrospective evaluations of CYP450 genotype association with intermediate (e.g., circulating drug concentrations) or, less often, final outcomes (e.g., adverse events or efficacy) and are largely small and underpowered or not designed to examine the clinical effects of homozygous variant Poor metabolizers and of UMs, where the strongest effects, if any, would be seen. The hazards associated with PMs are consequently difficult to interpret and decision making about how to use genotyping information is poorly defined with uncertain outcomes. As a result, for most of the indications described above, CYP450 genotyping is investigational. This includes, but is not limited to, CYP450 genotyping for the following applications:

- Selection or dose of SSRI
- Selection and dosing of SNRIs
- Selection and dosing of tricyclic antidepressant medications
- Selection or dose of antipsychotic medications
- Deciding whether to prescribe codeine for nursing mothers
- Dose of efavirenz (common component of highly active antiretroviral therapy for HIV infection)
- Dose of immunosuppressant for organ transplantation
- Selection or dose of beta blockers (e.g., metoprolol).
- Dosing and management of antituberculosis medications

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Cytochrome p450 Genotyping

Policy # 00169
 Original Effective Date: 07/15/2005
 Current Effective Date: 05/21/2014

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Codes used to identify services associated with this policy may include (but may not be limited to) the following:

Code Type	Code
CPT	81225, 81226, 81227, 81401, 81402, 81404, 81405
HCPCS	No codes
ICD-9 Diagnosis	410.00 thru 410.92, 411.0, 411.1, 434.10 thru 434.91, 443.9
ICD-9 Procedure	No codes

Policy History

Original Effective Date: 07/15/2005
 Current Effective Date: 05/21/2014

06/07/2005 Medical Director review
 06/21/2005 Medical Policy Committee review
 07/15/2005 Managed Care Advisory Council approval
 07/07/2006 Medical Policy Committee approval. Format revision including addition of FDA and or other governmental regulatory approval and rationale/source. Coverage eligibility unchanged.
 05/02/2007 Medical Director Review
 05/23/2007 Medical Policy Committee approval. Rationale/source. Coverage eligibility unchanged.
 05/07/2009 Medical Director Review
 05/20/2009 Medical Policy Committee approval. Added a statement with seven bulleted applications for clarification of CYP450 genotyping to, "Services Are Considered Investigational" section. Coverage eligibility unchanged.
 06/03/2010 Medical Policy Committee review
 06/16/2010 Medical Policy Implementation Committee approval. Policy statement regarding cytochrome p450 genetic testing to guide selection or dose of beta blockers added as investigational criteria.
 05/05/2011 Medical Policy Committee review
 05/18/2011 Medical Policy Implementation Committee approval. Changed the use of CYP450 genotyping with clopidogrel (Plavix) from investigational to eligible for coverage.

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Cytochrome p450 Genotyping

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Original Effective Date: 07/15/2005

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05/03/2012 Medical Policy Committee review
05/16/2012 Medical Policy Implementation Committee approval. Coverage eligibility unchanged.
05/02/2013 Medical Policy Committee review
05/22/2013 Medical Policy Implementation Committee approval.
05/01/2014 Medical Policy Committee review
05/21/2014 Medical Policy Implementation Committee approval. Added "dosing and management of antituberculosis medications" to the investigational applications.
Next Scheduled Review Date: 05/2015

*Investigational – A medical treatment, procedure, drug, device, or biological product is Investigational if the effectiveness has not been clearly tested and it has not been incorporated into standard medical practice. Any determination we make that a medical treatment, procedure, drug, device, or biological product is Investigational will be based on a consideration of the following:

- A. whether the medical treatment, procedure, drug, device, or biological product can be lawfully marketed without approval of the U.S. Food and Drug Administration (FDA) and whether such approval has been granted at the time the medical treatment, procedure, drug, device, or biological product is sought to be furnished; or
- B. whether the medical treatment, procedure, drug, device, or biological product requires further studies or clinical trials to determine its maximum tolerated dose, toxicity, safety, effectiveness, or effectiveness as compared with the standard means of treatment or diagnosis, must improve health outcomes, according to the consensus of opinion among experts as shown by reliable evidence, including:
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 2. credible scientific evidence published in peer-reviewed medical literature generally recognized by the relevant medical community; or
 3. reference to federal regulations.

**Medically Necessary (or "Medical Necessity") - Health care services, treatment, procedures, equipment, drugs, devices, items or supplies that a Provider, exercising prudent clinical judgment, would provide to a patient for the purpose of preventing, evaluating, diagnosing or treating an illness, injury, disease or its symptoms, and that are:

- A. in accordance with nationally accepted standards of medical practice;
- B. clinically appropriate, in terms of type, frequency, extent, level of care, site and duration, and considered effective for the patient's illness, injury or disease; and
- C. not primarily for the personal comfort or convenience of the patient, physician or other health care provider, and 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 that patient's illness, injury or disease.

For these purposes, "nationally accepted standards of medical practice" means standards that are based on credible scientific evidence published in peer-reviewed medical literature generally recognized by the relevant medical community, Physician Specialty Society recommendations and the views of Physicians practicing in relevant clinical areas and any other relevant factors.

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