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Elements concentrations in the scalp hair of methamphetamine abusers

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ABSTRACT

The concentrations of 16 elements (As, Au, Ca, Cd, Co, Cr, Cu, Fe, Hg, Mg, Mn, Mo, Ni, Se, Sr and Zn) in the hair of 40 methamphetamine (METH) abusers and control subjects were determined by inductively coupled plasma mass spectrometry (ICP-MS). Comparisons of the element levels in the hair of properly matched METH abuser and control groups revealed significant imbalances in the concentrations of 6 elements (As, Au, Ca, Cu, Mg and Sr) between the abuser and control groups. Ca ($p < 0.01$), Cu ($p < 0.05$), Mg ($p < 0.01$) and Sr ($p < 0.01$) levels are significantly lower in the hair samples of METH abusers compared to control subjects, whereas the As ($p < 0.01$) and Au ($p < 0.01$) concentrations are higher. The concentration of the remaining elements in the hair of METH abusers was similar to the concentration in the control subjects. The geometric means for each element in hair of METH abuser and control subjects are presented. The cause of these alterations is also discussed.

1. 1 Introduction

Methamphetamine (METH) is a highly addictive amphetamine analog that is a major public health and criminal justice problem in countries around the world. The use of METH has increased in the general population, with worldwide abuse of amphetamines surpassing that of cocaine and opiates combined [1]. METH use can produce significant psychiatric and medical consequences, such as psychosis, depression, anxiety and violent behaviors [2] and has been regarded as a serious social problem in some countries. A study found that those who used METH were significantly more likely to participate in aggressive behaviors [3].

A number of essential elements play a major role in various metabolic pathways and in many diseases. Researchers observed many correlations between the levels of essential elements in the human body and diseases [4–8]. Assessing the element levels, identifying changes in the patient's element levels in a timely manner and correcting the abnormal levels may assist in the treatment of diseases.

Hair analysis is a promising tool for routine clinical screening, diagnosis of heavy metal exposure and determination of essential trace element status in the human body [9]. Elemental analysis of hair material presents several advantages when compared with analysis of blood and urine. Hair is easily and noninvasively collected with minimal cost, and it is easily stored and transported to the laboratory for analysis [10]. Moreover, human hair grows at a rate of approximately 1 cm per month; thus, the level of an element in hair reflects its level in the body medium from which it was formed and provides long-term history of individual exposure [11]. Another advantage of hair analysis is the fact that the obtained results are not the result of any homeostatic mechanisms, unlike assays carried out on blood samples [12]. Additionally, while metal concentrations in blood and urine decrease rapidly after exposure, hair appears to be of greater value in evaluating past and ongoing exposure to high levels of metals [13].

No work with scalp hair samples of METH abusers has been done to determine the concentration of the 16 elements that are most likely to be involved in health issues. To our knowledge, this study is the first to describe the difference in scalp hair contents between METH abusers and health people. The objectives of the present study were to determine the hair elemental contents in people addicted to METH in order to provide help for treatment of METH withdrawal symptoms by adjustment with specific elements in the future.

2. Materials and methods

2.1. Instrumentation

An Agilent 7500Ce inductively coupled plasma mass spectrometer (Agilent Technologies, Tokyo, Japan) with an ASX-500

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Table 1
ICP-MS operating parameters.

RF power	1500 W
Nebulizer gas flow	0.91 L/min
Auxiliary gas flow	0.20 L/min
Sampling depth	8.0 mm
Sampling and skimmer cones	Nickel
Detector mode	Dual (pulse and analog modes)
Integration time	0.1 s
Replicates	3

auto-sampler (Agilent Technologies, Model G3286A, USA) was used for the analysis of hair samples. For sample introduction, a robust Babington nebulizer equipped with a Scott spray chamber (Agilent Technologies) was used. Details of the instrumentation and experimental parameters are shown in Table 1.

2.2. Reagents

ICP multi-element standard solutions VI containing the following elements of interest: As, Ca, Cd, Co, Cr, Cu, Fe, Mg, Mn, Mo, Ni, Se, Sr and Zn at concentrations of 1000, 100 or 10 mg/L were purchased from Merck (Darmstadt, Germany). Single-element standard solutions (Au and Hg) at concentrations of 1000 mg/L were purchased from NSI Solutions (Raleigh, NC, USA).

Ultrapure 65% HNO_3 (Merck, Darmstadt, Germany) and 29–32% hydrogen peroxide (Alfa Aesar, USA) were used in this study. High-purity deionized water (resistivity 18.2 MΩ cm) obtained using a Milli-Q laboratory water-purification system (Millipore, Massachusetts, USA) was used throughout. All solutions were stored in high-density polyethylene bottles.

From the 10 mg/L internal standard solution (Agilent, USA), 20 μg/L lithium(^{6}Li), germanium(^{72}Ge), yttrium(^{89}Y), indium(^{115}In) and terbium(^{159}Tb) were obtained and diluted with 5% HNO_3.

2.3. Sample collection and pretreatment

An experimental group (40 males) of people addicted to methamphetamine for over two years as diagnosed in accordance with criminal histories of drug addiction and urine test results in our laboratory was selected for the present study. The abusers' age range was 30–59 years and the abusers had the symptoms of malnourishment in various degrees, such as muscle atrophy, fatigue, and weakness and so on. The control group consisted of 40 age-matched individuals (40 males, 32–56 years old), who did not have a major disease and had no contact with METH. The control group's nutritional status was normal. All of the subjects from Shanghai are smokers. Before collecting hair samples, we did a survey to ensure that all participants had similar eating habits, and the districts where they lived were located close to few industrial regions. All of the subjects agreed to participate in this study and were informed that the amounts of chemical elements would be determined in their hair samples. In addition, ethical approval was obtained from the Ethics Committee of the Institute of Forensic Science, Ministry of Justice, PR China.

Hair was collected from the occipital region of the head, as close as possible to the scalp, using stainless steel scissors. Each collected hair sample was placed into a labeled paper envelope prior to analysis. Hair was washed according to the method proposed by Puchyr [14], with a 1:200 v/v dilution of Triton X-100, deionized water and acetone. After washing, the samples were dried in an oven at 75 ± 5 °C.

Samples (20 mg) were placed in 15-mL polypropylene tubes (Corning, New York, USA), and 0.8 mL HNO_3 (Merck, Darmstadt, Germany) and 0.2 mL H_2O_2 (Alfa Aesar, USA) were subsequently added. Then, the samples were digested at 90 °C for 3 h and diluted to 10 mL with high-purity deionized water. Samples were kept in 15-mL polypropylene tubes at 4 °C until measurement.

2.4. Analytical methods

Calibration curves for different concentrations of elements were prepared with standard solutions diluted with 5% HNO_3. The linear ranges of the 16 elements examined in this study have been described previously [15].

Two Certified Reference Materials (CRM, human hair powder GBW 09101b and GBW 07601, received from Shanghai Institute of Applied Physics, China and the Chinese Academy of Science and the Institute of Geophysical and Geochemical Exploration, China, respectively) were used to ensure the precision and accuracy of the entire analytical procedure. Accuracy and precision figures are given in Table 2. Satisfactory recoveries (92–113%) were obtained for the elements, and the RSDs were less than 13%.

2.5. Statistical analysis

Kolmogorov–Smirnov tests were performed to study the normal distribution for each element in the hair samples. Because

Table 2
Comparison of the results obtained for CRM-human hair GBW07601 and GBW09101b and the certified concentrations (n = 16).

Element	CRM	Concentration (mg/kg)		RSD (%)		Recovery (%)
		Certified mean ± SD	Measured mean ± SD	Intra-day (n = 6)	Inter-day (n = 18)	
Mg	GBW09101b	248 ± 14	257.63 ± 11.35	4.4	3.8	104
Ca	GBW09101b	1537 ± 68	1604 ± 21.24	1.3	3.1	104
Cr	GBW09101b	8.74 ± 0.97	9.14 ± 0.26	2.8	4.5	103
Mn	GBW09101b	3.83 ± 0.39	3.63 ± 0.17	4.7	4.0	105
Fe	GBW09101b	160 ± 16	167.8 ± 10.20	6.1	5.5	105
Co	GBW09101b	0.153 ± 0.015	0.16 ± 0.0061	3.8	5.0	105
Ni	GBW07601	0.83 ± 0.19	0.76 ± 0.083	10.9	3.7	92
Cu	GBW09101b	33.6 ± 2.3	36.12 ± 1.69	4.7	4.0	108
Zn	GBW09101b	191 ± 16	202.93 ± 9.21	4.5	3.3	106
As	GBW09101b	0.198 ± 0.023	0.22 ± 0.0088	4.0	3.9	111
Se	GBW07601	0.60 ± 0.04	0.68 ± 0.033	4.8	7.2	113
Sr	GBW09101b	8.17 ± 0.69	8.57 ± 0.38	4.5	3.8	105
Mo	GBW09101b	1.06 ± 0.12	1.04 ± 0.076	7.3	5.8	98
Cd	GBW09101b	0.072 ± 0.010	0.070 ± 0.0030	4.2	6.7	97
Au	GBW07601	0.0025[a]	0.0026 ± 0.00033	12.4	9.3	104
Hg	GBW09101b	1.06 ± 0.28	1.18 ± 0.031	2.6	4.3	111

[a] Informative value, not certified.