Q: Should we use pharmacogenetic testing when prescribing warfarin?

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The answer is not clear. There is evidence in favor of pharmacogenetic testing, but not yet enough to strongly recommend it. However, we do believe that physicians should consider it when starting patients on warfarin therapy.

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WARFARIN HAS A NARROW THERAPEUTIC WINDOW

Although newer drugs are available, warfarin is still the most commonly used oral anticoagulant for preventing and treating thromboembolism.1 It is highly effective but has a narrow therapeutic window and wide inter-individual variability in dosage requirements, which poses challenges to achieving adequate anticoagulation.1–3 Inappropriate dosing contributes to a high rate of bleeding events and emergency room visits.4

Warfarin is monitored using the prothrombin time. Because the prothrombin time varies depending on the assay used, the standardized value called the international normalized ratio (INR) is more commonly used.

Clinical factors such as age, body size, and drug interactions affect warfarin requirements and are important to consider,5 even though they account for only 15% to 20% of the variability in warfarin dose.6

Genetic factors also affect warfarin dosage requirements. The combination of genetic and clinical factors accounts for up to 47% of the dose variability.7

GENES THAT AFFECT WARFARIN

Several genes are known to influence warfarin’s pharmacokinetics and pharmacodynamics. Of these, the two most clinically relevant and well studied are CYP2C9 (which codes for cytochrome P450 2C9) and VKORC1 (which codes for vitamin K epoxide reductase).7 These genes are polymorphic, with some variants producing less-active enzymes that allow warfarin to be more active. Therefore, patients who carry these variants need lower doses of this drug (see below).

CYP2C9 variants

The CYP2C9 gene has several variants. Of these, CYP2C9*2 and CYP2C9*3 are associated with the lowest enzyme activity.

Patients with either of these variants require significantly lower warfarin doses to reach therapeutic levels than those with the wild-type gene (ie, CYP2C9*1). CYP2C9*2 reduces warfarin clearance by 40%, and the CYP2C9*3 variant reduces it by 75%.7 Having a *2 or *3 allele increases the risk of bleeding during warfarin therapy and the time needed to achieve a stable dose.8 Other variants associated with lower warfarin dose requirements are *5, *6, and *11.

The prevalence of these variants is significantly higher in people of European ancestry (roughly one-third) than in Asian people and...
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African Americans, although no one has recommended not testing in these low-prevalence populations. Limdi et al reported that by including the *5, *6, and *11 variants in genetic testing (in addition to *2 and *3), they could identify more African Americans (9.7%) who carried at least one of these abnormal variants than reported previously. Differences among ethnic groups need to be taken into account when interpreting pharmacogenetic studies.

**VKORC1 variants**

Patients also need lower doses of warfarin if they carry the VKORC1 –1639G>A variant, and they spend more time with an INR above the therapeutic range and have higher overall INR values. However, having this variant does not appear to increase the risk of bleeding.

The –1639G>A variant is the most common variant of VKORC1. Rarer ones have also been described, but most commercially available tests do not detect them.

Racial differences exist in the prevalence rates of the various VKORC1 polymorphisms, with the most sensitive (low-dose) genotype predominating in Asians and the least sensitive (high-dose) genotype predominating in African Americans. Over 50% of people of European ancestry carry the intermediate-sensitivity genotype (typical dose).

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**CURRENT RECOMMENDATIONS FOR OR AGAINST TESTING**

**FDA labeling**

In 2007, the US Food and Drug Administration (FDA) required that the warfarin package insert carry information about initial dosing based on CYP2C9 and VKORC1 testing. This recommendation was revised in 2010 to include a table to help clinicians select an initial warfarin dose if CYP2C9 and VKORC1 genotype information is available. However, the FDA does not require pharmacogenetic testing, leaving the decision to the discretion of the clinician.

**American College of Chest Physicians**

The American College of Chest Physicians recommends against routine pharmacogenetic testing (grade 1B) because of a lack of evidence that it improves clinical end points or that it is cost-effective.
smoking status, and other medications taken. In addition, models incorporating the INR on day 4 and days 6 to 11 have been developed for dose refinement.\textsuperscript{15} The algorithms explain 30\% to 60\% of the variability of the data, with lower values for African Americans.\textsuperscript{7}

A well-developed dosing model that includes traditional clinical factors and patient genetic status is publicly available online at www.warfarindosing.org.\textsuperscript{4}

**CPIC: A leader in applied pharmacogenetics**

In late 2009, PharmGKB joined forces with the Pharmacogenomics Research Network of the National Institutes of Health to form the Clinical Pharmacogenetics Implementation Consortium (CPIC). This organization issues guidelines that are written by expert clinicians and scientists and then are peer-reviewed, published in leading journals, and simultaneously posted to the PharmGKB website along with supplemental information and updates.

CPIC’s goal is to review the current evidence and to address barriers to the adoption of pharmacogenetic testing into clinical practice. Its guidelines do not advise when or which pharmacogenetic tests should be ordered. Rather, they provide guidance on interpreting and applying such testing, should the test results be available.\textsuperscript{7}

CPIC has guidelines on CYP2C9 and VKORC1 genotypes and warfarin dosing.\textsuperscript{8} If a patient’s genetic information is available, CPIC strongly recommends the use of pharmacogenetic algorithm-based dosing. If such an algorithm is not accessible, use of a genotype dosing table is recommended.\textsuperscript{8}

**Monitoring is still needed**

Many factors can affect an individual’s response to warfarin above and beyond the above-noted clinical and genetic traits. These include diet, concomitant medications (both prescription and over-the-counter and herbal), and disease state. There may also be additional genetic polymorphisms not yet identified in various racial and ethnic groups that may affect dosing requirements. And as with all medications, patient compliance and dosing errors have a large potential to affect individual response. Therefore, clinicians should still be diligent about clinical monitoring.\textsuperscript{15}

**Most useful for initial dose**

As with most pharmacogenetic information, the greatest benefit can be achieved when this information is used to guide the initial dose, although there is also some effect noted when this information is known and acted upon into the 2nd week of treatment.\textsuperscript{8}

Patients on long-term warfarin treatment with stable doses and those unable to achieve stable dosing because of variable adherence or dietary vitamin K intake are less likely to benefit from genetic testing.

There are no published guidelines on the utility of pharmacogenetic testing if a patient is already on a stable dose of warfarin or has a known historical stable dose. There are also no published guidelines on changing the frequency of monitoring based on known genotype.

In children, the data are sparse at this time regarding the utility of pharmacogenetically informed dosing.

**HOW DOES ONE ORDER TESTING, AND WHAT IS THE COST?**

The FDA has approved four warfarin pharmacogenetic test kits. To be used in clinical decision-making, these tests must be done in a laboratory certified by the Clinical Laboratory Improvement Amendments (CLIA) program.

Testing typically costs a few hundred dollars and may take days for results to be returned if not available on site.\textsuperscript{15} At Cleveland Clinic, CYP2C9 and VKORC1 testing can be run in-house at a cost of about $700. Generally, many third-party payers do not reimburse for testing without a prior-approval process.

**TO TEST OR NOT TO TEST**

Pharmacogenetic testing is available and may help optimize warfarin dosing early in treatment, as well as help maintain therapeutic INRs more consistently. There is preliminary evidence that using this information to guide dosing improves clinical outcomes. Several large trials are under way to address additional questions of clinical utility, with results expected in the next year. There are also readily available decision-support tools to guide therapeutic dosing, and when pharmacogenetic
test results are available, utilization of a warfarin dosing algorithm is recommended.

The largest barrier remaining appears to be cost (relative to perceived benefit), and until larger trials of clinical utility and cost-effectiveness are completed and analyzed, hurdles exist to obtaining coverage for such testing.

If it is readily available (and can be paid for by insurance companies or out-of-pocket) and test results can be obtained within 24 to 48 hours or before prescribing, pharmacogenetic testing can be a valuable tool to guide and manage warfarin dosing. Particularly for patients who want to be as proactive as possible, warfarin pharmacogenetic testing offers the ability to participate in this decision-making and to potentially reduce their risk of adverse drug events. And in view of the evidence and FDA recommendations, we propose that the discussion with our patients is not whether we should consider pharmacogenetic testing, but that we have considered pharmacogenetic testing, and why we have decided for or against it.

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REFERENCES

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