The Inter-Relationships Between Calcium Absorption and Bile

It has been shown that the addition of bile and bile salts increased the absorption of calcium from isolated loops of the intestine of rachitic chicks[1,2]. However, in vitamin D_3-treated chicks the increase in calcium absorption in the presence of bile, compared with the addition of the vitamin alone, was small and of doubtful statistical significance[1]. In rats, the influence of bile on calcium absorption is also conflicting. It has been found that stimulation of bile flow by i.p. injection of sodium taurocholate increased the absorption of calcium[3], while acute biliary obstruction (2–4 days) had no effect[4]. However, chronic bile duct obstruction (16–39 days) decreased the absorption of calcium[4].

There is then still some uncertainty whether bile is directly involved in the process of calcium absorption in normal, as distinct from rachitic animals. An investigation was therefore carried out on the influence of bile and bile components on calcium absorption in the normal chick. The proximal intestine is the major site for calcium absorption in the intact bird[5,6] and therefore segments were prepared from the duodenum for absorption studies in vivo. The initial calcium concentration was approximately 8 mg/ml solution and the disappearance of calcium per 30 min/g dry weight of intestinal segments was taken as a measure of calcium absorption.

The results of an experiment on 7-week-old cockerels to determine the response to increasing amounts of bile put into the duodenal loops are given in Table I. The results show that calcium absorption was increased by increasing the initial amount of bile in the duodenal loops.

Experiments were carried out to investigate whether bile salts alone, or in combination with lecithin (another major component of bile[7]) were responsible for the action of bile on the absorption of calcium. The results are given in Table II.

Table I. The influence of bile on calcium absorption from duodenal loops of 7-week-old cockerels

Treatments	Ca absorbed (mg/30 min/g dry weight of intestinal loops)	Ca absorbed (%)
Control	1.83 ± 0.12	21.2 ± 1.24
0.2 ml bile	4.61 ± 0.08	53.0 ± 0.65[a]
0.4 ml bile	5.86 ± 0.17	67.3 ± 1.23[a]
0.6 ml bile	7.59 ± 0.29	85.9 ± 3.74[a]

Means $\pm$ S.E.M. of 4 birds. [a] Significantly different from control and one another ($P < 0.001$).

Table II. The influence of sodium taurocholate (0.032 *M*), lecithin (6 mg) and bile (containing 0.032 *M* bile acids and 2 mg lecithin) on the absorption of calcium

Treatments	Ca absorbed (mg/30 min/g dry weight of intestinal loops)	Ca absorbed (%)
Control	1.97 ± 0.23	25.1 ± 2.9
Sodium taurocholate	2.54 ± 0.11	32.3 ± 1.4[a,c]
Sodium taurocholate + lecithin	3.54 ± 0.18	45.2 ± 2.4[b]
Bile	3.57 ± 0.31	44.1 ± 3.7[a]

Mean values $\pm$ S.E.M. of 6 birds. [a] Significantly different from control ($P < 0.002$). [b] Significantly different from control ($P < 0.001$). [c] Significantly different from sodium taurocholate + lecithin and bile ($P < 0.05$).

Bile salts exist as unassociated molecules in very dilute solutions, but above a certain concentration (critical micellar concentration) and temperature (critical micellar temperature) they form polymolecular aggregates, known as micelles[8]. The bile salts used in experiment 2 were above the critical micellar concentration (2–3 m*M*)[9] and critical micellar temperature (below freezing point of water)[9] and were thus presumably in the form of simple micelles. In the presence of phospholipids (lecithin) bile salts form mixed, swollen micelles[9] which are larger than simple micelles[10]. The simple and mixed micelles bear negative charges on the outside from their polar groups and counter ions such as Na^+ and Ca^{++} from aqueous solutions associate with these charges to neutralize them[9].

The present results indicate that the increase in the absorption of calcium is brought about by mixed micelles from bile salts and lecithin rather than by bile salts alone as has previously been suggested[1]. Calcium is known to bind to hydroxyl carboxylic acids and it is therefore possible that both the hydroxyl groups of the bile acids and the peripheral negative charges of the mixed micelles could play an important role in calcium binding and consequently in calcium transport processes. At present the means by which other intestinal substances such as fatty acids, which form mixed micelles with bile salts, are finally introduced into the microvilli are not fully understood.

A process of mixed micellar absorption of calcium would imply that the micelles merely bring the calcium into contact with the absorption surface rather than being absorbed and transported together, because the major site for bile salt absorption is the distal part of the intestine and that for calcium the proximal part[5,6,11].

In the absence of bile, calcium absorption can still take place and further work will be required to determine the relative importance of micellar and non-micellar mechanisms in this process.

Zusammenfassung. Es wird eine positive Korrelation der Kalziumabsorption in Küken bei steigender Gallenmenge gefunden. Gemischte Mizellen der Galle aus Gallensäuren und Lecithin waren am wirkungsvollsten.

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