



# Pharmacogenomic Biomarkers: Genetic Indicators for More Individualized Drug Selection and Dosing

Clara Bennett\*

Department of Pharmacogenomics, University of Cambridge, Cambridge, UK

## DESCRIPTION

Pharmacogenomic biomarkers are measurable genetic characteristics that can provide information about how an individual may respond to a particular medicine. Variations in Deoxyribonucleic Acid (DNA) sequence can influence drug absorption, distribution, metabolism, elimination, target interaction and susceptibility to adverse effects. By connecting genetic variation with medication response, pharmacogenomic biomarkers support more informed decisions about drug selection and dosage. Their applications extend across oncology, cardiology, psychiatry, infectious diseases, neurology and several other areas of clinical medicine. Human genetic variation occurs naturally among individuals and can influence the activity of proteins involved in drug handling. Single-nucleotide variants, insertions, deletions, copy-number changes and other genomic alterations may modify the expression or function of enzymes, transporters, receptors and signaling proteins. When a genetic variant changes the activity of a drug-related protein, the concentration or biological effect of a medicine may also change [1-3].

Drug-metabolizing enzymes are an important source of pharmacogenomic biomarkers. The cytochrome P450 enzyme family is responsible for the metabolism of many medicines. Genetic differences in genes such as *Cytochrome P450 2D6*, *CYP2C19* and *CYP2C9* can result in different enzyme activities among individuals. Depending on the medicine involved, a person may metabolize a drug rapidly, normally, slowly, or very slowly. These differences can influence drug exposure and therapeutic response. *CYP2C19* variation provides a well-known example. This enzyme participates in the metabolism of several medicines, including some antiplatelet agents. Individuals carrying certain *CYP2C19* variants may have reduced enzyme activity, which can affect the conversion of specific medicines into their active forms. Genetic information can therefore assist clinicians in selecting an appropriate treatment option when pharmacogenomic guidance is available [4].

*CYP2D6* is another important pharmacogenomic marker. It participates in the metabolism of numerous medicines used in cardiovascular, psychiatric, neurological and pain management settings. *CYP2D6* genetic variation is particularly diverse, with some individuals carrying gene copies associated with increased activity and others having reduced or absent activity [5]. The resulting differences can influence the amount of active drug or metabolite present in the body. Transporter genes can also serve as pharmacogenomic biomarkers. Transport proteins control the movement of medicines across cell membranes and influence absorption, distribution and elimination. Variants in genes encoding drug transporters may alter transporter expression or function. Consequently, genetic differences in transport pathways can contribute to variation in drug concentrations and treatment response [6,7].

Drug targets provide another category of pharmacogenomic biomarkers. A medicine may act by binding to a receptor, enzyme, ion channel, or signaling protein. Genetic changes affecting the structure or expression of these targets can modify the interaction between the medicine and its biological target. In some conditions, target-related genomic information can help identify individuals who are more likely to benefit from a particular treatment. Oncology has become an important area for pharmacogenomic biomarker application. Tumor cells can contain genetic alterations that influence sensitivity or resistance to particular medicines. Biomarker testing can identify molecular features associated with treatment response and may assist in selecting suitable therapies. Examples include genomic alterations involving Epidermal Growth Factor Receptor (EGFR), Human Epidermal Growth Factor Receptor 2 (HER2), B-Raf Proto-Oncogene, Serine/Threonine Kinase (BRAF), Anaplastic Lymphoma Kinase (ALK) and other molecular targets. The clinical relevance of each biomarker depends on the cancer type, medicine, disease stage and available treatment guidance [8].

Pharmacogenomic biomarkers can also contribute to the prevention of adverse drug reactions. Some genetic variants are

**Correspondence to:** Clara Bennett, Department of Pharmacogenomics, University of Cambridge, Cambridge, UK, E-mail: clara.bennett@pharmgen.uk

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associated with an increased risk of severe immune-mediated or other unwanted reactions to specific medicines. Testing for selected variants before treatment can help identify individuals who may require an alternative medication. This approach can be especially valuable when the adverse reaction is uncommon but potentially serious. The interpretation of pharmacogenomic results requires appropriate classification of genetic variants. A genetic change does not automatically indicate that a medicine will be ineffective or harmful. Its significance depends on the gene involved, the specific variant, the medicine, the patient's clinical condition and other biological factors. Laboratory methods therefore need to distinguish clinically meaningful variants from changes with limited or uncertain effects [9,10].

## CONCLUSION

Pharmacogenomic biomarkers can be detected using several laboratory approaches. Genotyping methods can identify specific variants, while sequencing can examine larger genomic regions. Microarray-based methods can evaluate numerous genetic markers simultaneously. More comprehensive sequencing approaches can provide information about multiple genes involved in drug response. The choice of testing method depends on the clinical purpose, number of variants being assessed, laboratory resources and required turnaround time. The clinical interpretation of genetic information can be supported by pharmacogenomic databases and clinical guidelines. These resources connect specific genetic variants with available evidence regarding drug metabolism, efficacy, or adverse reactions. Healthcare professionals can use such information alongside clinical history, laboratory results, concomitant medications, age, organ function and other factors when making treatment decisions.

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