A Clinical Study of Iron Absorption Using Two Radioiron Isotopes

S. TOMITA

The First Division, Department of Internal Medicine, Faculty of Medicine, Kyoto University, Kyoto

It has been suggested by Hallberg and Sölvell that the process of iron absorption in humans can be analyzed in two phases, rapid and slow, by the simultaneous use of two radioisotopes, ^{55}Fe and ^{59}Fe. To analyze mathematically the process of iron absorption, an atempt was made to explore the method for this, according to their method, in which the mathematical analysis of iron absorption has not been done so far. Furthermore, in view of the facts that the fecal excretion of a smaller dose of oral iron-deficient subjects, while the fecal excretion of oral ^{51}Cr was accomplished almost completely by the fifth day, an analytical method was devised to allow to estimate, in the two phases, the fecal excretion of ^{59}Fe following the simultaneous administration by mouth of ^{59}Fe and ^{51}Cr, the latter of which served as a non-absorbable marker (Fig. 1). The combination of these two methods seemed to be suitable to analyze in more details the process of iron absorption in humans in two phases not only the absorption itself but the mode of the excretion. Along this line, the iron absorption study was made by giving orally ^{59}Fe and ^{51}Cr and by injecting a tracer dose of ^{55}Fe intravenously to subjects to be tested. The present paper deals with these methods and some results obtained.

A) Analysis of the process of iron absorption.

An oral dose of radioiron containing 0.05, 1 or 40 mg of ferrous iron was given to normal, iron deficient and iron overloaded subjects at pH 2 with added 100 mg of ascorbic acid.

The results obtained by this method are summarized graphically in Fig. 2. The rapid absorption was markedly increased in subjects with iron deficiency as compared with those without iron deficiency at any dosage. The slow absorption, however, showed no significant difference between them at a smaller dosage. With increasing dosage, the slow absorption was decreased markedly in subjects without iron deficiency, while in those with iron deficiency no such a decrease was observed. This finding indicates that the increase of iron absorption in iron deficiency is due mainly to that of the rapid absorption. The rapid excretion was markedly increased in subjects without iron deficiency as compared with those with iron deficiency at a larger dose such as 40 mg. However, at a small dose of 0.05 mg, only a slight difference in the rapid excretion was observed between them. In the meantime, the slow excretion was almost zero in iron deficiency at any dosage. However, in non iron-deficient subjects it was considerably increased at a smaller dose such as 0.05 or 1 mg, although it was almost zero at a larger dose.

As to the process of iron absorption, no essential difference was observed between normals and iron excess through all the phases, in contrast to significant differences between iron deficient and non iron-deficienct subjects.

B) Mathematical analysis of the rapid absorption of iron.

The study of the rapid absorption at 1 mg or less revealed the following findings.

1) The plasma radioiron absorption curve can be expressed as the difference of two exponential curves, one of which having almost the same inclination as that of the plasma radioiron disappearance curve obtained following intravenous injection of the other kind of radioiron (Fig. 3).

2) The intersection of the two exponential curves was located at the administration time of the oral iron in two gastrectomized subjects, in which iron was supposed to enter the intestine immediately.

From these findings, a new analytical model as shown in Fig. 3 was devised to study the kinetics of iron absorption. Following ingestion, all the iron moves together from the stomach into the intestine after a certain

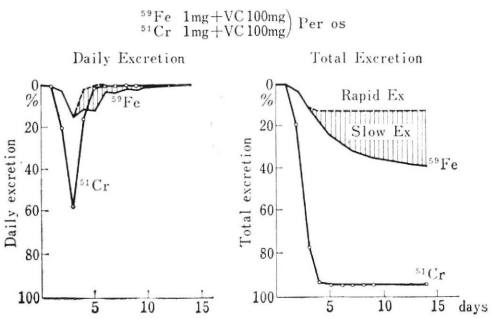
period. The iron in the intestine is transferred to the plasma at a rate α_1, proportional to its concentration in the intestine, and at the same time, the iron in the plasma to other tissues at a rate α_2. On the other hand, the iron in the intestine changes into non-absorbable forms at a rate constant α_3.

Based on this analytical model, the amount of iron absorbed in the rapid phase can be calculated by a formula $\frac{\alpha_1}{\alpha_1+\alpha_3}$ Thus calculated amount of absorbed iron was in good accord with that as determined by the method of Hallberg and Solvell.

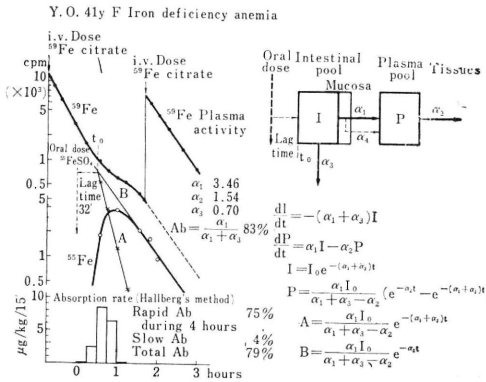
The rate constant α_1, which is for iron transfer from the intestine into the plasma at a 1 mg dose, ranged 0.11 to 1.58, 1.92 to 3.83 and 0.03 to 0.23 per hour in normals, iron deficiency and aplastic anemia, respectively. The amount of iron absorbed in the rapid phase or the rate constant α_1 was found to correlate well with either serum iron level or phasma iron disappearance (T1/2).

From the results mentioned above, it may be assumed that, in the state of iron deficiency, the absorption of iron in the rapid phase is increased as a result of the increase of the rate constant for iron transfer from the intestinal tract into the plasma, and consequently the total amount of iron absorbed is increased.

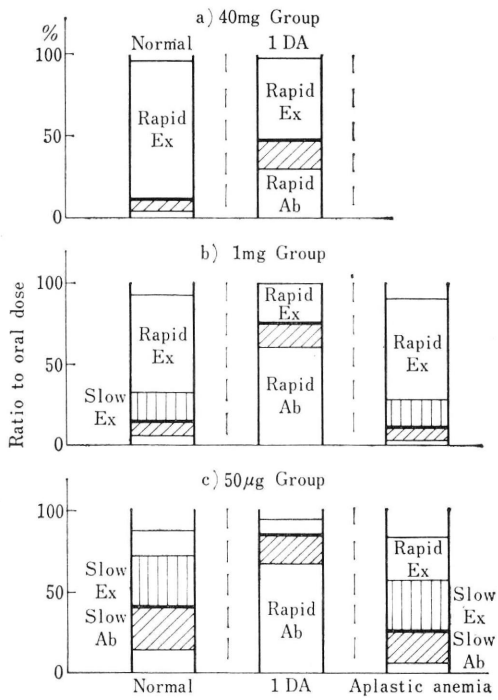
Stool Excretion of Orally Administered ^{59}Fe & ^{51}Cr



Model of Iron Absorption



Analysis on Iron Absorption in Various Patients



IDA: Iron deficiency anemia
Rapid Ex: Rapid excretion
Slow Ex: Slow excretion
Rapid Ab: Rapid absorption
Slow Ab: Slow absorption