ORGAN DISTRIBUTION OF MERCURY VAPOR INHALED BY ACATALASEMIA AND HYPOCATALASEMIA MICE

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(Received June 6, 1981 and in revised form, August 31, 1981)

Abstract: Acatalasemia and hypocatalasemia mice had decreased levels of mercury in the lung and blood and increased levels in the liver following exposure *in vivo* to metallic mercury vapor (1.4 mg/m^3 for 2 hours). The decreased uptake of mercury was roughly proportional to the decrease in catalase activity in these organs. Acatalasemia mice injected with ethyl alcohol showed a decrease in the mercury content of the lung and blood and an increase in the liver content in comparison with non-treated acatalasemia mice. The inhibitory effect of ethyl alcohol on the uptake of mercury was considered to derive from the peroxidase action of catalase with ethyl alcohol as substrate.

Key words: Hypocatalasemia mice—Acatalasemia mice—Metallic mercury uptake—Catalase

INTRODUCTION

Metallic mercury is rapidly oxidized to mercuric ion when exposed to human blood *in vitro* (Clarkson *et al.*, 1961)¹. Kudsk (1965)² reported that ethyl alcohol at blood concentrations of less than 0.04% (w/v) depressed the pulmonary absorption of mercury vapor. Magos *et al.* (1975)³ found that alcohol also affected the *in vivo* oxidation rate of metallic mercury, since the amount of mercury vapor exhaled from rats injected with elemental mercury after pretreatment with ethyl alcohol was higher than that in control rats. The inhibition of mercury uptake in the blood by ethyl alcohol (Kudsk, 1969)⁴ suggests that the primary hydrogen peroxide-catalase complex might be related to the oxidation of mercury in erythrocytes, since the complex has a high affinity with ethyl alcohol (Cohen *et al.*, 1964)⁵. Magos *et al.* (1974)⁶ also reported that pretreatment of rats with aminotriazole as an inhibitory substance of the catalase reaction, decreased the mercury content of the lung and increased that of the liver in rats exposed to metallic mercury. Sugata (1975)⁷ presented similar findings in acatalasemia mice. In previous studies, a difference in mercury uptake was found in various kinds of organs of normal and acatalasemia mice exposed to a high concentration of metallic mercury (10 mg/m^3 for 30 min)⁸.

An intimate correlation between catalase activity and amount of mercury uptake was observed using hemolyzates from normal, hypocatalasemia and acatalasemia mice after *in vitro* exposure to mercury vapor⁹⁾.

The present paper considers the relation between catalase activity and amount of mercury uptake in various organs in acatalasemia, hypocatalasemia and normal mice *in vivo*.

MATERIALS AND METHODS

1) *Animals*

Radiation-induced homozygote-acatalasemia mice ($C_3H/AnL C_s^b$), homozygote-hypocatalasemia mice ($C_3H/AnL C_s^c$) and normal mice (C_3H/C_s^d) of inbred strain, weighing 20–25 g, were obtained by courtesy of Feinstein (Feinstein *et al.*, 1964)¹⁰⁾.

2) *Exposure to mercury vapor*

Four groups of mice, i.e., normal, hypocatalasemia, acatalasemia and acatalasemia mice treated with ethyl alcohol (3.6 ml/kg of body weight) by intraperitoneal injection 15 min before exposure, were used for the exposure experiment.

The system for exposing animals to mercury vapor used in this experiment was based on that described by Magos *et al.* (1967)¹¹⁾ with a slight modification in that the mercury vapor flowed from the top to the bottom in the inhalation chamber. The mice were exposed to 1.4 mg/m³ of mercury vapor on average for 2 hours. The concentration of mercury vapor was measured every 10 min using an atomic absorption spectrophotometer.

One hour after exposure, the mice were anesthetized with ethyl ether and blood samples were taken from the orbital vein. Organs were removed, washed in saline and digested. The total mercury was determined by the same procedure as described in previous reports^{11, 12)} using an atomic absorption spectrophotometer.

3) *Measurement of catalase activity*

The assays of catalase activity in the blood and organs were carried out by the perborate method, and the activity value was expressed in perborate units (PU)¹³⁾.

4) *Determination of protein*

The protein of tissues other than blood was measured by the biuret method¹⁴⁾.

RESULTS

The catalase activities in each organ of the mice exposed to metallic mercury are shown in Table 1. In all organs, the catalase activity decreased in the order of normal, hypocatalasemia and acatalasemia, and the lowest activity in acatalasemia was found in the blood. The mercury concentrations in each organ are shown in Table 2, and the

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Table 1. Catalase activity* in tissue from normal, hypocatalasemia and acatalasemia mice.

Tissues	Normal	Hypocatalasemia	Acatalasemia
Brain	0.004±0.001	0.002±0.001	0.001±0.001
Heart	0.026±0.005	0.009±0.001	0.007±0.001
Lung	0.047±0.005	0.044±0.002	0.010±0.002
Liver	1.124±0.402	0.576±0.22	0.265±0.023
Kidneys	0.257±0.076	0.149±0.028	0.021±0.001
Gastrointestinal tract	0.025±0.004	0.009±0.002	0.003±0.001
Blood	1.410±0.036	0.253±0.097	0.004±0.003

* Units of catalase activity: PU/g Hb (blood), PU/mg protein (other organs).

Table 2. Tissue concentration of mercury in mice exposed to metallic mercury vapor (g/g wet weight, mean±SD)

Tissues	Normal	Hypocatalasemia	Acatalasemia	Acatalasemia treated with ethyl alcohol
Brain	0.079±0.007	0.071±0.004	0.058±0.003	0.030±0.000
Heart	0.622±0.247	0.508±0.181	0.498±0.184	0.215±0.013
Lung	1.931±0.208	1.156±0.007	0.792±0.056	0.175±0.051
Liver	0.076±0.001	0.079±0.004	0.093±0.008	0.166±0.011
Kidneys	0.409±0.083	0.435±0.067	0.537±0.090	0.239±0.003
Gastrointestinal tract	0.085±0.008	0.126±0.019	0.156±0.061	0.096±0.010
Blood	0.047±0.008	0.037±0.002	0.029±0.016	0.026±0.002

distribution ratios of mercury per whole body burden are shown in Table 3. The results of significance tests of variance by one way classification^{15,16} among the normal, hypocatalasemia and acatalasemia mice are summarized in Table 4. The mercury concentration and the distribution ratio in the lung and blood decreased in the other of normal, hypocatalasemia and acatalasemia, corresponding to the descending order of catalase activities in these organs. The mercury concentration and the distribution ratio in the brain of hypocatalasemia and acatalasemia mice were slightly lower than those of normal mice. However, in the case of the mercury concentration and the distribution ratio in the liver, an opposite phenomenon was observed, i.e. the mercury content was in inverse proportion to the catalase activity.

The mercury content in some organs thus paralleled the catalase activity and in other organs did not, indicating that factors other than the catalase activity were related to the mercury contents in such organs.

Pretreatment of acatalasemia mice with ethyl alcohol resulted in a decrease in the mercury concentration and distribution ratio of the lung and blood, but an increase in

Table 3. Tissue distribution of mercury in mice exposed to metallic mercury vapor (mercury content as percent of body burden)

Tissues	Normal	Hypocatalasemia	Acatalasemia	Acatalasemia treated with ethyl alcohol
Brain	2.533±0.333	2.568±0.129	1.820±0.143	1.065±0.045
Heart	4.523±1.028	4.335±0.856	3.965±1.214	2.640±0.090
Lung	17.913±1.782	12.305±1.269	10.268±1.608	2.540±0.700
Liver	5.723±0.758	8.270±0.583	8.445±0.566	25.175±2.445
Kidneys	11.995±2.502	17.430±1.026	18.200±1.094	13.015±1.575
Gastrointestinal tract	10.613±0.905	16.053±1.881	20.000±7.539	18.950±0.280
Blood	7.278±1.472	6.693±1.109	4.903±2.357	4.790±0.180

Table 4. Analysis of variance by one way classification

Tissues	Tissue concentration of mercury				Tissue distribution of mercury			
	N-H	N-A	H-A	N-N-A ¹⁾	N-H	N-A	H-A	N-H-A ¹⁾
Brain	*	*	*	*	—	*	*	*
Heart	—	—	*	—	—	—	—	—
Lung	*	*	*	*	*	*	—	*
Liver	*	*	*	*	*	*	—	*
Kidneys	—	—	—	—	*	*	—	*
Gastrointestinal tract	—	*	—	—	*	*	—	—
Blood	—	*	—	—	*	*	—	—

* Level of significance for a difference of below 5%.

¹⁾ Significant difference in N-H-A can be interpreted as indicating differences among the normal, hypocatalasemia and acatalasemia groups.

them in the liver compared to non-treated mice as shown in Tables 2 and 3. Similar changes in mercury distribution among organs induced by ethyl alcohol treatment have been described previously in normal mice⁸⁾.

DISCUSSION

The present *in vivo* experiment which was carried under exposure to mercury vapor at 1.4 mg/m³ for hours in normal, hypocatalasemia and acatalasemia mice, confirms the previous observation⁸⁾ that acatalasemia mice had decreased levels of mercury in the lung and blood, and increased levels in the liver following exposure to metallic mercury vapor (10 mg/m³) for 30 min *in vivo*. The marked decrease in mercury contents in the lung and blood was roughly proportional to the decrease in catalase activity, suggesting that the primary oxidative site of the inhaled elemental mercury existed in the lung.

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On the other hand, the large increase in mercury content in the liver, which was observed to be in inverse proportion to the catalase activity, was an unexpected finding. Similar increases have also been reported in ethyl alcohol-treated rats (Magos *et al.*, 1973)³⁾ (Harsh *et al.*, 1980)¹⁷⁾, aminotriazole-treated rats (Magos *et al.*, 1974)⁶⁾ and acatalasemia mice⁸⁾. The results contradict with our *in vitro* observations on liver homogenates⁸⁾, so that further investigations are required. Ethyl alcohol inhibited mercury uptake by the peroxidative action of catalase as substrate in contrast to aminotriazole, which decreases the catalase activity. Based on the mercury distribution among mouse organs, a similar mechanism may exist in *in vivo* conditions, since the effect of ethyl alcohol on mercury uptake simulated the mercury uptake in the tissues of acatalasemia mice and aminotriazole-treated rats⁶⁾. The mercury content of the blood showed similar trends to those observed in the lung, but the mercury distribution in the blood was not more than 5.0–7.0% per whole body burden, suggesting that the blood is not the main oxidative site of inhaled elemental mercury.

Our results indicate that lung and blood catalases play an important role in the uptake of elemental mercury and that the distribution of mercury administered to actalasemic mutant mice, with their inborn errors of metabolism, differs from that in the wild type.

ACKNOWLEDGEMENTS

The authors wish to thank Miss Ikuko Kakisaka for her assistance in the present experiments. This work was supported by a grant ((No. 557143) from the Ministry of Education, Japan.

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