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Symptoms of Intoxication in Dentists Associated with Exposure to Low Levels of Mercury

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Abstract: The present study examined the effects of occupational exposure of a group of dentists to low levels of mercury. The study population consisted of 106 dentists and 94 general practitioners (referent group), from private and public clinics in Shiraz city. Subjects were requested to complete a questionnaire on demographic variables, suspicious symptoms of intoxication and work practices. Additionally, atmospheric and urinary concentrations of mercury were measured by Atomic Absorption Spectroscopy technique. The data were analysed by χ^2 test, independent sample *t*-test and multivariate logistic regression analysis, where applicable. Both groups were similar as far as most demographic and socioeconomic variables, but age and number of personal amalgam fillings, were concerned. Median of atmospheric concentration of mercury was found to be 3.35 μg/m^3. Likewise, the urinary concentration of mercury in dentists was estimated to be 3.16 μg/g creatinine. This value was significantly higher than that of the referent group. Similarly, analysis of the data revealed that neuropsychological, muscular, respiratory, cardiovascular and dermal symptoms were more prevalent in dentists. Our findings indicate that occupational exposure of dentists to mercury, even at low levels, is associated with a significant increase in the prevalence of symptoms of intoxication.

Key words: Dentists, Amalgam filling, Occupational exposure, Mercury, Intoxication symptoms

Introduction

Exposure to elemental mercury through amalgam dental fillings is a prevalent and distinct source of exposure. Dentists are occupationally exposed to elemental mercury from placements of mercury-containing amalgam in addition to that from their own personal amalgam fillings[1)]. Dental amalgam is an alloy that results from trituration of powdered silver, tin and copper which hardens quickly to a solid phase. Dental amalgams have been used as the main restorative agents for more than 150 yr[2)]. Occupational exposure to elemental mercury in dentistry has attracted considerable attention over the last few decades[3)]. The primary source of occupational exposure in dentists is via inhalation of elemental mercury vapour. A number of investigations have been conducted among dentists to examine the adverse effects of this exposure.

The various factors that may contribute to levels of mercury exposure in dentists are categorized into a) personal characteristics (i.e. diet, age and cleaning habits), b) office characteristics (i.e. flooring material, dimensions of the workplace, ventilation and type of equipment) and c) professional practice (i.e. number of amalgam fillings per day, the method amalgam scrap is stored and handling of spills)[3–6)].

Mercury is known to have adverse effects on nervous

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system, kidney, muscles and immune system[5–7]. Many studies have shown high occurrence of neurological symptoms such as memory problem, sleep disturbances, concentration difficulties and fatigue among dental clinics personnel[8, 9]. Studies have also revealed that chronic exposure to mercury may lead to adverse effects such as salivation, gingivitis, insomnia, excitability, depression and sensory losses[10–13].

There is still widespread concern about possible ill effects of chronic low-level mercury exposure on dentists[14, 15]. Additionally, in a study conducted by Karahalil and his colleagues[15] high background levels of mercury in the air of dental clinics as well as elevated levels of this toxic heavy metal in the urine and hair of dentists associated with poly-neuropathies have been reported. These observations along with the absence of any information on current exposure scenarios and possible health effects of occupational exposure of Shiraz dentists to mercury prompted this investigation.

Subjects and Methods

Study subjects

The design of the study, from an epidemiological point of view, was a cross sectional investigation in which data from a group of dentists (exposed group) and general practitioners (GPs) as referent individuals, were gathered. One hundred and six dentists were selected by simple random sampling technique from about 400 dentists working in private and public clinics of Shiraz city, capital of Fars province. Sampling fraction was, therefore, 25%. Additionally, 94 GPs were selected from private and public clinics in a similar manner.

All subjects voluntarily participated in the study after receiving written information about the aims and the protocol of the study. Additionally, the study was conducted in accordance with the Helsinki Declaration of 1964 as revised in 1989. All participants signed an informed consent form before commencement of the study. The study was reviewed and approved by Shiraz University of Medical Sciences ethics committee.

Measurements of study variables

Demographic characteristics, suspicious symptoms of intoxication and work practices

Subjects completed a 3-part self-administered questionnaire with questions about a) demographic and job-related variables (i.e. age, gender, height, weight, marital status, length of exposure or employment, number of amalgam fillings or replacements per day), b) symptoms and signs such as memory deficit, depression, anxiety, moodiness, muscle spasm, skin, heart and respiratory disorders and c) work practices and equipment used (i.e., type of amalgam and amalgamator, handling of waste, type of suction, wearing mask and safety goggles).

Measurement of atmospheric mercury level

The concentrations of mercury vapour in dental clinics were measured with an Hg monitor 3000 mercury analyzer, Seefelder Messtechnik, Germany. The Hg monitor 3000 is a compact fixed wavelength UV photometer that operates on the principle of Atomic Absorption Spectroscopy. Using the built-in flow pump, air passes through an optical cuvette in the instrument and real-time values are displayed continuously. During the visit to the dentists' clinics, long term continuous measurements were taken of airborne mercury concentrations present at four points within the clinics.

Urinary mercury analysis

Subjects were asked to provide a sample of urine for mercury determination. Mercury analysis was carried out using cold vapour atomic absorption spectrophotometry by Chemtech AA Spectrophotometer (model CTA 3000). Urinary mercury levels were reported as both μg/l of urine and corrected to urinary creatinine (μg/g creatinine).

Data analysis and statistical procedures

Chi-Square test was used to compare the prevalence of symptoms among both groups. Fisher's exact test was used when numbers were too small for χ^2 tests to be valid. Odds ratio and the 95% confidence intervals (95%CIs) were calculated. Independent sample *t*-test and Mann-Whitney's U-test were used to compare the mean and median of quantitative data of both groups. *p*-value of less than 0.05 was considered significant. Multivariate logistic regression analysis was used to examine the adjusted effect of job category (dentist vs. referent) and amalgam fillings on the occurrence of various symptoms and disorders. Statistical analyses were performed using SPSS software (Version 11.5).

Results

Demographic information

Table 1 depicts subjects' demographic as well as job-related characteristics. Although referent subjects were significantly older than their exposed counterparts and number of personal amalgam fillings was significantly higher in dentists than in GPs, no significant differences were noted between both groups as far as other demographic variables were concerned.

Table 1. Demographic and job-related characteristics of the study subjects (Mean ± SD or n (%))

Variable	Dentists (n=106)	GPs (n=94)	*p*-value
Age (yr)	38 (± 8)‡	40.8 (± 7.7)	0.01*
Weight (kg)	69.3 (± 11.1)	70.2 (± 10.1)	0.5*
Height (cm)	169 (± 8.1)	169.5 (± 8.5)	0.6*
BMI	24.2 (± 3.1)	24.3 (± 2.5)	0.7*
Length of exposure or employment (yr)	11.7 (± 7.3)	11 (± 5.9)	0.4*
No. of amalgam fillings per day	5.8 (± 2.7)	-	-
No. of amalgam replacements per day	2 (± 1.5)	-	-
No. of personal amalgam fillings	5.8 (± 4)‡	3.35 (± 6)	0.001*
Sex			
Male	63 (59.4%)	57 (60.6%)	0.8†
Female	43 (40.6%)	37 (39.4%)	
Marital status			0.2†
Single	18 (17%)	10 (10.6%)	
Married	88 (83%)	84 (89.4%)	
Type of clinic			0.2†
Private	35 (33%)	39 (41.5%)	
Public	71 (67%)	55 (58.5%)	

*Independent *t*-test,
†χ^2 test,
‡Significantly different from its corresponding value for the control group.

Self-reported symptoms and signs

Table 2 illustrates the frequency of self-reported symptoms and signs among exposed and non-exposed subjects. Univariate analysis showed that hyperpigmentation, respiratory disorders, irregular pulse, hand tremor, spasm of the upper extremities, moodiness, nervousness, anxiety, insomnia, erethism, memory deficit, depression and chronic fatigue were significantly more prevalent in dentists than in general practitioners (GPs) ($p<0.05$). Similarly, multivariate logistic regression analysis revealed that these differences were statistically significant even after adjusting for age, marital status, number of personal amalgam fillings and type of clinic (Table 2).

Given the fact that number of amalgam fillings per day is the major determinant of exposure to mercury by dentists, association between this variable and organ/system-related symptoms after adjusting for potential confounders (i.e. age, marital status, number of personal amalgam fillings, type of clinic and length of employment) was studied (Table 3). As seen, there was a significant association between the number of amalgam fillings per day and neuropsychological and muscular disorders ($p\leq0.001$).

Urinary and atmospheric mercury concentrations

Table 4 presents urinary mercury concentrations in exposed and non-exposed groups as well as mercury levels in dental clinics ambient air. As shown, a significant difference exists between the median of urinary mercury levels ($p=0.02$) in both groups. Similarly, median of creatinine corrected urinary mercury levels were significantly higher in dentists than in GPs ($p=0.049$).

Discussion

The present study aimed to investigate the health effects of occupational exposure to low levels of mercury by dentists and compare the results with a non-exposed referent population. Apart from age and number of personal amalgam fillings, exposed and non-exposed groups were similar as far as other important demographic variables were concerned.

Univariate analysis (Table 2) revealed that the prevalence of hyperpigmentation, respiratory disorders, irregular pulse, hand tremor, spasm of the upper extremities as well as neuropsychological symptoms were significantly more prevalent among exposed individuals. Similarly, logistic regression analysis showed that these differences remained statistically significant even after adjusting for important confounding variables such as age, marital status, number of personal amalgam fillings and type of clinic. Interestingly, the adjusted odd ratios for the majority of the symptoms were higher in logistic regression analysis than those of univariate analysis (crude odd ratios). Given the above and taking demographic similarities between the two groups into account, it may be concluded that a significant increase in the prevalence of symptoms and signs reported by dentists as

Table 2. Association between exposure to mercury and the frequency (%) of self-reported symptoms/signs

Symptoms/signs		Dentists (N=106)	GPs (N=94)	Univariate Analysis		Multivariate Analysis*	
				OR (CI)	*p*-value	OR (CI)	*p*-value
Skin	Dermatitis	10 (9.4%)	8 (8.5%)	1.12 (0.42–2.96)	0.82	1.06 (0.37–3.04)	0.9
	Eczema	13 (12.3%)	7 (7.4%)	1.73 (0.66–4.55)	0.25	1.86 (0.68–5.04)	0.22
	Hyperpigmentation	13 (12.3%)	3 (3.2%)	4.24 (1.16–15.37)	0.01	4.62 (1.2–17.68)	0.02
Respiratory	Shortness of breath and burning sensation	14 (13.2%)	3 (3.2%)	4.61 (1.28–16.6)	0.01	4.96 (1.19–20.65)	0.02
Cardiovascular	Tachycardia	12 (11.3%)	5 (5.3%)	2.27 (0.77–6.71)	0.12	2.92 (0.92–9.24)	0.06
	Irregular pulse	16 (15.1%)	3 (3.2%)	5.39 (1.51–19.14)	0.004	6.83 (1.83–25.53)	0.004
Oral cavity	Gingivitis	5 (4.7%)	7 (7.4%)	0.61 (0.18–2)	0.41	0.55 (0.17–1.79)	0.32
	Salivation	4 (3.8%)	5 (5.3%)	0.69 (0.18–2.68)	0.59	0.73 (0.18–2.89)	0.65
	Painful chewing	5 (4.7%)	1 (1.1%)	4.6 (0.53–40.14)	0.13	7.15 (0.71–72.04)	0.09
Muscular	Hand tremor	17 (16%)	5 (5.3%)	3.4 (1.2–9.61)	0.02	3.41 (1.16–10.01)	0.02
	Spasm of the upper extremities	22 (20.8%)	3 (3.2%)	7.94 (2.29–27.51)	<0.001	8.72 (2.38–31.96)	0.001
Metabolic	Weight loss	4 (3.8%)	6 (6.4%)	0.57 (0.15–2.1)	0.39	0.63 (0.16–2.42)	0.5
	Thyroid enlargement	2 (1.9%)	1 (1.1%)	1.78 (0.16–20.04)	0.63	1.56 (0.12–20.14)	0.73
Neuropsychological	Moodiness	33 (31.1%)	8 (8.5%)	4.86 (2.11–11.17)	<0.001	4.45 (1.88–10.51)	0.001
	Nervousness	25 (23.6%)	4 (4.3%)	6.94 (2.31–20.8)	<0.001	6.93 (2.24–21.43)	0.001
	Anxiety	42 (39.6%)	13 (13.8%)	4.08 (2.02–8.26)	<0.001	3.88 (1.85–8.12)	<0.001
	Insomnia	23 (21.7%)	5 (5.3%)	4.93 (1.79–13.57)	0.001	5.08 (1.8–14.35)	0.002
	Erethism	20 (18.9%)	1 (1.1%)	21.62 (2.84–164.6)	<0.001	22.37 (2.65–188.51)	0.004
	Vague fears	12 (11.3%)	4 (4.3%)	2.87 (0.89–9.23)	0.06	2.92 (0.83–10.22)	0.09
	Difficulties in writing	8 (7.5%)	2 (2.1%)	3.75 (0.77–18.14)	0.07	2.57 (0.5–13.22)	0.25
	Memory deficit	33 (31.1%)	2 (2.1%)	20.8 (4.8–89.5)	<0.001	23.04 (4.83–109.84)	<0.001
	Depression	24 (22.6%)	5 (5.3%)	5.21 (1.89–14.29)	0.001	4.66 (1.66–13.1)	0.003
	Chronic fatigue	48 (45.3%)	16 (17%)	4.2 (2.26–7.8)	<0.001	4.42 (2.34–8.34)	<0.001

*Adjusted for age, marital status, number of personal amalgam fillings and type of clinic, using logistic regression.

Table 3. Association between number of amalgam fillings per day and organ/system-related symptoms

Organ/system*	$\beta^{\dagger}$	OR (95%CI)‡	*p*-value
Skin	0.039	1.04 (0.93–1.16)	0.48
Respiratory	0.092	1.09 (0.93–1.29)	0.27
Cardiovascular	0.11	1.11 (0.98–1.26)	0.07
Oral cavity	0.076	1.08 (0.95–1.22)	0.24
Muscular system	0.173	1.19 (1.06–1.32)	0.001
Metabolic Disorder	–0.006	0.994 (0.83–1.18)	0.99
Neuropsychological	0.241	1.27 (1.13–1.42)	<0.001

*A symptomatic subject is defined as a person with even one positive organ/system related symptom.
†Exponentiation of β yields the estimated OR for an increase of one unit in number of amalgam fillings per day.
‡Adjusted for number of personal amalgam fillings, age, marital status, type of clinic and length of employment, using logistic regression.

well as significantly higher urinary concentrations of this heavy metal among them may be explained by their occupational exposure to this element.

This conclusion is supported by the findings of others[4, 8, 16]. Additionally, other symptoms such as tachycardia, painful chewing, thyroid enlargement, vague fears and difficulties in writing were also more prevalent among dentists than in GPs, however the differences did not reach statistical significance.

Significant positive associations between number of amalgam fillings per day and the prevalence of neuropsychological and muscular disorders were detected. It is noteworthy that dentists apart from mercury are exposed to a number of other harmful chemicals such as organic solvents, disinfectants, acrylate compounds etc.[17] as well as harmful physical factors (e.g. noise and vibration[18]) that may result in similar outcomes. Therefore, while the reported symptoms could not necessarily be causally linked with mercury exposure; however, the fact that symptoms such as memory deficit, hand tremor and nervousness have been reported to be significantly more prevalent in dentists than in control subjects[8] indicate that the role of mercury as a potential contributing factor could not be overlooked.

This assumption is further supported by the find-

Table 4. Median and range of atmospheric and urinary concentrations of mercury in dental clinics and study population

Variable	Dentists (n=106)	GPs (n=94)	*p*-value*
Urine Hg conc. (μg/l)	2.86 (0.01–18.1)	2.26 (0.21–5.6)	0.02
Urine Hg conc. (μg/g creatinine)	3.16 (0.01–30)	2.18 (0.33–5.08)	0.049
Mercury levels in ambient air (μg/m^3)	3.35 (0.4–7.7)†	N/D‡	—

*Mann-Whitney test,
†Based on 90 measurements,
‡Not detectable.

ings of Shapiro *et al*.[16] where anxiety was observed to be more common in dentists than in control individuals. Similarly, Moen *et al*. reported that hand tremor, memory deficit and moodiness were significantly more prevalent among dental assistants than in a group of non-exposed subjects, assistant nurses[9].

In this study, a logical and reasonable association was noted between airborne and urinary concentrations of mercury in dentists (Table 4) which is a good indicator of the accuracy of environmental and biological measurements. This conclusion is based on the assumption that a ratio of about 1:1 exists between these two variables[7].

The Threshold Limit Value (TLV) for this toxic metal has been set at 25 μg/m^3 by both ACGIH[19] and WHO[7]. Although median airborne concentration of mercury in the dental clinics in our study was below this value, self-reported symptoms of intoxication were significantly higher in dentists. Similarly, while median urinary mercury levels in dentists were significantly higher than those of the referent subjects, they did not exceed the current value of Biological Exposure Index (BEI) for this chemical (35 μg/g creatinine)[19].

Given the above, one might tentatively conclude that the current TLV and BEI values for this toxic metal do not provide sufficient protection to prevent the occurrence of symptoms with toxicological importance, particularly neuropsychological outcomes. This proposition is in agreement with the views expressed by Richardson *et al*.[20] in that the relationship between mercury exposure and neurobehavioral outcomes in the development of Recommended Exposure Limit (REL) for mercury is generally ignored. Additionally, these observations cast doubt on the usefulness of the current value of BEI, per-se, as a sensitive biological marker of exposure to mercury for early detection of intoxication. This conclusion is also indirectly implied by the findings of the study conducted by Ritchi *et al*.[8] in which no significant association was found between urinary mercury levels and the prevalence of toxicity symptoms.

While these findings, at a glance, may seem somehow unusual and peculiar, it has to be reiterated that quantitatively similar findings have been reported by Langworth *et al*.[4] and Martin *et al*.[3] in which a significant increase in the prevalence of symptoms among a group of dentists exposed to airborne concentration of mercury of about 1.8 μg/m^3 and urinary mercury of 3 nmol/mmol creatinine (5.3 μg/g creatinine) has been observed. Furthermore, the results of a recent study has shown that dentists and dental assistants experienced a decline in neurobehavioral performance at urinary mercury concentrations below 4 μg/l[21].

Conclusions

The findings of this study collectively indicate that occupational exposure to mercury, even at low levels, is associated with a significant increase in the prevalence of symptoms of intoxication. Additionally, they provide circumstantial evidence in favour of the notion that the current value of TLV of this metal do not provide sufficient protection against the appearance of neuropsychological symptoms. Finally they may cast doubt on the appropriateness of current value of BEI, per-se, as a sensitive means for biomonitoring of mercury exposed individuals.

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