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Toxic and Essential Trace Metals in First Baby Haircuts and Mother Hair from Imam Hossein Hospital Tehran, Iran

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Abstract Hair metal level in newborn and mother pairs from Iran is reported. Toxic metals including cadmium (157 vs. 87.5 μg/kg), mercury (246 vs. 198 μg/kg), copper (14,313 vs. 11,776 μg/kg) and aluminum (52,022 vs. 408,207 μg/kg) were higher in newborn hair when compared to their mothers; suggesting that metals maybe discarded in the fetus as a detoxification method. Comparison with available data from Germany and Poland, and Iraq suggests overall similarities and significant differences in the case of the Iraqi subjects. Public protection from mixture toxicity of metals will be facilitated by studies such as ours.

Keywords Toxic and trace metals · Mother and newborn · Hair · Tehran · Iran

Many metals are essential to living organisms and serve specific biological functions in the body. Others are toxic even at low doses. Selected trace metals are integral to enzyme function and regulate enzyme activity, but may become toxic at higher levels. Among toxic metals, lead is of serious concern because of its established adverse effects on the developing nervous system in humans. Cadmium, arsenic, mercury, copper and aluminum are also toxic and ubiquitous in the environment. Despite the inherent dangers of toxic metals and their prevalence in the environment, exposure of mothers and their developing fetuses to metal pollutants are not well characterized in the "developing countries". In addition, even globally, the extent of mother-infant-child exposure to multiple toxic metals is not well described.

Tehran is a large city of approximately 11 million people, where for a substantial length of time (during the winter months) the population is exposed to dangerously high levels of air pollutants including metals. The consequences of this periodic and chronic exposure to toxicants are not fully described but may include a variety of respiratory illnesses and even early death. Vulnerable populations (such as the elderly, pregnant women, developing fetuses, infants and young children) are at high risk for adverse effects of these toxicants. Our aim was to investigate levels of thirty four metals in hair samples of mothers and their newborns to establish a baseline for future studies. More extensive studies are necessary to understand effects of metals on vulnerable populations. Furthermore, identifying effective interventions for protection of the general public from single and mixture toxicity of metals will be facilitated by studies such as ours. We opted to examine metal levels in hair because hair has frequently been used in biomonitoring of metals and its use is advantageous in many ways. Hair collection is noninvasive and easy. Hair is also easy to transport and store. In addition, hair reflects long term exposure of the individual. In this article we also review the literature on metals in mother-newborn pairs from other locals and compare those values to what we see in Iranian mother-newborn pairs.

Materials and Methods

A questionnaire, which included fifty five questions about reproductive history, residence, diet, water source, drug use

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during pregnancy, and possible exposure to war contaminants was prepared. This questionnaire was used to enroll mothers and their infants into the study. Mothers had come to Imam Hossein Hospital in Teheran (Iran) for normal child birth. Questionnaires were completed for each participant by their respective physicians and patient consent was obtained. A stainless steel scissor was used to cut 2–5 g of hair from mothers and their newborn babies from the base of the scalp. Hair was cut close to the scalp behind the right ear. Samples were collected from 6 mothers and their newborns during the first week of birth in August 2010. Samples were placed in clean and pre labeled plastic bags for analysis of thirty four metals.

Hair samples treatment, digestion, and analysis followed that of Batista et al. (2009) without any modification. A XSERIES 2 ICP-MS (Thermo Fisher Scientific, Germany) was used with standard configuration and an ASX-510 autosampler (Cetac, USA). Instrument optimization was done by auto-tune function, when required. Instrument parameters were: RF Power was 1,400 (W), Cool Gas Flow was 13, Auxiliary Gas Flow was 0.8, and Nebulizer Gas Flow was 0.85–0.90 (L/min). Sample Uptake Rate was approximately 0.4 mL/min. Sample Introduction System Concentric nebulizer with low-volume impact bead spray chamber (not cooled) and one-piece torch (1.5 mm ID injector); Cones Nickel, Xi Design; Detector Simultaneous pulse/analogue; Uptake Time 25 s at 50 rpm; Stabilization Delay 10 s at 17 rpm; wash time 40 s at 50 rpm, Survey Runs 1—scanning; Main Runs 3—peak jumping; Number of Points per Peak 1; Dwell Time—Point 5–50 ms; Number of Sweeps/ Replicate 25. Internal Standardization Technique Interpolation, using 6Li, 45Sc, 115In, 159 Tb. Total Time per Sample was 2:45 min.

Results and Discussion

Mothers were generally in good health and did not report history of any chronic condition or illness. Mother's average age was 30.5 ± 2 (mean ± SEM, range between 26 and 36 years). Mean "weeks of gestation" was 38.5 ± 0.6 (range 37–41 weeks). All mothers were housewives who had lived in Tehran or nearby suburbs for at least the past 5 years. They did not smoke cigarettes or drink alcohol. They had used no painkillers or antidepressants during pregnancy and they did not dye their hair. Except for one mother who reported a miscarriage in 2009, all other mothers had never experienced any miscarriages or stillbirths. No birth defects were reported by any of the mothers in their previous pregnancies. Mothers in this study reported to have a total of 30 normal siblings who themselves had a total of 27 normal children. No one had lived near war-zones. All mothers had consumed city tap water during their pregnancy. Average birth weight of the newborns was 3,883 ± 374 (g) and weight of the babies varied between five and 2.9 kg.

Scalp hair is a favored tissue for measurement of metals. During hair growth this tissue acts as an excretory means for the metabolic removal of permanently accumulated metals (Razagui and Ghiribi 2005). In hair, metals are found in easily measurable concentrations. We opted to look at scalp hair because it offered a noninvasive method and a suitable medium in which to study metal levels in mother-infant pairs (Tables 1, 2, 3).

A thorough review of the literature on metal levels in mother-infant pairs is tabulated in Table 4. We focus on discussing lead, cadmium, zinc, copper, and mercury in this paper for two reasons. Our first reason was that background/ normal values were available for these metals in mother-infant pairs from other locations, which would allow a comparative comparison/assessment of metal levels in hair of the participants in the current study. Secondly, there is a wealth of knowledge on lead, cadmium, zinc, copper, mercury and their effects on human embryogenesis, fetal growth, and neural development. Lead content of the Iranian newborn first hair cuts were comparable to reports from Germany, Poland, and the US but lead in English newborns were almost twice higher than what we report here in Iranian newborns. Normal newborns from Iraq had four times higher lead in their hair (11,277 ± 695 μg/kg, n = 11 unpublished data), than normal Iranian newborns. This high lead level in Iraqi newborns may be attributable to

Table 1 Toxic metal levels (mean ± SEM μg/kg) in newborns and mothers from Imam Hossein Hospital in Tehran, Iran

Toxic metal μg/kg	Mothers (n = 6)		Newborns (n = 6)	
	Mean	SEM	Mean	SEM
Arsenic (As)	85.3	31	24	6.4
Cadmium (Cd)	87.5	35	157	45
Lead (pb)	5,156	2,453	2,711	1,234
Mercury (Hg)	198	58	246	85
Uranium (U)	75	39	47	25
Copper (Cu)	11,776	1,738	14,313	3,200
Aluminum (Al)	408,207	382,267	52,022	9,080

Table 2 Essential trace metal levels (mean ± SEM μg/kg) in newborns and mothers from Imam Hossein Hospital in Tehran, Iran

Essential trace metal μg/kg	Mothers (n = 6)		Newborns (n = 6)	
	Mean	SEM	Mean	SEM
Chromium (Cr)	414	161	428	61
Copper (Cu)	11,776	1,738	14,313	3,200
Manganese (Mn)	2,179	1,480	1,125	173
Zinc (Zn)	160,333	16,690	227,683	19,491

Table 3 Other metals (mean ± SEM μg/kg) in newborns and mothers from Imam Hossein Hospital in Tehran, Iran

Mothers	Mean	SEM	Newborns	Mean	SEM
Li	58.0	10.0	Li	55.0	7.0
Be	1.5	0.2	Be	5.0	1.3
B	1,033.0	423.0	B	2,777.0	500.0
Na	969,033.0	359,656.0	Na	3,591,533.0	826,806.0
Mg	384,933.0	160,156.0	Mg	309,683.0	20,087.0
K	1,255,137.0	326,251.0	K	1,402,217.0	242,562.0
Ca	115,955.0	50,505.0	Ca	116,823.0	7,810.0
V	176.0	54.0	V	88.0	27.0
Fe	28,448.0	10,767.0	Fe	25,395.0	3,936.0
Co	53.0	22.0	Co	73.0	21.0
Ni	2,718.0	809.0	Ni	3,371.0	801.0
Ga	70.0	48.0	Ga	9.0	1.5
Rb	611.0	162.0	Rb	902.0	187.0
Sr	89,086.0	62,578.0	Sr	103,970.0	1,553.0
Mo	40.0	9.0	Mo	117.0	38.0
Ag	51.0	13.0	Ag	60.0	27.0
In	49.0	10.0	In	85.0	17.0
Sn	13,868.0	3,323.0	Sn	24,059.0	5,089.0
Sb	43.0	17.0	Sb	44.0	7.0
Cs	6.0	1.5	Cs	8.0	2.0
Ba	7,314.0	3,490.0	Ba	8,347.0	334.0
W	371.0	87.0	W	570.0	124.0
TI	3.2	1.5	TI	1.0	0.5

war contaminants. Since there is no placental-fetal barrier to lead transport, maternal and fetal blood lead are often reported to be nearly identical. Newborns and mothers in the present study had similar lead levels in their hair ($p = 0.4$), which agrees with reports in the literature.

Cadmium is a common and highly toxic environmental pollutant that accumulates in human placenta. Elevated levels of cadmium are associated with impaired micronutrient (i.e. zinc) transfer to the fetus. Cadmium levels in mother-newborn pairs of this study were (87 and 157 μg/kg) respectively, which was significantly lower than values reported for the British and Polish subjects in other studies, but higher than Iraqi and German mother-newborn pairs. Similar to most studies, mother hair had less Cd than newborn hair. Cadmium and lead are metabolic antagonists to zinc and copper, their release from maternal tissues during pregnancy can negatively affect maternal systemic status of both nutrients as well as their availability for fetal absorption and uptake. Cadmium toxicity in fetus may cause premature birth and low birth weight. Cadmium exposure is also suggested to perturb placental production of chorionic gonadotrophin and impair development of the vascular system (Kolluru et al. 2006). Furthermore, Cd can affect the genes involved in growth regulation (Fang et al. 2002).

Zinc levels in the hair samples of Iranian mother-infant pairs were similar to normal mother-infant pairs from other regions (Table 4). Zinc and copper play an important role in reproductive function of both humans and animals. In addition, their critical role in embryogenesis, fetal growth, and development has been extensively explored. Normal neuro-developmental process is highly sensitive to

Table 4 Review of available data in hair metal levels in mothers and their newborn (values are mean ± SEM µg/kg)

Study and country	Lead	Cadmium	Copper	Zinc	Aluminum	Mercury
Korea (Rep of) (Kim et al. 2008)						
Mother	910					
Newborn						
England (Razagui and Ghiribi 2005)						
Mother	7,950	490	18,400	122,500		
Newborn	4,560	570	6,700	146,900		
India (Srinivas et al. 2001)						
Mother				142,300		
Newborn				188,800		
Turkey (Cavdar et al. 1991)						
Mother				180,000		
Newborn				192,000		
Germany (Wilhelm et al. 1994)						
Mother	600	37	16,000	165,000		
Newborn	2,700	80	13,400	116,000		
Austria (Gundacker et al. 2010)						
Mother						413
Newborn						
Morocco (Souad et al. 2006)						
Mother						
Newborn	6.6				9.5	
Poland (Popko et al. 2003						
Mother	770	710	12,300	244,000		
Newborn	1,930					
US (Holmes et al. 2003)						
Mother						
Newborn	3,630					
Iraq (unpublished data)						
Mother	2,012	75				525
Newborn	11,277	57				1,414
Iran current study						
Mother	5,156	87.5	11,776	160,333	408,207	198
Newborn	2,711	157	14,313	227,683	52,022	246

maternal zinc levels. Folic acid supplementation is recommended and has reduced incidents of Neural Tube Defects (NTD) worldwide. In humans NTD is considered one of the most frequently encountered congenital malformations. It has been reported that hair zinc levels of babies with NTD and their mothers are significantly lower than normal infant-mother pairs (Srinivas et al. 2001).

Copper levels in hair of Iranian mother-infant pairs were similar to normal mother-infant pairs from Germany (Table 4). Copper is an important co-enzyme that is essential in many vital biological processes. While copper is normally bound to proteins, it can be freed to catalyze the formation of highly reactive hydroxyl radicals (•OH). In vitro and cell culture investigations suggest that Cu can unleash oxidative damage and obstruct important cellular events. Environmental contamination by Cu has been linked to chronic Cu overload and oxidative damage. Abnormal Cu metabolism and neurodegenerative effects can result from Cu induced oxidative damage. Vitamin E, high intakes of ascorbic acid, and zinc can protect against Cu toxicity (Gaetke and Chow 2003).

First baby haircuts in this study had higher mercury levels (246 ± 85 µg/kg) than what we found in their mother's hair 198 ± 58 ($p = 0.07$). Normal Iraqi newborns had 6 times higher mercury in their first haircut (1,414 ± 963 unpublished data). Mercury and lead are an integral part of war ammunition. Large numbers of bullets have been expended into the Iraqi environment during the recent attacks (Buncombe 2005). The large level of mercury and lead in Iraqi children's hair may be due to military sources of this toxic heavy metal. In humans, it is well established that both methyl mercury and inorganic mercury readily pass the placenta (Ask et al. 2002). In mice, mercury is deposited in offspring both in utero and during lactation, and in the offspring transplacentally absorbed mercury is excreted very slowly. Higher levels of mercury in the newborns versus mothers of this study corroborates with previous studies that suggest mercury deposition in the offspring as a maternal metal detoxification mechanism. Early mercury exposure in humans has been linked to neurodevelopmental disorders such as autism. Some studies have pointed to the possibility that impaired mercury excretion may be a key susceptibility factor for manifestation of autism in children. Holmes et al. (2003) reported significantly higher mercury in normal first baby haircuts while autistic children had lower mercury in their; hair suggesting impaired mercury excretion mechanisms in autistic children.

Levels of over thirty metals in mother-newborn pairs from Iran are reported here. Comparison with available data from Germany, Poland, and Iraq suggests overall similarities and significant differences in the case of Iraqi subjects. Like essential metals, most heavy metals can move rather freely across the human placenta. Toxic metals including cadmium (157 vs. 87.5 μg/kg), mercury (246 vs. 198 μg/kg), copper (14,313 vs. 11,776 μg/kg) and aluminum (52,022 vs. 408,207 μg/kg) were higher in newborn hair when compared to their mothers; suggesting that metals maybe discarded in the fetus as a detoxification method. More extensive studies are necessary to understand effects of metals on vulnerable populations including mother-newborn pairs. Identifying effective interventions for protection of the general public from toxic metal effects will be facilitated by studies such as ours.

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