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Trace elements in the serum of mothers and their children

By

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The serum copper, zinc and iron levels, iron binding capacity and coeruloplasmin activity were determined in 28 maternal and cord bloods and in 50 infants and children. At the end of the gestation period the serum copper level increased, iron concentration remained unchanged while the level of zinc decreased significantly as compared to the values for healthy, non-pregnant women. Iron and zinc concentrations at birth were significantly higher in the newborn than in the mother, whereas the copper level amounted only to 20% of the maternal value. Subsequently, the copper level increased to reach the lower limit of healthy adults in the first to second year of life. The remarkably high neonatal zinc concentration fell significantly in the first 2 to 4 weeks of life and decreases to the normal adult level at one year of age.

The changes in the trace element concentrations may be due to quantitative differences in the transporting proteins, variations in placental permeability and in the function of transfer proteins.

Severe, chronic metabolic disturbances may result from deficiency of certain trace elements. Their homeostasis [7] is scarcely known, in spite of data on the particular importance of iron, copper and zinc ions [2, 4, 5], especially in the fetus and the newborn child.

In an earlier paper we have reported on changes in the transferrin level and iron binding capacity of the sera of healthy newborns, infants and children [3]. The present study has been aimed at determining iron, iron binding capacity, copper, coeruloplasmin and zinc in maternal and cord blood and to study the serum concentration of zinc and copper in infancy and childhood.

MATERIAL AND METHOD

The material consisted of 28 maternal (M) and cord blood (C) samples collected immediately after delivery and of those of 50 children free from any current disease. Sampling was made on an empty stomach without the use of anticoagulant; sera were obtained by centrifugation. The infants and children were divided into four groups. The first consisted of 8 infants from 2 weeks to 1 month of age (I). The second group (II) included 18 infants from 6 weeks to 10 months of age. In the third group (III) there were 10 children, from 1 to 2 years; and in the fourth (IV), 14 children of 2 to 7 years.

Copper was determined by the Boehringer kit and by its modification elaborated by us for the Beckman–Spinco apparatus with the use of 200 μl serum. Comparison of this micromethod with atomic absorption spectrophotometry gave comparable

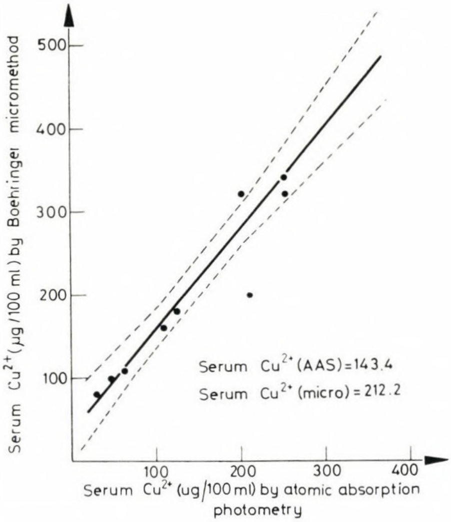

FIG. 1. Copper values estimated by atomic absorption photometry and the micro Boehringer method. Dots indicate values obtained by parallel measurements of the same serum samples. Equation of regressive curve: $Y = 3.0557 + 0.9979\ X$; correlation coefficient: 0.9903. Mean values yielded by the two method are indicated in the Figure

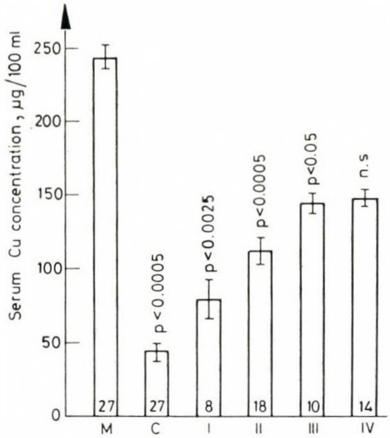

FIG. 2. Serum copper level. The height of the columns represents the mean copper concentration, vertical lines indicate S. E.; figures within the columns refer to the number of cases. *p* above the columns represents the statistical significance of the difference between the given and the preceding columns. Symbols: M = maternal serum; C = cord serum; I = 2 week-1 month old group; II = 6 week-10 months old group; III = 1-2 years old group; IV = 2 1/2-7 years old group

results (Fig. 1) except in the case of lipaemic samples where the micromethod yielded significantly higher values.

Zinc concentration was measured with a Varion A type atomic absorption spectrophotometer, in serum samples diluted 5fold with distilled water.

Iron concentration and iron binding capacity were studied by Scarlata and Moore's procedure [11] adapted to the Beckman—Spinco apparatus. Coeruloplasmin activity was measured by Ravin's method [9].

RESULTS

Serum copper level

Serum copper concentration was lowest (43.4 μg/dl) in cord blood; the value was one fifth of the maternal one, but the latter was significantly higher (249 μg/dl) than in normal, non-pregnant females (mean, 160 μg/dl) [7]. In the 2 to 4 week-old infants (Group I), copper concentration was almost double of the value found in cord blood. The level rose with age and in Group III approached the adult value. There was no further rise in Group IV.

Serum coeruloplasmin concentration

Coeruloplasmin amounts to 93% of the serum copper level, the rest is bound to albumin which can be regarded as a fraction of transient character. Copper intake results in an immediate rise in the blood

TABLE I

Coeruloplasmin in maternal and cord blood

Coeruloplasmin activity	Mean ± S. D.	p
Maternal blood	0.551 ± 0.034	λ 0.005
Cord blood	0.078 ± 0.012	

copper concentration which will decrease exponentially parallel with its accumulation in the liver [6]. Table I shows that the p-phenylenediamine oxidase activity of cord blood is only 14% of maternal serum activity. These results also imply that the ratio of copper and coeruloplasmin levels are nearly identical in maternal and fetal sera.

Serum zinc level

As it is shown in Fig. 3, in the 28 mothers examined the mean zinc concentration was 58 ± 4 μg/dl, about 45% less than in non-pregnant women. In the newborns, the mean serum zinc level was significantly higher, 85 ± 9 μg/dl, closely corresponding to the lower limit of the adult level. In 2 to 4 week-old infants, the level was lower but between 2 and 10 months it reached the concentration measured at birth and in the first year of life it attained the normal adult value.

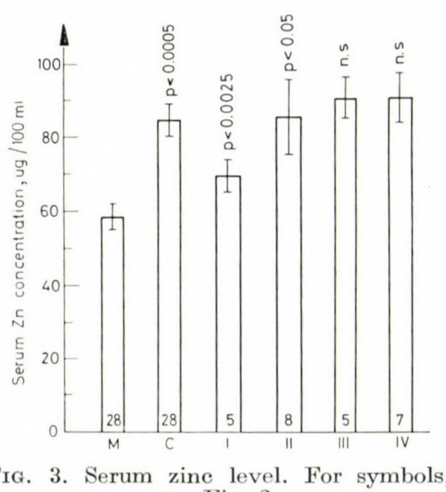

FIG. 3. Serum zinc level. For symbols, see Fig. 2.

Iron concentration and iron binding capacity

Iron concentration was higher in cord blood (151 ± 10 μg/dl) than in maternal blood (Fig. 4) in agreement with our earlier data [3]. The blood iron level was always high (120-140 μg/dl) in the newborns, to decrease to its lowest level between 3 and 4 months when the value was only half of that measured at birth. Later, iron concentration increased again.

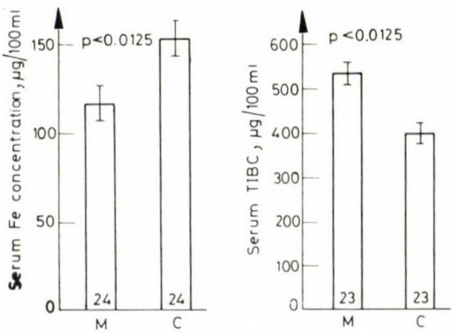

FIG. 4. Serum iron level. For symbols, see Fig. 2.

Iron binding capacity was significantly lower in cord blood than in maternal blood (Fig. 4), and the lowest in the newborn babies.

Discussion

Little is known concerning the mechanisms regulating the concentration of essential trace elements. In the fetus their level depends on the rate of placental transport and of their incorporation by the tissues.

In the rat large amounts of iron and copper are stored by the fetal liver. Storage is promoted by the special proteins ferritin and mitochondrocuprein. The hepatic stores are utilized in the first period of postnatal life, mother's milk being poor in iron and copper. Simultaneously, the new-born rat's iron binding capacity begins to decrease to the adult level and the copper is gradually incorporated into coeruloplasmin [8].

The present findings obtained in humans have shown that the copper concentration in maternal serum exceeds that found in non-pregnant women (Fig. 2), confirming the observation that the coeruloplasmin level increases in the course of pregnancy to almost double of the normal (non-pregnant) level [7]. The low copper and coeruloplasmin levels in cord blood indicate a high incorporation rate into the liver, brain, heart and kidney [13, 14]. Considering the structural identity of coeruloplasmin in newborns and adults [15], the low coeruloplasmin activity suggests that there are less copper transporting proteins in early infancy than at later age. Finally, the differences in the copper level of maternal and cord sera suggest that the permeability of placenta for copper is slight, and the increase of the copper level during pregnancy is a sign of physiological regulation. An increase of the concentration gradient is indispensable to ensure the necessary copper intake of the fetus during intrauterine life.

The zinc level was significantly higher in cord blood than in maternal blood (Fig. 3), to decrease significantly by 2 to 4 weeks after birth. This was in partial agreement with the earlier observation of a 20 to 25% fall of the plasma zinc concentration at term [1].

Thus, considerable amounts of zinc may accumulate in the fetus owing to the better permeability of the placenta for zinc than for copper. This also follows from the observation that the zinc level may reach 300 μg/dl in the 4 month fetus, threefold of the maternal serum zinc concentration [1]. During fetal development, the plasma concentration of zinc decreases, presumably because of its accumulation in the tissues. The process continues for a time after birth, as shown by the fact that the zinc level is higher in the blood of preterm than of term newborns. Two factors may be of particular importance in decreasing the zinc concentration. One is the rapid zinc incorporation into red blood cells after birth with a parallel increase of their carboanhydrase activity. On the other hand, the infant's zinc intake originates entirely from milk and while the zinc content of colostrum is 2 mg/dl or higher, mature mother's milk contains only 30 μg/dl of zinc.

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