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16. Abstract (Limit: 200 words)

An effort was made to develop a safe and effective x-ray fluorescence system for monitoring mercury (7439976) and other elements in human tissues in-situ, to determine mercury levels in 207 dental auxiliaries exposed to dental amalgam on the job, to evaluate mercury in matching nonexposed populations and in 298 dentists using mercury amalgam, and to evaluate deficiencies in central and peripheral nervous systems resulting from the mercury exposure. Mercury levels were below 20 micrograms/gram in 60 percent of the dentists and 90 percent of the dental auxiliaries. Dentists with the higher mercury concentrations in their heads or wrists had considerably longer median motor distal latencies and median F-wave latency. Five of them demonstrated abnormalities consistent with carpal tunnel syndrome; seven had polyneuropathies defined as reduced motor or sensory conduction velocities of response amplitudes in two or more nerves. No significant differences were found in the results of neurological studies conducted on dental auxiliaries, whether they had high levels or no detectable levels of mercury in their bodies. Neuropsychological tests indicated both groups of dental workers were adversely affected by mercury exposure. Deficits were noted in performance in grooved pegboard and recurrent figures tests.

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Final Report

Mercury Burden and Health Impairment in Dental Auxilaries

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1. Background to the problem. The hazard of mercury poisoning is of major importance to dental workers. As of 1976, there were over 30,000 dental hygienists in the U.S most of whom are involved in some chairside activities, and 1,200 dental auxiliaries. The mean yearly utilization of mercury by each auxiliary in this population exceeds 1 Kg. The auxiliary dispenses metallic mercury, triturates the mercury with a silver-tin alloy to make the amalgam filling material and participates in the delivery, filling and carving of the amalgam.

Because of the long term continous exposure to mercury, observations continue to be made regarding the safety of amalgam in the dental office and warnings are periodically issued concerning the toxicity associated with improper handling. Yet, despite the development of alternative, non-mercury containing restorative materials, the vast majority of dental procedures involving the treatment of dental caries, utilizes silver-mercury amalgam.

The extent of the mercury hazard has been studied in laboratories in the U.S., Europe and Australia. Using blood or urine mercury levels as indicators of biological exposure, a number of workers have reported that mercury intoxication does not occur in modern dental offices, if adequate attention is given to mercury hygiene. However, there is evidence to indicate that mercury hygiene is grossly inadequate. In a much publicized survey, Gordon and colleagues report that 40% of dental offices have "serious problems associated with the handling of mercury and potentially toxic mercury vapor levels are present in 10-15% of dental offices" (New York Times, 17th April, 1977). Reviewing the problem with dental mercury, Battistone et al. concluded that knowledge of the mercury hazard was limited by "absence of more definitive data on the actual body burden of mercury carried by the individual dentist and the functional significance of that burden." The investigation Mercury Burden and Health Impairment in Dental Auxiliaries addressed itself to measuring the body burden of mercury of dental auxiliaries and dentists. Mercury levels in select tissues were measured in situ. Using an X-ray fluorescence technique that was developed in our laboratory, to ascertain whether the mercury burden was associated with health deficits, subjects with high mercury burdens were further studied using selected tests of neurological, renal and neuropsychological function.

2. Aims of the investigation.

a. To develop a safe and effective X-ray fluorescence system for monitoring mercury and other elements in human tissues in situ.

b. To determine the mercury levels in a population of dental auxiliaries who have been occupationally exposed to mercury through contact with dental amalgam.

c. To evaluate the mercury status of other population groups. These included: (1) non-exposed age-matched females, and (2) a population of dentists who had been exposed to mercury through work-related use of mercury amalgam.

d. To ascertain whether health deficits related to normal functioning of the peripheral and central nervous systems were associated with the mercury burden.

3. Research findings.

a. The use of the X-ray fluorescence technique to measure mercury levels in human tissues in situ.

i. Introduction. Although the concentration of mercury in blood and urine has generally been accepted as an index of exposure, the analysis of these fluids has certain inherent limitations that profoundly restrict its use. The major limitation is that the mercury content of body fluids is not an indication of the total body burden. Indeed, once the exposure ceases, the blood mercury level normally declines. Thus, the mercury content of these fluids is only a measure of the current mercury exposure. Furthermore, the mercury content of these fluids is affected by variables such as time since mercury exposure, mode of intake, mercury excretion, and sequestration by different tissues.

Recognizing the inherent limitations of body fluid analysis, we have developed an X-ray fluorescence (XRF) technique to measure heavy metal concentration in teeth, bones, and soft tissue in situ. The method devised is non-invasive, safe, rapid, and sensitive to the levels of many heavy metals that accumulate in human tissues.

ii. X-ray fluorescence technique. Fluorescent X-rays from mercury produced by the filling of a K shell vacancy by an L shell electron results in the emission of a photon having energy of either 68.9 ($K_{\alpha 2}$) or 70.8 ($K_{\alpha 1}$) KeV.

Figure 1 shows scattered radiation spectrum in the energy interval between 68-72 KeV from a 20 ml volume of water containing 500 μg/g of mercury. The spectrum clearly shows the two characteristic X-ray peaks of mercury at 68.8 and 70.8 KeV. Figure 1 also shows the scattered X-ray spectrum in this energy interval from photons that have undergone Compton scattering events in the same volume of mercury-free water.

The XRF system for in vivo assay of metals consists of an intrinsic germanium diode detector (Princeton Gamma Tech Model 1 G110-7) having a cross-sectional area of 110 mm and a thickness of 7 mm. The output pulses from the germanium detector were amplified (Princeton Gamma Tech Model 34 amplifier) and sorted using a Tracor Northern 4096 channel pulse height analyzer. A sealed 10 mCi ^{57}Co point source (Amersham Searle Model X.130.5) used to excite the K shell electrons in mercury, was housed in a cylindrical tantalum shield 16 mm in diameter and 15 mm long. A bore hole 4 mm in diameter and 7 mm deep in the tantalum shield served to collimate the ^{57}Co gamma ray beam. At 2 cm from the source the radiation beam was 12 mm in diameter.

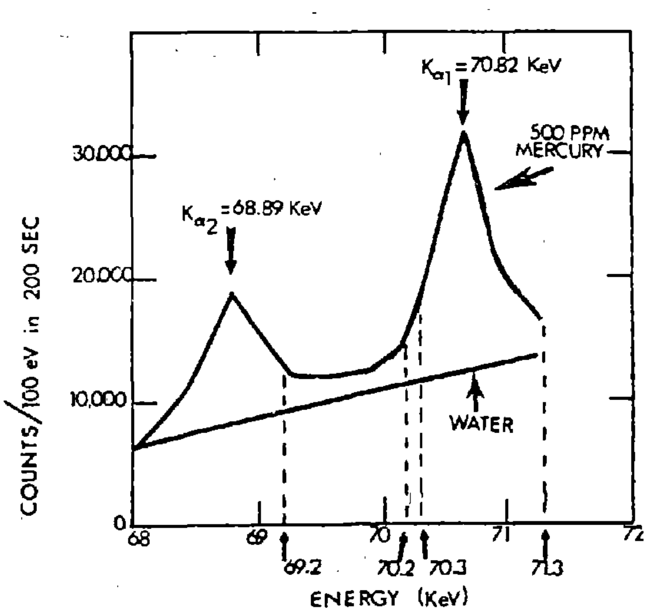

FIG. 1. Scattered radiation spectra in the energy interval between 68 and 72 keV from a 20 ml volume of water and from the same volume of water containing 500 μg/g of mercury. The number of events in the $K_{\alpha 1}$ window, 70.3–71.3 keV, and number of Compton scattered x-rays recorded in an adjacent energy interval, 69.2–70.2 keV, was used to quantify the mercury content.

iii. Mercury measurements. In the energy interval 70.3-71.2 KeV, events are recorded that result from characteristic X-rays from mercury together with Compton scattered X-rays from the water. The number of scattered X-rays recorded in the fluorescence peak of mercury are estimated by recording simultaneously the number of events in an adjusted interval 69.2-70.2 KeV.

The mercury concentration in a sample was calculated from the measured number of events in the two energy intervals using signal-to-noise ratio analysis. The signal-to-noise ratio, s/n, is defined as

$$s/n = \frac{(N_f + N_c') - N_c}{N_c} \approx \frac{N_f}{N_c} \qquad (1)$$

where N_f is the number of fluorescence X-rays recorded in the energy interval 70.3-71.3 KeV. N_c' is the number of Compton scattered X-rays recorded in the same energy interval, and N_c is the number of events recorded in the energy interval 69.2-70.2 KeV. Since N_c' is nearly the same as N_c, the signal-to-noise ratio represents the number of mercury fluorescence X-rays (signal) to the number of Compton scattered X-rays (noise). The concentration of mercury in a sample, C, in μg/g is obtained using the following expression:

$$C = K\,[(s/n - (s/n_o)] \qquad (2)$$

where K is the calibration constant, (s/n) is the signal-to-noise ratio from a sample containing unknown amounts of mercury, and (s/n_o) is the signal-to-noise ratio from a sample containing no mercury.

The measured signal-to-noise ratio was found to vary linearly with the mercury content for aqueous samples containing 0-200 μg/g of mercury. The calibration constant, K, in Equation (2), was obtained from the slope of the measured signal-to-noise ratio versus concentration, and (s/n_o) is the intercept. In practice, the equipment was calibrated daily prior to its use. Typical values of K and (s/n_o) were 3,500 μg/g and 0.07, respectively.

iv. <u>Correlations between XRF sensitivity and tissue density.</u> X-ray fluorescence was used to measure the mercury content of a number of tissues of differing density. Theoretically, the number of scattered photons from the radiated volume is directly proportional to the number of atoms irradiated. For a fixed volume, the number of atoms irradiated is directly proportional to the density of the medium. As the mercury content of both hard and soft tissues was being studied, it was necessary to verify this relationship experimentally.

The XRF signal-to-noise ratio was measured for various concentrations of mercury suspended in 20 ml solutions of differing densities. The solutions consisted of known quantities of mercuric chloride dissolved in a small amount of detergent (Contrad-D) and added to bromoform (density 2.8 g/cm^3), carbon tetrachloride-bromoform (density 2.3 g/cm^3), methanol (density 0.8 g/cm^3), and water. The sensitivity for detecting mercury, given by the slope of the curve of the signal/noise versus concentration (expressed in μg of mercury per g of substrate) was the same within ± 3% for the different density solutions. This indicates that if the calibration of the XRF equipment is known with unit density solutions, the calibrated factor, K, used for other materials can be obtained by dividing by the density of the media. For in vivo measurements, we have assumed a nominal density of 2 g/cm^3. We have chosen a nominal density of 1 μg/cm^3 for calculating the mercury content in the head.

v. Effect of overlying tissue on the XRF signal-to-noise ratio. At the outset of the investigations it was planned to use the XRF technique for the measurement of the mercury content of organs that were overlaid with connective tissue and muscle. For example, we were interested in measuring the mercury concentration in the kidneys and the liver. To determine the depth of these organs, ultrasound scans were made on 27 dentists. The liver and kidneys were found to be 5-7 cm from the posterior surface. To simulate this situation, scattering material consisting of Lucite sheets was placed in front of a solution containing 200 μg/g of mercury (20 ml). The signal-to-noise ratio was measured for this geometry at 5 cm from the source. The number of counts collected in the fluorescent window exceeded 500,000 events, resulting in a standard deviation of the signal-to-noise ratio of less than 1%.

The decrease in the signal-to-noise ratio as a function of the inserted scattering thickness is shown in Fig. 2. The figure indicates that if a large concentration of mercury (greater than 200 μg/g) is in an organ at a 5 cm depth, the overlying tissue would degrade the signal-to-noise ratio to such an extent that the mercury would be difficult to detect. Furthermore, the data indicate that to determine the concentration of mercury in an organ, in situ, it is necessary to know its depth in the tissue. The degradation in the measured signal-to-noise, with the thickness of the overlying tissue, limits the applicability of the XRF mercury assay to organs that are near a surface. Thus, the XRF technique can be used to measure the mercury concentration in

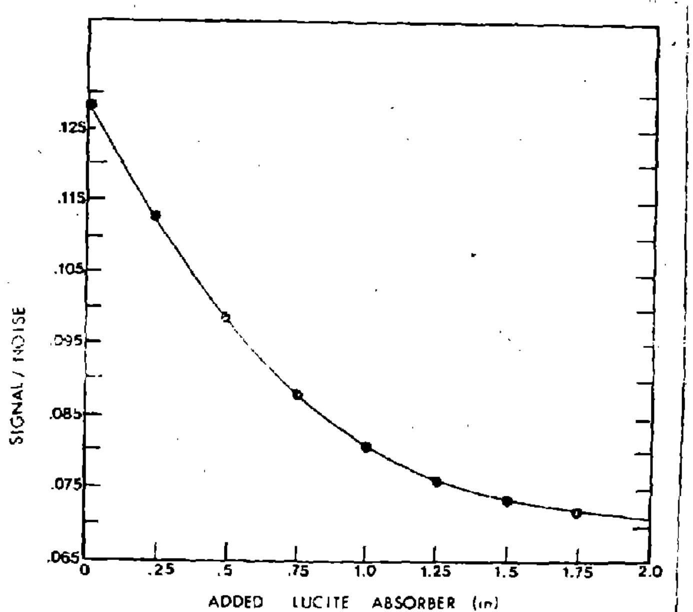

FIG. 2. Effect of scattering material on measured XRF signal-to-noise ratio.

situ of the superficial tissues in the head and bones. However, for organs located at a depth, such as the kidney and liver, the XRF technique may significantly underestimate the mercury content.

vi. Comparison of XRF and chemical assays of tissues in vitro. At postmortem, scapular, liver, kidney, lung, spleen, and sternum were obtained from a 55 year old dentist with 30 years of occupational exposure to mercury-containing amalgams. Samples of the tissue were analyzed by XRF to quantitate their mercury content. Each sample was counted for approximately 20 minutes; this resulted in approximately 900,000 measured events in the fluorescence window. The large number of events recorded for the in vitro assay resulted in sufficient precision to detect, with 70% confidence, the presence of 3 μg/g of mercury.

Table I shows the correlation between the chemical and the XRF determination ($\underline{r}$ = 0.98). The data indicate that the two assays agree within 3 μg/g. The very high concentration of mercury in the liver may indicate an acute exposure to mercury. Further, the high concentrations in the brain and bone may indicate long-term exposure. The data presented in the table is interesting in itself. However, it is only being used here to demonstrate the excellent correlation between the two mercury assays.

TABLE I. Comparison of x-ray fluorescent and chemical analysis of different tissues *in vitro*.

Sample	Density (g/cm^3)	Chemical assay (μg/g)	XRF assay (μg/g)
Bone (Scapular)	2	7.4 ± .9	4.7 ± .69
Liver	1	21.4 ± 1.3	25.0 ± 3.1
Kidney	1	0.9 ± 1.3	trace
Lung	1[a]	1.4 ± 0.2	1.8 ± .27
Spleen	1	3.7 ± 0.6	6.3 ± .82
Sternum	2	7.1 ± 0.8	7.2 ± .99

[a] Lung tissue density assumed to be unity.

b. Recruitment of the study population.

i. Dental auxiliaries. Our objective was to identify and recruit a sample of 300 chairside dental auxiliary workers that had at least 5 years continuous clinical experience. It was recognized that this may present problems, since there is significant mobility in this sector of the work force. Further, as the majority of workers are trained in the offices in which they worked, and since no certification of licensing is required, a central listing of dental auxiliaries did not exist.

The initial approach was to address a letter to dentists requesting their help in the recruitment of their Chairside Assistants (auxiliaries). At the same time, each auxiliary was informed of the rationale of the investigation, the use of the XRF technique to measure mercury, and their possible involvement in subsequent neurologic and neuropsychologic tests for measuring mercury-related health deficits. Similar letters were also sent to dental auxiliaries who worked in clinics sponsored by municipal and federal agencies.

Dentists exhibited considerable opposition to the recruitment of their auxiliaries into the study; institutional supervisors, representing municipal and federal agencies, also exhibited marked opposition to participation in the project. In many situations, resistance to the study was overt and our efforts to communicate directly with the auxiliaries were completely frustrated. In most cases, however, it was more subtle. For example, following direct mailing, and subsequent telephone calls to the auxiliaries' residence, we were advised that participation would jeopardize continued employment and that the health-related risks of mercury exposure were not considered to be of sufficient magnitude to justify participation. Less than one-third of the total sample was recruited using direct mail and telephone procedures and <u>none</u> of the institutions collaborated.

We than utilized the listings of technical training schools, including vocational secondary schools and junior colleges, to obtain the current addresses of dental auxiliaries who received some formal education or training. Following meetings with administrators, letters were sent to the alumni and telephone calls were made to respondents. In addition, we contacted offices of local dental auxiliary societies and organizers of continuing education courses. Seminars on the health risks due to the use of dental amalgam in the dental office were presented by the investigators and their assistants. Following each presentation, some auxiliaries were recruited into the study.

Examination of the sample indicated that the resultant geographic distribution of the sample by residence and by location of work did not differ from the sample of dentists (see page 12). Except for expected age and sex bias, the health inventory of the auxiliary sample was similar to that of the dentists' sample. Once the enrollment process was completed, the primary phase of the study was completed without incident and, the auxiliaries' mercury level in wrist and head was measured. Assignment for the subsequent clinical studies presented some problems such as non-attendance for the tests.

The major problem with sampling was the extended time required to recruit auxiliaries for the studies and the need to develop alternative strategies. Both of thes problems required considerable effort, ingenuity and time. Finally, since there was such uniform resistance by dentists to this project, loss of salary by participants emerged as a valid constraint. It was apparent that supervisors of dental auxiliaries were concerned that if evidence of toxicity was revealed, litigation might result. Because of the work-related constraints all candidates who volunteered for the study received a small stipend. Similar cash reimbursements were provided for those participants who were selected for the second (neuropsychological) and third (neurologic) phases of the project.

The study population resided and worked predominantly in the New Jersey-Philadelphia area. X-ray fluorescence analyses were performed on 207 dental auxiliaries. The mean age of the study population was 33.99 years ± 12.22 years (range 20-85 years). The mean number of years of dental practice was 10.76 ± 7.14 years. There was no evidence to suggest that the recruitment process resulted in a biased sample.

ii. Dentists. Two hundred and ninety-eight male dentists, age 36-65 years (mean age 54 years) practicing in the Delaware Valley region of the northeast of the United States participated in the study. Information concerning length and type of practice, frequency of use of dental amalgam, design and construction of operatory and general health was solicited by questionnaire. As with the auxiliary populations signed informed consent was obtained from all study subjects.

iii. Control population. Baseline values of the distribution of mercury level in non-exposed populations were not available. To provide this information, we accessed to the study a population of women whose body burden was assessed utilizing the same XRF procedure. These women all worked in Philadelphia, resided in the Delaware Valley and none were exposed to mercury in the course of their work. The mean age of this population was 31.38 ± 13.50 years (range 17-62 years).

c. Measurements of mercury burden X-ray fluorescence analysis.

i. Dental auxiliaries and dentists. More than 60% of the dentists (Figure 3) and about 90% of the dental auxiliaries (Figure 4) had mercury levels that were below the detection limit (20 μg/g) of the XRF technique. For both types of dental personnel, the distribution of mercury levels in the head resembled the wrist. Subtle differences between the samples were observed. In all exposure categories, the head mercury values of dentists were greater than the wrist. It is likely that these differences reflected variations in the metabolic activities and composition of the different tissues at the two sites. A different pattern was observed for the distribution of mercury values in the auxiliaries. Thus, at the high exposure level category (greater

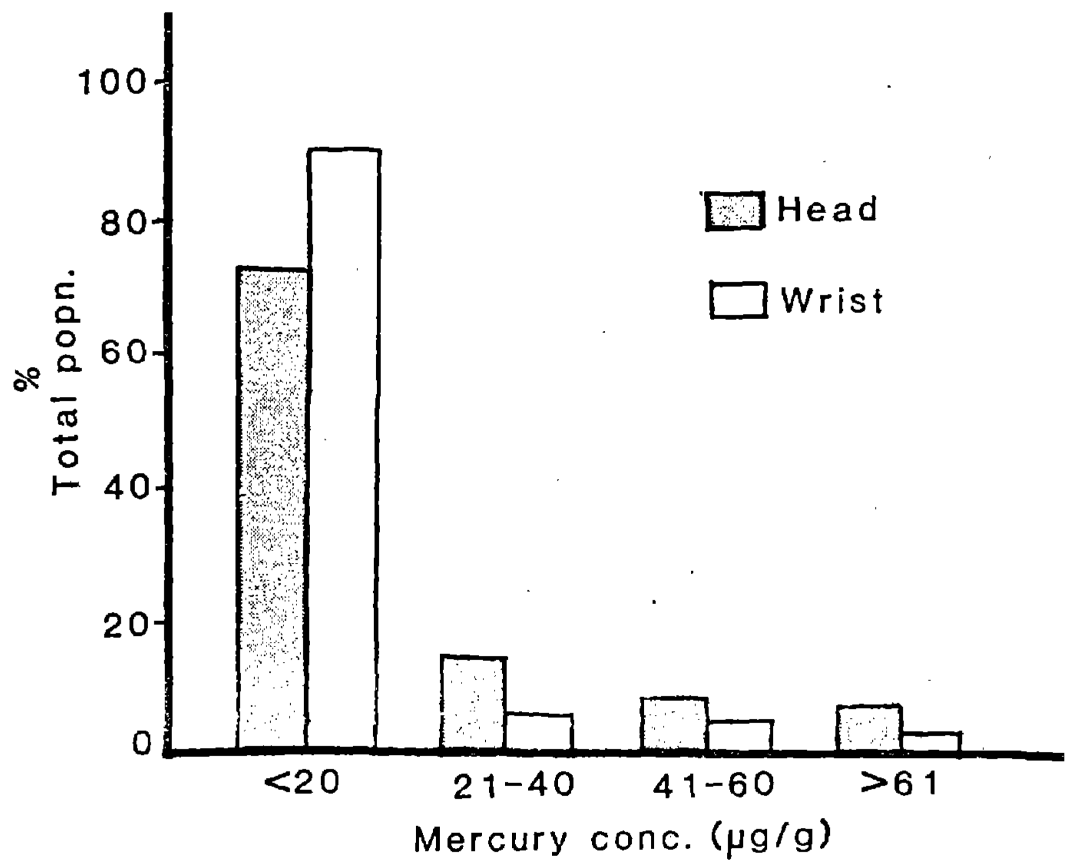

Fig. 3. Distribution of head and wrist mercury levels in dentists. Closed bars represent head mercury values; open bars represent wrist mercury values.

than 21 μg/g), there was a trend for the wrist values of a particular individual to be higher than the head. We suspect that this difference may be associated with personal hygiene. After hand washing, soap and mercury residues were deposited on the wrist. Indeed, in two individuals that were examined, the mercury level at the wrist was lowered by vigorous scrubbing of the skin at the wrist.

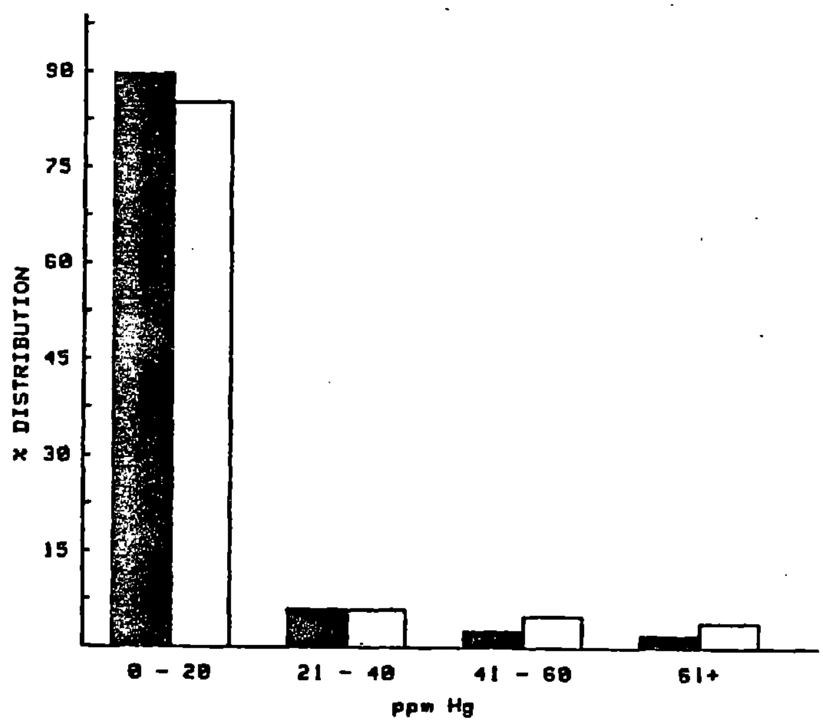

Fig. 4. Distribution of head and wrist mercury values in auxiliaries. Closed bars represent head mercury levels; open bars represent wrist mercury values.

ii. Control population. Data are not presented for the distribution of mercury values in the control population. This is because mercury was not present in any measurable amounts in subjects of this group. This finding is what might be expected from a non-exposed population.

d. Neurological evaluations.

i. Introduction. Neurophysiological evaluations were carried out on individuals ranked on the basis of their mercury level to be in the highest 10%. Neuropsychological evaluations were performed on the upper mercury-ranked 25% of the population. Control values were obtained from subjects with no evidence of mercury accumulation in their tissues. It should be noted that prior to being accepted into the study, medical histories were completed for all participants. Nevertheless, when abnormalities of function were noted and more detailed medical examinations were required, medical explanations were often found for the mono- or polyneuropathies or abnormal psychomotor test results. Data from these individuals who had pre-existing neuropathies were not included in the statistical analyses. To obtain comparative values, a similar number of individuals who were ranked in the bottom 10 and 25% of the population respectively and who had no measurable quantities of mercury in their head or wrist were also studied by both neurological and neuropsychological tests.

ii. Methods. Sensory action potentials of the sural, median and ulnar nerves were measured with near-nerve subcutaneous pin-electrodes ("grass E2B"). Sensory amplitudes were measured peak to peak after computer averaging of 8-64 responses (EISA-15607 or TECA TE4-DAB6). Sensory velocities were measured from the stimulus artifact to the peak of the first positive wave. Further conduction studies of the median and perineal nerves were done by percutaneous nerve stimulation. Muscle compound action potentials were recorded by the use of subcutaneous muscle belly-tendon needle electrodes. Compound action potentials amplitudes were measured from baseline to negative peak. Minimum F-wave latencies for at least 20 responses were also determined for these motor nerves. Limb temperatures were kept at 36°C by an external source. Mean values of the two groups were compared by the use of the Student *t*-test and the *t*-test was used to compare individual values with those of laboratory controls.

iii. Results: Dentists. Table 2 shows that the mean sural sensory and median motor conduction velocities of the high mercury group were significantly slower than those of the controls ($p < 0.05$). In addition, the high mercury group had a significantly longer median motor distal latencies ($p < 0.0005$) and median F-wave latency ($p < 0.01$).

Table 2

-RESULTS OF ELECTROPHYSIOLOGICAL TESTS OF PERIPHERAL FUNCTION IN DENTISTS

Nerves tested	High-mercury group (n = 23)	Controls (n = 22)
Sensory		
Sural		
Amp (μV)	17±10(1–50)	21±17(9–90)
CV (ms^{-1})	45±6(34–56)	48*±6(33–60)
Ulnar		
Amp (μV)	14±7(4–31)	12±4(6–22)
CV (ms^{-1})	52±5(43–62)	54±3(48–60)
Median		
Amp (μV)	17±7(8–31)	16±5(10–29)
CV (ms^{-1})	52±7(40–65)	54±4(47–65)
Motor		
Peroneal		
DL (ms)	3·9±0·6 (2·9–5·1)	3·8±0·8(3·0–6·4)
Amp (mV)	7±3(1–13)	6±4(2–14)
CV (ms^{-1})	45±5(38–53)	45±4(37–57)
F (ms)	51±5(42–64)	50±4(43–58)
Median		
DL (ms)	4·0±0·7(3·1–5·2)	3·5‡±0·4(3·1–4·3)
Amp (mv)	13±3(4–20)	11±4(4–19)
CV (ms^{-1})	54±3(48–61)	56*±4(49–62)
F (ms)	30±3(25–35)	28†±2(25–31)

Results are given as mean±SD; range in parentheses
Amp = amplitude of the evoked response; CV = conduction velocity; DL = distal latency; F = minimum latency of 20 F wave responses
*p<0·05 between the two groups; †p<0·01; ‡p<0·005.

When values obtained from the individual dentists were compared with our laboratory controls, further abnormalities were seen (Table 3). Five dentists in the high mercury group had electrode physiological abnormalities consistent with Carpal Tunnel Syndrome (CTS)--i.e., a median motor distal latency greater than 4.6 ms and/or slowed median sensory conduction across the wrist, with normal median motor conduction in the forearm. These abnormalities were not seen in the control dentists (p = 0.03). Polyneuropathies, defined as reduced motor or sensory conduction velocities of response amplitudes in two or more nerves were found in seven dentists, all in the high mercury group (p = 0.08). Three of these seven dentists had as one manifestation of their polyneuropathy localized slowing of conduction at the wrist consistent with CTS.

Table 3

ELECTROPHYSIOLOGICAL FINDINGS IN DENTISTS WITH RAISED TISSUE MERCURY LEVELS AND NEUROPATHY

Nerves tested	Subject no:									Normal	
	1	2	3	4	5	6	7	8	9	Upper limit	Lower limit
Sensory											
Sural											
Amp (μV)	5	9	15	9	10	14	1	21	14	NA	10
CV (ms^{-1})	36·8	41·1	38·9	41·2	42·8	48·2	33·7	55·7	41·1	NA	40
Ulnar											
Amp (μV)	5	10	14	11	9	22	4	11	10	NA	8
CV (ms^{-1})	42·8	43·7	53	55·5	46·1	42·5	57·1	50	52·2	NA	48
Median											
Amp (μV)	8	14	11	10	15	25	16	8	7·5	NA	10
CV (ms^{-1})	42·8	39·3	58·5	42·1	45·3	48·3	53·7	46·5	45·1	NA	48
Motor											
Peroneal											
DL (ms)	5·1	4·7	3·8	3·7	4·1	4·3	4·9	2·9	3·6	5·5	NA
Amp (mV)	13	3	4	1·2	10	5·5	9	6	6	NA	1
CV (ms^{-1})	47·8	44·9	39·1	41·8	41·0	41·0	41·2	43·2	52·9	NA	40
F (ms)	55·2	. .	64·3	51·5	52	52·5	57·2	49·8	50·9	NA	NA
Median											
DL (ms)	4·8	5·2	3·9	4·9	5·0	4·9	4·1	4·7	4·7	4·6	NA
Amp (mV)	13	18	19	15	5	17	8	13	13	NA	3
CV (ms^{-1})	48·8	53·7	47·8	53·5	48·1	56·5	53·8	51·7	51·7	NA	50
F (ms)	32·3	34·1	32·7	31·8	34·4	32	31·9	30·4	31·5	NA	NA

Normal values are those of laboratory controls. Abbreviations as for table I. . . = no reading taken. NA = not applicable.

iv. Results: Dental auxiliaries. Neurological studies were conducted on individuals having high mercury burdens and on auxiliaries who had no measurable quantities of mercury in their head and wrist. The data are presented in Table 4. When subjected to multivariate analysis, no significant differences were observed between the groups with respect to mean conduction velocity and amplitude of the sural, peroneal, ulnar and median nerves; there were no significant differences in the F-wave latencies of the peroneal and median nerves. Furthermore, the neurological values of all of the subjects fell within the normal range. It should be emphasized that the two groups of auxiliaries differed only in their tissue mercury levels. All subjects in this group were female, their mean ages were similar (high mercury group 44 ± 14 years, control groups 41 ± 11 years) and they had similar periods of exposure to amalgam (high mercury group, 16 ± 8 years; control group, 13 ± 5 years). Accordingly, the data indicate that no abnormalities of peripheral neurologic function, as measured by these tests, were associated with elevation in tissue mercury levels.

Table 4. Results of Electrophysiological Tests of Peripheral Nerve Function in Auxiliaries

Nerve tested	High mercury group (n = 9)	Control (n = 13)
Sensory		
Sural		
Amp (μV)	25 ± 20 (9-72)	26 ± 13 (13-54)
CV (ms^{-1})	48 ± 6 (39-57)	55 ± 4 (48-60)
Ulnar		
Amp (μV)	17 ± 5 (11-25)	18 ± 9 (10-37)
CV (ms^{-2})	53 ± 3 (49-61)	58 ± 4 (49-63)
Median		
Amp (μV)	27 ± 17 (11-58)	29 ± 13 (13-63)
CV (ms^{-1})	54 ± 6 (40-61)	55 ± 9 (30-66)
Motor		
Peroneal		
DL (ms)	3.5 ± 1.2 (2.7-6.6)	3.2 ± 0.5 (2.6-4.5)
Amp (μV)	6 ± 3 (1-10)	5 ± 2 (2-8)
CV (ms^{-2})	48 ± 5 (41-57)	51 ± 4 (48-56)
F (ms)	44 ± 10 (41-55)	44 ± 4 (29-54)
Median		
DL (ms)	3.4 ± 0.5 (2.6-4.0)	3.1 ± 0.5 (2.6-4.6)
Amp (mV)	9 ± 5 (5-17)	12 ± 2 (8-15)
CV (ms^{-1})	59 ± 4 (52-65)	59 ± 6 (49-66)
F (ms)	27 ± 2 (24-30)	23 ± 6 (22-31)

Results are given as means ± S.D.; range in parentheses.
Amp = amplitude of the evoked response; CV = conduction velocity; DL = distal latency; F = minimum latency of 20 F wave responses.

e. Neuropsychological evaluations.

i. Methods. Neuropsychological evaluations were administered to the dental auxiliaries and dentists in the high mercury and in the control groups. These consisted of the assessments according to the Weschler Adult Intelligence Scale (WAIS) and the Bender-Gestalt, Finger Tapping and Grooved Pegboard Tests. In addition, the auxiliaries were also subjected to Rey's A-V Learning, Recurrent Figures and PASAT Tests. Perceived symptoms were assessed by the use of the symptom check list (SCL-90-R). Scoring for the Bender-Gestalt was done blind following the procedures described by Pascal and Suttell. The neuropsychological tests lasted about 2.5 hours.

ii. Results.

Dentists. The full-scale intelligence quotient scores (WAIS) of the two groups were nearly identical (Table 5). A Bonferroni t statistic for multiple comparisons showed that the Bender-Gestalt Test values of the high mercury group were significantly different from those of the controls ($p < 0.01$). The Finger-Tapping-Rate and the Grooved Pegboard Tests did not indicate differences between the high-mercury and the control groups. The median T-value of the General Distress Index, an overall measure of distress levels was 58 (range 33-73) for the high mercury group and 53 (range 41-67) for the control group. Fourteen dentists in the high mercury and 3 in the control group had T-scores greater than the normal range (40-60). This difference between the number of raised scores in the two groups is significant according to the X^2 test ($p < 0.05$).

Table 5

NEUROPSYCHOLOGICAL TESTS IN DENTISTS

Test	High-mercury group (n=26)	Control group (n=17)
WAIS full scale	123 (1·5)	124 (1·4)
*Bender-Gestalt (errors)**	65 (1·8)	58 (2·9)
Grooved pegboard (sec)		
Preferred hand	67 (1·3)	64 (1·8)
Non-preferred hand	72 (1·7)	70 (1·4)
Finger tapping (rate)		
Preferred hand	70 (1·5)	73 (1·7)
Non-preferred hand	64 (1·3)	64 (2·0)

Results given as means; SEM in parentheses.
*$p<0 \cdot 01$.

Dental auxiliaries. Because of considerable variations in the age of the dental auxiliaries that participated in the study, subjects who had high mercury burdens were matched for both age and years of work. The mean age of the high mercury group was 42.2 ± 13.0 years; the mean age of the matched control group was 39.8 ± 10.2 years. The number of years of work experience for the high mercury and control groups was 15.3 ± 6.1 and 13.8 ± 5.0 years respectively. Table 6 shows the values obtained for neuropsychological tests conducted on the two groups. The intelligence quotient scores (WAIS) for the high mercury and the control groups were very similar. Significant differences in neuropsychological test performances were seen between the two groups. Thus, the Recurrent Figures Test and the Grooved Pegboard Test (non-dominant hand) were different at $p < 0.01$ and 0.05 levels respectively.

Table 6. Results of Neuropsychological Tests Conducted on Dental Auxiliaries

Test	High mercury group (n = 13)	Control group (n = 13)
WAIS (full scale)	104 ± 1.6	106 ± 2.6
Bender-Gestalt (errors)	64.5 ± 4.3	62.5 ± 3.1
Rey's A-V Learning (number correct)		
Trial I	5.8 ± 0.4	6.5 ± 1.3
Trial V	12.5 ± 0.5	13.2 ± 0.4
Recurrent Figure** (number correct)	15.2 ± 0.7	18.6 ± 1.2
PASAT (number correct)	26.9 ± 2.7	30.3 ± 3.4
Finger Tapping (rate)		
Dominant hand	53.5 ± 2.7	48.5 ± 2.1
Non-dominant hand	46.9 ± 2.6	45.8 ± 2.5
Grooved Pegboard (time)		
Dominant hand	67.3 ± 3.1	63.4 ± 2.5
Non-dominant hand*	76.6 ± 4.8	64.7 ± 2.3

Results given as means ± SEM.
*$p < 0.01$.
**$p < 0.05$.

The self reported symptom distress values for the dental auxiliaries is presented in Table 7. For each of the eleven items scored on the check list, the high mercury group exhibited more distress than the control group. Symptom dimension in the obsessive-compulsive, interpersonal sensitivity, anxiety and paranoid ideation categories were significantly different using the Mann-Whitney U Test. The Global Distress Index and Positive Symptom Total which are cumulative measures of distress indicated that the high mercury group was higher than the control.

Table 7. Symptom Distress Check List (SCL-90R) Values for Dental Auxiliaries

Symptom dimensions	High mercury group	Control group
Somatization	0.49 ± 0.8	0.38 ± 0.11
Obsessive-Compulsive **	0.98 ± 0.16	0.42 ± 0.08
Interpersonal Sensitivity*	0.69 ± 0.17	0.32 ± 0.07
Depression	0.72 ± 0.12	0.37 ± 0.08
Anxiety*	0.36 ± 0.10	0.09 ± 0.03
Hostility	0.37 ± 0.11	0.26 ± 0.07
Phobic Anxiety	0.14 ± 0.07	0.08 ± 0.04
Paranoid Ideation**	0.57 ± 0.15	0.26 ± 0.08
Psychotism	0.22 ± 0.07	0.04 ± 0.02
General Distress Index**	0.52 ± 0.09	0.26 ± 0.04
Positive Symptom Total**	32 ± 4	13 ± 3

Results presented as means ± SEM.
*$p < 0.05$.
**$p < 0.01$.

4. Conclusions. With reference to dentists, the X-ray fluorescence values of the wrist and head indicated that a considerable percentage of dentists had elevated body burdens of mercury. If the sample we studied is representative of dentists nation-wide, then a large number of dentists have high levels of exposure to mercury and may have evidence of functional abnormalities. The dental auxiliary population had considerably lower levels of mercury than the dentists. This need not necessarily indicate lower levels of exposure, but could indicate a shorter period of exposure. Nevertheless, a small proportion of auxiliaries had elevated levels of mercury in their tissues.

The study revealed that the tissue mercury level is associated with deficits in neurophysiological and neuropsychological function. In dentists, both functions were seen to be affected. Thus, 30% of dentists with raised tissue mercury levels had electrophysiological evidence of a subclinical polyneuropathy. Polyneuropathies were not found in dentists without tissue mercury accumulation (p = 0.008); 22% of dentists in the high-mercury group had electrophysiological delays characteristic of the Carpal Tunnel Syndrome (CTS). The CTS is not unusual in persons pursuing a manual occupation. It has been reported to be present in 2 of 19 dentists (10%)* However, in our study, all 5 cases of CTS came from the high-mercury group (p = 0.03). Experiments have shown that neurotoxins predispose peripheral nerves to local damage at common sites of entrapment, so subclinical mercury vapor exposure may also predispose the median nerve to local damage at the wrist.

Despite careful neurophysiological evaluation of dental auxiliaries with the highest mercury burdens, no evidence of neurophysiological dysfunction was observed. We believe that this is probably due to the shorter work-related exposure period of this group of women, and the lower level of accumulated mercury in the tissues of this group.

The neuropsychological tests showed that both groups of dental workers were adversely affected by exposure to mercury. In dentists, mild neuropsychological impairment in the high-mercury group was indicated by more visuographic alterations (number of errors by the mercury group in copying the Bender-Gestalt designs) and high distress levels (measured from symptom self-reports on a check list) than in the control group. In general, these findings accord with previous descriptions of the effects of mercury exposure in humans. Surprisingly, despite the low levels of mercury exposure, mild neutopsychologi-

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*Dyck, P. J., et al., Anaesthiology 53, 205 (1980).

cal impairment were also seen in dental auxiliaries. Deficits in performance in the Grooved Pegboard and the Recurrent Figures Tests were observed. In addition, auxiliaries in the high mercury group exhibited a higher distress level in all symptom dimensions than the control group. It is therefore concluded that despite the lower exposure levels, health risks are associated with the use of dental amalgam by auxiliary workers in general dental practices.

Finally, it should be noted that data were cellected on the design of the work place, the type and frequency of operations performed, and duration of practice. Data on frequency of contact with amalgam, social factors, habits, and previous illnesses were also obtained. Analyses of such information for factors predisposing the dentist and the auxiliary to neurophysiological-neuropsychological deficits did not show differences between the high-mercury and the control groups. Thus, no single factor seemed to account for the differences in the health status of the high mercury and control groups other than variations in mercury levels.

One series of evaluations that needs to be performed relates to the presence of dental amalgam in the teeth of dental workers. While it has been assumed that filings are biologically inert, this assumption has not been tested. Clearly, it would be desirable to know whether dental amalgams: (1) can act as point-sources of mercury, and to what extent amalgams contribute to the body burden; (2) can result in, or exacerbate health deficits associated with mercury. Answers to these questions are of importance not only to dental workers, but also to the public that receives amalgam filings as the major restorative material.

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