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Opinion Article

Pharmacokinetics should be Central to Personalized Medicine, not an Afterthought

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DESCRIPTION

Medicine has entered an era in which individualized care is increasingly recognized as the ideal approach to disease management. Considerable attention has been directed toward identifying genetic biomarkers, developing targeted therapies and applying artificial intelligence to clinical decision making. Yet one critical component of precision medicine often receives less attention than it deserves: Pharmacokinetics. Although healthcare professionals routinely prescribe medications according to standardized dosing guidelines, patients frequently exhibit substantial differences in drug exposure, therapeutic benefit and adverse effects. The traditional concept of a standard dose assumes that most patients process medications in similar ways. While this approach is practical for many clinical situations, it does not accurately reflect biological diversity. Drug absorption from the gastrointestinal tract, distribution into tissues, metabolism by hepatic enzymes and elimination through the kidneys vary considerably among individuals. Consequently, two patients receiving identical doses may experience dramatically different blood concentrations of the same medication. One patient may fail to achieve therapeutic benefit, whereas another may develop dose related toxicity. This variability is particularly important in medications with narrow therapeutic windows. Small changes in drug concentration may determine whether treatment is effective or harmful. Despite this well established principle, individualized pharmacokinetic assessment remains underutilized outside specialized clinical settings. Many hospitals still rely primarily on generalized dosing recommendations rather than patient specific pharmacokinetic evaluation. As healthcare increasingly embraces precision medicine, this gap deserves greater attention.

One reason pharmacokinetics remains underemphasized may be its perceived complexity. Concepts such as clearance, volume of distribution, elimination half life and bioavailability are often viewed as technical calculations relevant only to researchers and clinical pharmacologists. However, these parameters directly influence every prescribing decision made in clinical practice. Simplifying pharmacokinetic information through digital decision support systems could allow clinicians to apply these principles without requiring advanced mathematical expertise. Patient diversity further strengthens the argument for individualized pharmacokinetic evaluation. Elderly patients frequently exhibit reduced renal and hepatic function, altering drug elimination and increasing susceptibility to adverse reactions. Children possess developing metabolic pathways that differ substantially from those of adults. Pregnancy introduces physiological changes affecting drug distribution and clearance. Patients with obesity, liver disease, kidney impairment, or critical illness may require substantial dose adjustments to achieve appropriate therapeutic concentrations. Treating these diverse populations using identical dosing strategies is increasingly difficult to justify when pharmacokinetic tools are available.

Pharmacogenomics has added another important dimension to pharmacokinetic variability. Genetic differences in drug metabolizing enzymes influence how rapidly medications are activated or eliminated. Some individuals metabolize drugs exceptionally quickly, reducing therapeutic effectiveness, while others metabolize them slowly, increasing toxicity risk. Integrating pharmacogenomic information with pharmacokinetic modeling could substantially improve prescribing decisions. However, genetic information alone cannot predict clinical response unless interpreted alongside pharmacokinetic principles and patient specific physiological characteristics. Therapeutic drug monitoring provides one of the clearest examples of pharmacokinetics improving patient care. Measuring circulating drug concentrations allows clinicians to optimize dosage according to individual patient responses rather than relying exclusively on standardized recommendations. This approach has demonstrated value for medications used in infectious diseases, epilepsy, transplant medicine and oncology. Nevertheless, therapeutic drug monitoring remains limited to relatively few medications. The growing availability of artificial intelligence presents another opportunity to modernize pharmacokinetic practice. Machine learning algorithms can analyze extensive clinical datasets to predict individualized dosing requirements based on laboratory values, demographic characteristics, genetic information and disease status. Rather than replacing clinical judgment, these technologies could support healthcare professionals by providing evidence based

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recommendations tailored to each patient's unique physiological profile. Such tools may eventually become integrated into electronic prescribing systems, making individualized pharmacokinetic guidance readily accessible during routine clinical care.