Macro-, micro- and trace elements concentrations in mother’s and newborn’s hair and its impact on pregnancy outcome: a review

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Abstract

The 21st century, together with the successes of global civilization, forced upon us the life style dominated by developments of science and industry. We forget, that the body itself knows what is necessary for it to survive. Our health conditions and mood are affected by innumerable biochemical and physicochemical processes taking place in billions of cells. The human metabolism is determined by the consumed food and eliminated waste products of metabolism. It depends entirely on us whether the food we deliver to our organism contains all macro and microelements, necessary for the normal course of metabolism. During pregnancy macro-, micro- and trace elements are indispensable for life maintenance for the women and for the fetus. Intrauterine fetal growth is associated with maternal macro-, micro- and trace elements status. Many studies tried to explore the relationship between macro-, micro- and trace element status in pregnant women and their newborn and its impact on the pregnancy outcome. Some of them investigated the relationship between development of IUGR, onset of preeclampsia and maternal and newborn macro-, micro-and trace elements status. There have been a few reports on determination of macro-, micro- and trace elements levels in maternal, umbilical cord and fetal blood. Blood samples analysis is often difficult in newborn because of small amount of circulating blood. Concentration of trace elements in the blood often does not provide a complete picture of the content of these elements in the organism. This is caused by the fact, that the composition of plasma in large measure depends on homeostatic mechanisms and the final concentration of components is a result of balancing of their concentrations by various homeostatic mechanisms. It has been proved, that the best method of determining the quantity of trace elements in human body is evaluating their concentration in hair. The currently used methods of evaluating the concentration of over 30 trace elements in hair show high sensitiveness. Hair can be easily collected, stored and constitute a good source for determination of many elements during one analysis. So far, only few studies focused on relationship between maternal and newborn hair levels of trace elements and perinatal outcome. The results of these studies could put a new light on our understanding of pathomechanisms of various perinatal and neonatal complications.

Key words: hair, mineral concentrations, mineral status, trace elements, pregnant women, newborn

Introduction

Global civilisation, forced upon us the life style dominated by developments of science and industry. Our health condition is affected by innumerable biochemical and physicochemical processes taking place in billions of cells. The human metabolism is determined by the consumed food and eliminated waste products of metabolism. Various mineral substances take active part in metabolic processes. Due to their physico-chemical properties they play an essential role as components of biochemical structures. Metabolism of inorganic compounds, and in particular cations of metals (macro and micro-elements) is connected with enzymatic reactions in the body. The metabolism of macro- and microelements is regulated by organic components. It is dependent on the efficiency of hormonal and nervous systems activity and it plays a decisive part in all metabolic processes. Depending on the type of food, physical activity and degree of pollution of the environment, various processes of mineralisation (deposition of mineral substances), demineralisation (elimination of mineral components) or transmineralisation (transfer of mineral components within the body) take place. Among trace elements synergistic and antagonistic relationships exist, which directly affect the body metabolism. Maintaining of proper balance between individual elements is in many cases more important than their appropriate concentration. Many pathological conditions are closely connected with changes of concentrations of trace elements in tissues. It has been proved, that the best method of determining the

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quantity of trace elements in human body is evaluating their concentration in hairs and nails. This is an alternative method to blood and urine analysis. Collecting blood or tissue samples for mineral analysis is often impractical because of small amount of circulating blood in newborn, limited facilities and personnel trained to collect samples. Hair can be easily collected and stored. Growing hair as a metabolically active and a recording filament reflects to metabolic effects occurred when the hair was formed. During hair mitosis, differentiation, maturation and synthesis of melanin, many macroelements and microelements enter the newly formed hair cells. External keratin cuticle of the hair effectively prevents both loss of internal components and penetration of exogenous contamination inside. Hairs can be cleaned of exogenous contamination very easily, which allows for best repeatability of analytic results. Samples of hair may be obtained in a non-invasive way. They may be stored and sent without any change in their chemical composition. The analysis of toxic trace elements in hairs is particularly valuable. The analysis of the concentration of trace elements in hairs is the best method of evaluating the mineral status of the body. In this way very often the concentrations of most elements in hair are higher than found in the blood [1-3].

It is very interesting to find out relationships between pregnant women and their newborns macro-, micro- and trace elements status. Many studies have examined the relationship between maternal blood concentration of macro-, micro- and trace elements and fetal growth but these findings are conflicting [4-6].

Among macro-, micro- and trace elements present in the body some of them are indispensable for life maintance, but at the same time these elements in excessive amounts are responsible for toxic symptoms in mother and/or fetus. There are only few data on macro-, micro- and trace elements patterns in pregnant women and their fetus and its correlation with various complications of pregnancy. The adequate researches concerning this problem is often lacking or sometimes conflicting [5-9].

**REVIEW**

**Hair growth**

The hair shaft – a keratinized filament develops from matrix cells of a hair follicle. Follicle localized in the epidermal epithelium is a miniature organ consisting of smooth muscle and sebaceous or apocrine glandular components, nerves and plexus of blood vessels. Sweat secreted by the sebaceous glands is an important source of minerals in hair. Fatty secretions of apocrine glands lay an important role in exogenous mineral binding to hair. Having a contact with secretions from sebaceous, apocrine and eccrine glands hair is exposed to many endogenous origin trace elements and minerals. Important source of trace elements is eccrine sweat. The eccrine sweat consists of water, salts of sodium and potassium, urea, lactic and pyruvic acids and significant amounts of calcium [Ca], phosphorus [P], copper [Cu], manganese [Mn] and zinc [Zn] which may be absorbed onto hair. During hair growing significant quantities of macro-elements and microelements are adsorbed onto the hair surface especially when hair growth is very slow. Humans hair is formed at a rate of 0.2 to 5 mm per day. After approaching the skin surface metabolic activity phase of hair is finished and keratinization begins. Disulfide bonds present in keratins are major binding sites of minerals in hair. Probably metal-S bonds and carboxyl groups are metal binding sites in hair. The hair tissue is built up of proteins containing a lot of cysteine. This aminoacid, due to the presence of the thiol group [SH], can chelate elements from transitory groups. Because of this, the concentration of trace elements in hairs is about fifty times higher than their concentration in blood and urine. When the follicle is not producing a hair fiber mineral deposition in hair does not cease. [13].

An adequate supply of nutrients during gestation is required to meet the needs for the mother and fetus and for good pregnancy outcome. An inadequate supply of nutrients can destroy the balance between the needs of mother and those of growing fetus. The situation of low nutrient reserves takes place especially in two groups of women: one of them is a group of young girls who are pregnant less than 2 years after menarche because they have used nutrients reserves for their own growth and the second group of women with short interval between pregnancies – less than 18 months, because they have not had time to replace nutrients reserves. In these women their nutritional status at conception is not optimal and during pregnancy the well-being of both organisms is at risk.

Most of the research is focused on maternal protein and energy status in pregnancy, but it seems reasonable to assess the micronutrients status, socioeconomic status, lifestyle, stress, kind of job, exposure on different toxins etc. before conception [9-11].

Hair as an indicator of trace elements, vitamins and heavy metal status in human body

Hair is a good biopsy tissue. There are strong argument for it because:
– hair may be collected easily without any trauma; this fact is very important in newborn group,
– hair does not deteriorate readily it can be stored for a long time,
– the trace elements are accumulated in hair at concentrations that are at least 10 times higher than in blood or serum or urine [1, 2].

The body stores of minerals may be estimated from hair analyses.

Growing hair as a metabolically active and a sequestering tissue is an indicator of body minerals concentration at the time when the hair was formed.

**Hair analysis**

Hair analyses have been proposed as a method of assessing exposure of humans to some heavy metals for example lead \([Pb]\), arsenic \([As]\) and cadmium \([Cd]\) and to detect deficiencies of some required minerals \([1, 3]\). Lead \([Pb]\), arsenic \([As]\) and cadmium \([Cd]\) levels in hair may be related to dietary or environmental exposure. It is well documented that lead and arsenic contents of hair are indicators of dietary intake of them and/or diagnostic aid in lead and arsenic toxicity \([1]\). Major sources of lead are waste motor oils, paints based on lead and pesticides. It is possible to become chronically poisoned from environmental lead exposure and lead toxicity is one of the common acute poisoning. Hair lead level is positively correlated with human exposure on it \([1, 3]\). Arsenic \([As]\) is deposit in human body in low, but variable concentrations. The sources of it are arsenical sprays used for insect control. Arsenic is released to air in large amount during burning of coal and it is also widely distributed in natural environment. It does not accumulate in human organs. The best way to assess arsenic body level are hair and/or urine analyses \([1, 3]\). Cadmium \([Cd]\) is widely distributed in industry. Cadmium can interact with divalent cations as zinc, selenium, cooper and ferrum. It deposition in hair occur via dietary intake, pulmonary or skin routes. Cadmium is toxic to nearly every body system and Cd toxicity as anemia, retarded testicular development or their degeneration, scaly skin, failure of liver and kidney, increased risk of death \([1]\). Concentrations of calcium \([Ca]\), phosphorus \([P]\) and copper \([Cu]\) in hair seem to be not affected by dietary intake of these minerals but zinc \([Zn]\) and selenium \([Se]\) – may reflect dietary intake \([1, 3]\). In hair calcium \([Ca]\) and phosphorus \([P]\) levels are correlated with their intake under some circumstances. More over calcium and phosphorus intakes appear to affect uptake of other minerals in hair. The hair analysis did not appear as a sensitive indicator of calcium and phosphorus status. These results are in agreement with other researches of serum concentration of these elements suggesting that fetal homeostasis of Ca, Mg, Fe and Zn is at least partly independent of maternal factors \([1, 3, 12]\).

During pregnancy iron \([Fe]\) is mobilized from maternal stores. If iron status is poor at conception, an insufficient supply of Fe can cause iron deficiency anemia – a common problem among pregnant women associated with preterm delivery, intrauterine growth restriction and low birth weight of newborns. Deficiency of iron can also be the reason of failure to thrive. Increased ferritin serum level in the second and third trimester is a predictor of early spontaneous preterm delivery. The reserves of iron remain low for several months after delivery \([6, 10, 13]\).

Selenium \([Se]\) is a cofactor of glutathione peroxidase which protects human cells from free radicals damage. Decreased level of selenium in children blood is connected with increased risk of osteoarthritis, cancer and cardiovascular diseases. Noteworthy is that some researches indicate that the placenta stocks the selenium maintaining constant level of it in fetus in the IUGR pregnancies. Maternal selenium serum level decreases slightly during pregnancy.

Selenium and zinc play a protective role for pregnant women and their fetuses. Some researches indicate a possibility of reduced consumption efficiency of selenium and zinc in pregnancies with intrauterine growth restriction of fetuses \([5-7, 14]\). Selenium deficiency in animal provokes muscle disease while in human – cardiomyopathy. Zinc \([Zn]\) is a catalytic component of more than 200 enzymes and structural component of nucleotides, proteins and hormones. It plays a critical role in many biochemical functions like protein synthesis and metabolism of nucleic acids. The circulating concentrations of zinc decline during pregnancy because of hormonal suppression and iron-folate supplementation which reduces zinc absorption. Zinc reserves return to normal shortly after delivery. Zinc concentration in human hair decline sharply after birth and remains low for 2 or 3 year of life when it reaches normal values. Zinc as the component of several enzymes is very important to fetal growth. Its deficiency in newborn can be reason of IUGR (intrauterine growth restriction), congenital anomalies, nail hypoplasia or dysplasia and dermatitis. Other clinical signs of its deficiency can be failure to thrive, diarrhea and alopecia. The most common clinical signs of low plasma zinc concentrations are low birth weight of newborn or preterm labour. If zinc intake befo-
re and during pregnancy was restricted a lot of the im-
plantation sites is resorbed and many of the offspring 
finally born is malformed, especially with skeletal and central nervous system malformations [1, 5, 6, 10, 15].

Manganese plays an important role in enzyme activation (e.g. superoxide dismutase) so it can take a part in some neonatal diseases like necrotizing enterocolitis and bronchopulmonary dysplasia. Manganese is important for normal bone structure too.

There is a serious problem of exposure to many tox-
ins for pregnant women, because many of them pass easily through the placenta and there are not any bar-
riers to transfer them from the mother to the fetus, for example mercury [Hg] and cadmium [Cd]. Detection of their level in the mothers’ blood plays a crucial role in estimating the extent and degree of fetal exposure but toxins in the blood are in dynamic phase of metabolism, tissue distribution and excretion so their blood levels may not represent the true risk of exposure to the them. The absence of toxins in the maternal compartments is not indicative of the absence of them in the fetus. Cord blood toxins level shows correlations with maternal blood level. Sometimes the cord blood concentration of them is higher than in maternal blood.

Copper [Cu] is an important component of metallo-
enzymes like cytochrome C and superoxide dismutase which protects cells from damage by free radicals. Be-
cause the Copper is associated with multiple enzyme activities so clinical effects of its deficiency like: osteoporo-
sis, depigmentation of hair and skin, ataxia later in life, neutropenia, poor weight gain and hypotonia are described. Especially three last ones can be observed in newborn. Copper is critical for production of red blood cells as well as hemoglobin formation and iron absorp-
tion too and the deficiency of copper is one of the rea-
sions of anemia. Maternal copper serum concentrations increases in the second and third trimester of pregnancy. Some studies indicate reduced consumption efficiency of magnesium [Mg] and copper in fetuses with intrauterine growth restriction (IUGR) [5, 6].

Chromium plays an important role in insulin metab-
olism and in this way it regulates glucose levels. Its defici-
cency in human can provoke the diabetes.

The circulating concentrations of other nutrients, such as vitamin A, vitamin B-6 or vitamin B-12, also de-
crease during pregnancy, but the concentrations of those vitamins increase to normal plasma level shortly after de-
ivery [10].

It is important to know that trace elements in the at-
mosphere can circulate and therefore be widely disper-
sed from their sources of emission. Some of them are biological transformed by bacteria or other organisms and enter the food chain [7, 16]. Maternal ingestion of contaminated food can be the reason of newborn disea-
ses as for example microcephaly resulting in seizures and mental retardation after Hg toxicity [7, 17].

Some studies tried to determine the influence of many trace elements level in maternal blood, cord blood or breast milk on the level in fetus/ newborn blood or tissues [7, 8, 18-20]. In this situation the risk of newborn congenital malformations or diseases increases [7, 14, 16]. Some researches reveal possibility of fetus malformed or fetus death after constant low level exposure on Hg realizing from dental amalgam fills [7, 18, 19].

Still, there are only few studies on paired maternal and newborn hair levels of trace elements in relationship to perinatal outcome. The results of these studies could put a new light on our understanding of pathomecha-
nisms of various perinatal and neonatal complications. An estimation of fetal-maternal ratios of the macro-, micro- and trace elements can be useful in explanations of severe perinatal pathologies. The estimation of mother’s hair level of macro-, micro- and trace elements can be an indication to supplement the deficiency of these elements and to decrease the risk of neonatal complica-

References


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