

EXPOSURE TO MERCURY VAPORS IN DENTAL WORKERS IN POLAND

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Abstract

Objectives: The study aimed at assessing the effect of low-level exposure to mercury (Hg) vapor from amalgam fillings among dental surgery staff in the city of Łódź, Poland. **Materials and Methods:** The study group was composed of 51 workers (mean age, 39.25 ± 11.05 years) employed in dental surgeries; the control group comprised 16 white-collar workers (mean age, 40.05 ± 10.57 years) of the Nofer Institute of Occupational Medicine, Łódź, who had no or a few amalgam dental fillings. Total urine mercury (Hg-U) concentration was determined with cold vapor atomic absorption spectrometry (CV-AAS) based on tin (II) chloride mercury reduction after overnight digestion of urine sample with potassium permanganate in sulfuric acid solution. The reliability of mercury determinations was verified by measuring Hg concentration in the reference material and via participation in the external quality assessment scheme. **Results:** No statistically significant differences were found in geometric mean of urine Hg concentrations between the study and control groups ($GM \pm SD$, 0.44 ± 0.440 and 0.5 ± 0.270 $\mu\text{g/g}$ creatinine, respectively, $p = 0.242$). Among different factors affecting Hg exposure in dental surgeries, only the duration of dental practice showed a statistically significant influence on total Hg-U ($r = 0.3000$; $p = 0.024$). Having divided the subjects into two groups, with and without amalgam fillings, we noted a statistically significant difference in urine Hg concentrations (0.60 ± 0.720 , $n = 38$; 0.36 ± 0.650 , $n = 29$; $p = 0.004$) between these two groups. **Conclusions:** The results of biological monitoring of dental surgery staff did not reveal current exposure to Hg vapors from amalgam fillings. However, these dental workers may have been the subject to such an exposure in the past. The only statistically significant correlation was that between total Hg-U concentrations and the duration of dental practice.

Key words:

Dentists, Mercury, Urine, CV-AAS, SnCl_2 reduction

INTRODUCTION

Exposure to mercury (Hg) or mercury vapor is recognized as a potential health hazard to the staff of dental surgeries. Exposure can occur through a direct skin contact with Hg or Hg-containing compounds or through inhalation of Hg vapors. The primary route of exposure is through the respiratory tract: about 80% of inhaled Hg is absorbed in the lung [1,2]. Dentists and dental nurses who handle preparation and fitting of Hg-containing amalgam fillings are at risk of being exposed to inorganic mercury, although the recent changes in dental practice that have resulted in a largely decreased use of Hg amalgams have diminished the health risk among dental surgery workers. Elemental

Hg is still an important material used in dentistry in Poland. Generally, amalgam fillings have been used since 1895 to fill dental defects. An amalgam filling is a mixture of metallic mercury about 50%, silver 35%, tin 9%, copper 6%, and trace amounts of zinc [3]. Sources of Hg contamination in dental surgery included expression of excess mercury from amalgam; leakage from amalgam capsules and dispensers; improper storage of scrap amalgam; mercury vaporization from contaminated instruments placed in sterilizers; and mercury vapor generated during the removal of amalgam fillings [3–5]. The implementation of proper mercury hygiene procedures could reduce the potential hazard resulting from Hg exposure in dental practice [4,6].

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To assess low-level occupational mercury exposure of dental staff, urine mercury (Hg-U) concentration was used as an exposure index [4,6–16]. The recent literature data confirm that Hg-U remains the most practical and sensitive marker of monitoring low-level occupational exposure to inorganic mercury [7]. In view of well established dose-effect and dose-response relationships between Hg-U concentrations and critical health effects, the recommended Hg-U levels are used as the main guideline for workers' health protection. For the assessment of occupational mercury exposure, based on mercury level in urine, the biological exposure indices (BEI) are available. In Poland, the current BEI value for exposure to inorganic or metallic mercury is 35 µg/g creatinine [17]. In Germany, the biological tolerance value (BAT), according to the Commission for the Investigation of Health Hazards of Chemical Compounds in the Work Area for urine, is 100 µg/l [18] while the value of 35 µg/g creatinine for BEI was adopted by the American Conference of Governmental Industrial Hygienists (ACGIH) in 2004 [19].

The recommended value for non-occupational population is 1–5 µg/g creatinine and is considered to be within a normal range [20–22]. Following the regulations of the German Commission on Human Biological Monitoring for Environmental Pollutants, Hg-U concentration, below which there is no risk of adverse health effects, should be 5 µg/g creatinine (HBM I for children and adults), and 20 µg/g creatinine (HBM II) is the concentration, above which there is an increased risk for adverse health effects in susceptible individuals in the general population [18–20]. According to the 1998 German Environmental Survey, the reference Hg-U value for adults, aged 18–69 years, without amalgam fillings has recently been revised and lowered from 1.4 to 1.0 µg/l [21].

The purpose of the present study was to determine the current level of occupational mercury exposure among the staff of selected dental surgeries in the city of Łódź, Poland. In our country, the use of amalgam fillings is quite often since they are available free-of-charge for the treatment of molar and pre-molar teeth under the services covered by the National Health Fund. The assessment of exposure to Hg vapors was based on the determination of total Hg-U concentrations in the study population.

MATERIALS AND METHODS

Study population

The study group included 51 dentists and dental nurses (aged 25–63 years, mean, 39.25 ± 11.05) working in dental surgeries and whose services are covered by the Regional Division (City of Łódź) of the National Health Fund. The mean duration of dental practice was 14.3 ± 11.5 years). The control group comprised 16 healthy individuals (aged 25–56 years; mean, 40.05 ± 10.57), workers of the Nofer Institute of Occupational Medicine, Łódź, who were not occupationally exposed to Hg vapors.

Questionnaire data

All the subjects were asked to fill out a questionnaire, which sought information concerning the subject's age, gender, number of seafood servings consumed per week, and number of amalgam fillings in their teeth. Dentists and their assistants were also asked about their professional career: years of dental practice, number of amalgam fillings placed or removed per week.

Urinary mercury analysis

Spot urine samples were collected into polypropylene sampling vials (after they had been washed with acid solution and flushed with deionized water).

For mercury analysis, 20 ml of collected urine was transferred to an acid- and deionized water-washed glass tube and then acidified with 0.1 ml of concentration H_2SO_4 to pH < 1.

For creatinine measurements, 5 ml of urine sample was placed into a polyethylene tube.

Specimens for total mercury and creatinine analyses were frozen at $-20^\circ C$. Urinary creatinine measurements were performed by Perkin Elmer Lambda Spectrophotometer according to Jaffe's picrate method using an Aqua-Med (Aqua-Med., Łódź, Poland).

Instrumentation

Urine mercury concentration was measured using a MERCURY RA-3 analyzer, model 3110 PL (TESTCHEM, Polish division of Nippon Instruments Corporation) connected with an SC-3 auto-sampler and RD-3 reagent dispenser.

Determination of total mercury in urine

Total Hg-U concentrations were determined with cold vapor atomic absorption spectrometry (CV-AAS) [23]. The method involves the determination of the total mercury content after overnight digestion of the urine sample with potassium permanganate in sulfuric acid solution at room temperature. The excess of oxidants is reduced with the hydroxylamine hydrochloride solution. The ionic mercury Hg (II) from digested urine is converted into Hg⁰ by a reduction with tin (II) chloride and then vaporized. The vaporized Hg content is determined from the absorbance measurement at the absorption Hg wavelength of 253.7 nm.

Quality control

The accuracy of the method for total Hg-U determination was verified by determining urine mercury concentration in reference materials: Seronorm™ Trace Elements Urine (SERO AS) and ClinCheck® — Urine Control (Recipe®) as well as via the performing laboratory's participation in the German External Quality Assessment Scheme (G-EQUAS) within External Intercomparison Programme 36/2005 for toxicological analyses of biological materials. Our involvement in G-EQUAS was confirmed by a certificate for urinary mercury determination in the fields of occupational medicine and environmental health.

Statistical analysis

Student's t-test, simple linear regression analysis, and Pearson correlation coefficients were used for statistical analysis. When geometric means of urinary mercury were calculated for the control group, one person with a particularly high level of urinary mercury was excluded from the analysis.

Table 2. Relationship between questionnaire data and total urine mercury (Hg-U) concentrations (in µg/g creatinine)

Questionnaire item	Group	Linear regression equation	r	No. of subjects	P
No. of years (duration) of dental practice	Exposed	$y = 0.0120x + 0.4119$	0.3000	51	0.024
No. of amalgams placed/removed per week	Exposed	$y = 0.0073x + 0.5499$	0.0980	51	0.495
No. of daily working hours of dental staff	Exposed	$y = 0.0039x + 0.5587$	0.0173	51	0.905
No. of amalgams in the investigated exposed subjects	Exposed	$y = 0.0546x + 0.5212$	0.1780	51	0.211
No. of amalgams in the investigated control subjects	Control	$y = 0.0660x + 0.5210$	0.2740	16	0.323

r — linear correlation coefficient; P — level of significance.

RESULTS

Biological monitoring

Table 1 displays geometric means and Hg-U concentration ranges in the study and control groups. The values of total Hg-U (0.44 ± 0.44 and 0.57 ± 0.27 µg/g creatinine, respectively) did not show statistically significant differences between these two groups ($p = 0.242$). The numbers of amalgam fillings (arithmetic means) amounted to 1.16 ± 1.44 and 1.53 ± 1.07 , respectively, with no statistically significant differences.

Correlations

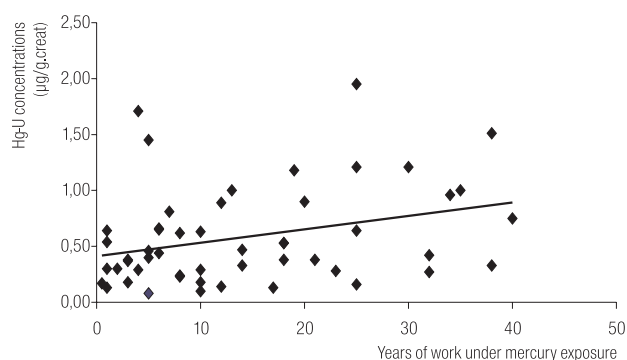
In our study, the influence of different factors, such as years of dental practice, numbers of amalgam fillings placed/removed per week, daily working hours of dental staff, and amalgam restorations in the dental staff and control group, on total urinary mercury excretion was investigated (Table 2).

Among different factors that may have influence on Hg vapor exposure, listed in Table 2, a statistically significant correlation between Hg-U concentration and duration of dental practice ($r = 0.3$; $p < 0.05$) was noted only in the

Table 1. Geometric means and concentration ranges for urinary mercury (Hg-U) in the exposed and control groups

Group	No. of amalgams (arithmetic mean)	Mercury urinary concentrations		
		No. of subjects	Mean* ± SD (µg/g creatinine)	Range (µg/g creatinine)
Exposed	1.16 ± 1.40	51	0.44 ± 0.44	$0.08 \div 1.95$
Control	1.53 ± 1.07	15	0.57 ± 0.27	$0.22 \div 1.07$

* Geometric mean and standard deviation.



$\text{Ln Hg-U} = 0.0120x + 0.4119$; $n = 51$; $r = 0.3000$; $p < 0.05$; $\text{SEE} = 0.4205$.

Fig. 1. Relationship between years of work under exposure to mercury and urine mercury (Hg-U) concentrations.

exposed group (Fig. 1). For other factors likely to affect urinary Hg excretion, the observed correlations were not statistically significant ($p > 0.05$) (Table 2).

Exposure to mercury from amalgam restorations

In our project, we estimated mercury exposure from the total number of amalgam fillings in the oral cavity of the examined subjects. To this end, this population was divided into two groups with (subgroup 1; $n = 38$) and without (subgroup 2; $n = 29$) amalgam fillings. The geometric mean of Hg-U concentration in subgroup 1 (No. of amalgam fillings, 2.36 ± 1.15) was 0.60 ± 0.720 µg/g creatinine compared to 0.36 ± 0.650 µg/g creatinine in subgroup 2 (without amalgam fillings). Statistically significant difference in Hg-U concentrations was found between the two subgroups. Hg-U concentrations in the subjects of subgroup 1 were significantly higher than those in subgroup 2 (Table 3).

DISCUSSION

A number of reports have shown that exposure to mercury vapor in dental practice can reach relatively high levels (Table 4). Joselow et al. [8], who in 1968 summarized the results of studies on Hg exposure in the U.S. dental profession ($n = 50$), reported that average Hg concentration ranged from 40.0 µg/l up to 155 µg/l (Table 4). At that time, very high levels of Hg exposure could be explained by low hygiene of work with mercury. Many dentists kneaded the amalgam mass in the palm of their hands. New dental technologies and better hygiene standards have significantly reduced the exposure. In 1985, Naleway et al. [9] published the results obtained under the health-screening program for 4272 U.S. dentists, including an analysis of Hg-U. At that time, the mean urine mercury concentrations were much lower (14.2 µg/l; $\text{SD} = 25.4$) than those reported by Joselow et al. [8] and were positively related to weekly hours of practice, number of amalgams placed or removed, method of amalgam fillings preparation and application, type of amalgam capsules used, and type of cooling and heating systems. The U.S. data indicated a dramatic decline in Hg-U concentrations, from 40 µg/l in 1968, through 11.9 µg/l in 1987, to 4.9 µg/l in 1995 (Table 4). The factors accounting for this decrease might be a better work hygiene when handling amalgam fillings, decreasing caries prevalence since 1995, and also to some extent due to the use of alternative materials for dental fillings. In Sweden, the exposure to Hg vapor in the dental profession was much lower in 1986 and in 1997 comparable to the American data. The mean values for Hg-U in the dental

Table 3. Mean urine mercury (Hg-U) concentrations in subgroup 1 with and subgroup 2 without amalgam fillings

Subgroup	No. of amalgam fillings (arithmetic mean)	Mercury urinary concentration		
		No. of subjects	Mean* \pm SD (µg/g creatinine)	Range (µg/g creatinine)
With amalgam fillings (subgroup 1)	2.36 ± 1.15	38	$0.60^a \pm 0.720$	$0.13 \div 1.95$
Without amalgam fillings (subgroup 2)	0	29	0.36 ± 0.650	$0.10 \div 1.51$

* Geometric mean and standard deviation.

^a P (level of significance) = 0.004 for Hg-U in subgroup 1 vs. subgroup 2.

Table 4. Mercury concentration in urine samples obtained from the dental staff: the results of major studies

Country	Year	Mean	Range	References
USA	1968	40 µg/l (n = 50)	0 ÷ 155 µg/l	Joselow MM et al. [8]
USA	1985	14.2 µg/l (SD = 25.4) (n = 4272)	5% > 50 µg/l	Naleway C et al. [9]
Sweden	1986	4.2 µg/l (n = 505)	< 1 ÷ 70.6 µg/l	Nilsson B et al. [10]
Control group		2.7 µg/l (n = 41)		
USA	1987	11.9 µg/l (n = 1298)	0 ÷ 396 µg/l	Langan DC et al. [6]
The Netherlands	1988	11.4 µg/l (n = 312)	5.1 ÷ 22.3 µg/l	Herber RFM et al. [11]
Norway	1990	8.2 µg/l (n = 945)	0 ÷ 55 µg/l	Jokstad A [12]
USA	1995	4.9 (SD = 6.61) µg/l (n = 1352)	2% > 20 µg/l	Martin MD et al. [4]
Sweden	1997	5.3 µg/g creatinine (n = 44)	1.6 ÷ 26.7 µg/g creatinine	Langworth S et al. [13]
Control group		4.1 µg/g creatinine (n = 44)	0 ÷ 23.1 µg/g creatinine	
Venezuela	2000	22.3 (SD = 6.1) µg/g creatinine (n = 66)	6.3 ÷ 34.4 µg/g creatinine	Rojas M et al. [14]
Mexico	2002	3.2 µg/l (SD = 2.74) (n = 30)	0.2 ÷ 12 µg/l	Millán MAP et al. [15]
United Kingdom	2002	1.45 (SD = 1.55) µg/g creatinine (n = 162)	0.01 ÷ 11.74 µg/g creatinine	Ritchie KA et al. [16]
Control group		0.38 (SD = 0.38) µg/g creatinine (n = 163)	< 0.0056 ÷ 2.36 µg/g creatinine	

staff were 4.2 µg/l (n = 505) and 5.3 µg/g creatinine (n = 44) [10,13].

In some countries, the mean and range of Hg-U concentrations in the dental staff are still rather high. In Venezuela, the mean urine mercury level amounted to 22.3 µg/g creatinine in 2000 [14]. The high concentration in some dentists may indicate that a substantial change in work hygiene would be necessary.

Biological monitoring of selected dental surgeries in the city of Łódź, Poland, indicates the absence of current exposure to Hg vapors from placed/removed amalgam fillings. The HG-U results within the range of 0.08–1.95 µg/g

creatinine (study group) and 0.22–1.07 µg/g creatinine (control group) (Table 1) are substantially below the current biological threshold limit of 35 µg/g creatinine for occupationally exposed workers [17] and are within the range of reference values, 1.0–5.0 µg/g creatinine for Hg-U in non-exposed adults (18–69-years-old) with no amalgam fillings [20,21]. No statistical differences in the mean total Hg-U between the dental staff and the control group may point to a much lower exposure to Hg vapors than that reported earlier. A lower or no exposure in this group of practitioners may result from more modern standards of dental practice.

Statistically significant correlation was found between urinary mercury concentration and years of dental practice ($p < 0.05$) (Fig. 1, Table 2). The majority of the dental practitioners had been exposed to mercury for many years (mean, 14.3 years) and their exposure to inorganic mercury in the past was probably higher than in the present study.

In the study group, statistically significant differences ($p = 0.004$) were found in Hg-U concentration between the subjects with (subgroup I) and without (subgroup II) amalgam fillings (Table 3). The release of mercury vapor from amalgams is well documented [5,24–26]. It is estimated that a single 0.4 cm amalgam filling releases daily about 15 µg mercury. In a patient with 6 amalgam dental fillings, the volume of mercury released daily amounts to about 60 µg [3,5]. On the other hand, mercury is also absorbed with food and environmental media, such as air and water. A daily mercury intake with seafood is estimated at about 2.3 µg while with other foodstuffs, air, and water at about 0.3 µg.

In many countries, including Poland, the use of amalgam as a filling material has substantially declined over the last decade. In the countries for which relevant statistical data are available, such as the USA, the UK, Australia, and Scandinavian countries, the use of amalgam was found to decrease by several times [25]. There is a number of restrictions on its use worldwide. For example, in Germany, amalgam fillings should not be placed or removed in pregnant women.

The high level of mercury exposure in the past might be connected with the method of preparing amalgam fillings. Amalgam was rubbed by hand and then mixed mechanically. These procedures might have contributed to an increased concentration of mercury vapors in the ambient air of dental surgeries as evidenced by high Hg-U levels detected earlier in dentists. The level of exposure depended on the type of dental equipment, internal ventilation system, floor covering, and mercury residues on the floor as well as on the preparation, insertion and removal of amalgam fillings. The use of disposable amalgam capsules and adhesive tape to check whether the capsules are airtight when reused, have contributed to a 20–50% decrease

in mercury vapor concentration in the ambient air. New dental technologies and the introduction of more restrictive rules of occupational hygiene have brought about a radical reduction of mercury exposure in dental surgeries [6,25–26].

Poland has no regulations prohibiting or restricting the placement of dental amalgam fillings, however, due to the widespread use of composite resins, amalgams are now less often used compared to the past.

CONCLUSIONS

The results of the study indicate that current exposure to mercury vapors in the dental profession in Poland is very low. In some dental surgeries covered by the study, no evidence of exposure to mercury vapors was found, nor were there any statistically significant differences between the study group and controls. In the study group, among factors likely to contribute to Hg exposure in dentists, a statistically significant correlation was noted only between years of work in dental surgery and total urine mercury concentrations. This could imply previous exposure to mercury vapors in this group.

Biological monitoring based on urinary mercury determination is a valuable tool in assessing mercury exposure and the effectiveness of hygiene practice in the dental surgery staff.

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