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1. Discuss in details the factors affecting drug metabolism.

Answer:

Metabolism is a biotransformation or chemical alteration of a drug to other molecular species usually called the metabolites, within the body via an enzymatic or non-enzymatic process. The primary site for drug metabolism is liver and other sites are kidney, intestine, lungs and plasma.

Drugs can be metabolized by many different pathways, and many factors can determine which pathway is used by which drug and to what extent a particular drug is bio-transformed by a particular pathway. These factors range from the species of organism studied, to the environment in which that organism lives.

In order to discuss this topic, the factors affecting drug metabolism will be split into three major factors. However, much interaction exists between the various factors (hormones, sex and age are often influenced by each other), and such interactions will be pointed out. This is an important study, as these various factors must be considered during administration and also in proper dosing of any drug to patients.

**Factors Affecting Metabolism**

A number of factors may influence the metabolism of a drug. Some of them are:

**1. Chemical factors:**

**i. Enzyme induction:** The phenomenon of increasing the drug metabolizing ability of enzymes by several drugs and chemicals is called enzyme induction. Agents which bring about such an effect are called enzyme inducers. The mechanism of enzyme induction is an:

a. Increase in both liver size and liver blood flow.

b. Increase in both total and microsomal protein content.

c. Increased stability of enzymes.

d. Increased stability of cytochrome P-450.

e. Decreased degradation of cytochrome P-450.

f. Proliferation of smooth endoplasmic reticulum.

**Consequences of enzyme induction include**:

1. Decrease in the activity of the drugs.
2. Increased activity where the metabolites are active.
3. Altered physiological status due to enhanced metabolism of endogenous compounds such as sex hormones.

Some examples of enzyme inducers are alcohol (CNS stimulant) which increases the metabolism of pentobarbital, coumarins and phenytoin because of induction, environmental chemicals such as pesticides (DDT), and polycyclic aromatic hydrocarbons present in cigarette smoke.

ii. Enzyme inhibition: A decrease in the drug metabolizing ability of an enzyme is called as enzyme inhibition. The process of inhibition may be direct or indirect. It results in an increase of the duration of the drug in the body and also an increase in toxicity.

1. **Direct inhibition:** It may result from interaction at the enzyme’s site, the net outcome being a change in enzyme activity. Direct enzyme inhibition can occur by one of the following mechanisms:

i. Competitive inhibition: occurs when structurally similar compounds compete for the same site on an enzyme.

ii. Non-competitive inhibition: occur when a structurally unrelated agent interacts with the enzyme and prevents the metabolism of drugs.

iii. Product inhibition: occurs when the metabolic product competes with the substrate for the same enzyme.

2) **Indirect inhibition**: it is caused by one of the following mechanisms:

i. Repression: it may be due to fall in the rate of enzyme synthesis or rise in the rate of enzyme degradation.

ii. Altered physiology: it may be due to nutritional deficiency or hormonal imbalance.

An example of inhibition is: metacholine (anti-asthmatic) inhibiting the metabolism of acetyl choline by competing with it for cholinesterase. Similarly, isoniazid (antitubercular) inhibits the metabolism of phenytoin. More examples of inhibitors are anticoagulants, anti-epileptics, and heavy metals; mercury, nickel, cobalt and arsenic which inhibit drug metabolizing ability of enzymes.

**2**. **Environmental factors**: Environmental factors that may influence drug metabolism are temperature, altitude, pressure, atmosphere, etc. also, one might live in areas where environmental conditions such as presence of chemicals like pesticides (DDT), and polycyclic aromatic hydrocarbons are present, and this will definitely affect the metabolism of drugs.

**3. Biological factors**

i. **Age**: The drug metabolic rate in the different age groups differs mainly due to variations in the enzyme content, enzyme activity and haemodynamics. In neonates (up to 2 months) and in infants (2 months to 1 year), the microsomal enzyme system is not fully developed. So, many drugs are metabolized slowly. For example, caffeine has a half-life of 4 days in neonates in comparison to 4 hours in adults. Children (between 1 year and 12 years) metabolize several drugs much more rapidly than adults as the rate of metabolism reaches a maximum somewhere between 6 months and 12 years. As a result they require large mg/kg dose in comparison to adults. In elderly persons, the liver size is reduced, the microsomal enzyme activity is decreased and hepatic blood flow also declines as a result of reduced cardiac output, all of which contributes to decreased metabolism of drugs. For example, chlomethiazole shows a high bioavailability within the elderly, therefore they require a lower dose.

ii. **Diet**: The enzyme content and activity is altered by a number of dietary components. Examples are:

1. Generally, low protein diet decreases and high protein diet increases the drug metabolizing ability as enzyme synthesis is promoted by protein diet and also raises the level of amino acids for conjugation with drugs.
2. Fat free diet depresses cytochrome P-450 levels since phospholipids, which are important components of microsomes become deficient.
3. Grapefruit inhibits metabolism of many drugs and improve their oral bioavailability.
4. Dietary deficiency of vitamins like Vitamin A, B2, B3, C and E) and minerals such as Fe, Ca, Mg, Zn retard the metabolic activity of enzymes.
5. Starvation results in decreased amount of glucuronides formed than under normal conditions.

iii. **Sex difference**: Since variations between males and females are observed following puberty, sex related differences in the rate of metabolism may be due to sex hormones. Such sex differences are widely studied in rats, where male rats have greater drug metabolizing capacity.

In humans, women metabolize benzodiazepines slower than men. Several studies have shown that women on contraceptive pills metabolize a number of drugs at a slow rate.

iv. **Species difference:** Species difference have been observed in both Phase-I and Phase-II reactions. In Phase-I reactions, both qualitative and quantitative variations in the enzyme and their activity have been observed. Qualitative differences among species generally result from the presence or absence of specific enzymes in those species. Quantitative differences result from variations in the amount and localization of enzymes, the amount of natural inhibitors, and the competition of enzymes for specific substrates.

Human liver contains less cytochrome P-450 per gram of tissue than do the livers of other species. Rat liver contains approximately 30 to 50 nmol/g of Cytochrome P450, whereas human liver contains 10 to 20 nmol/g. Furthermore, human liver is 2 percent of body weight, whereas rat liver is approximately 4 percent. Similarly, in men, amphetamine and ephedrine are predominantly metabolized by oxidative deamination, whereas in rats aromatic oxidation is the major route in Phase-II reactions.

v. **Strain difference**: Just as the difference in drug metabolizing ability between different species is attributed to genetics, the differences are observed between strains of same species also. It may be studied under pharmacogenetics.

*Pharmacogenetics* is the study of inter-subject variability in drug response. The inter-subject variations in metabolism may either be monogenetically or polygenetically controlled.

A polygenetic control is observed in twins. In identical twins (monozygotic), very little or no difference in metabolism of halothane, phenylbutazone, dicoumaral and antipyrine was detected but large variations were observed in fraternal twins (dizygotic).

vi. **Ethnic Variations:** Differences observed in the metabolism of drug among different races are called ethnic variations. Such variations may be monomorphic or polymorphic. Example: Approximately equal percent of slow and rapid acetylators are found among whites and blacks whereas the slow acetylators dominate Japanese and Eskimo population.

vii. **Altered physiological factors**:

1. Pregnancy: Pregnancy is known to affect hepatic drug metabolism. Physiological changes during pregnancy are probably responsible for the reported alteration in drug metabolism. These include elevated concentrations of various hormones such as estrogen, progesterone, placental growth hormones and prolactin. For example: in women, the metabolism of promazine and pethidine is reduced during pregnancy. It was also confirmed by the study in animals. In pregnant Sprague-Dawley rats, hexobarbital biotransformation indicated unchanged or slightly elevated microsomal enzyme activity compared to normal rats.
2. Diseased State: There are many diseased states that affect the metabolism of drugs. Some of them are cirrhosis of liver, alcoholic liver disease, cholestatic jaundice, diabetes mellitus, acromegaly, malaria and various bacterial and viral infections. It can be seen that major effects are seen in the disease affecting liver as liver is quantitatively the important site for metabolism. The possible cause in the effect of metabolism due to diseases may be:
3. Decreased enzyme activity in liver.
4. Altered hepatic blood flow.
5. Hypoalbuminaemia (leading to lower plasma binding of drugs). For example: glycine conjugation of salicylates, oxidation of Vitamin D and hydrolysis of procaine are impaired in kidney diseases.
6. Hormonal imbalance: Higher level of one hormone may inhibit the activities of few enzymes, while inducing that of others. Adrenolectomy, thyroidectomy and alloxan-induced diabetes in animals showed impairment in the enzyme activity with subsequent fall in the rate of metabolism. A similar effect was also observed in the pituitary growth hormone and stress related changes in ACTH levels.

**4. Physicochemical properties of the drug:** Molecular size and shape, pKa, acidity/basicity and steric and electronic characteristics of a drug influence its interaction with the active sites of enzymes, and the metabolism to which it is subjected.