Prospective study of hepatic, renal, and haematological surveillance in hazardous materials firefighters

S N Kales, G N Polyhronopoulos, J M Aldrich, P J Mendoza, J H Suh, D C Christiani

Abstract

***Objectives*—To evaluate possible health effects related to work with hazardous materials as measured by end organ effect markers in a large cohort over about 2 years, and in a subcohort over 5 years.**

***Methods*—Hepatic, renal, and haematological variables were analysed from 1996–98 in hazardous materials firefighters including 288 hazardous materials technicians (81%) and 68 support workers (19%). The same end organ effect markers in a subcohort of the technicians were also analysed (n=35) from 1993–98. Support workers were considered as controls because they are also firefighters, but had a low potential exposure to hazardous materials.**

***Results*—During the study period, no serious injuries or exposures were reported. For the end organ effect markers studied, no significant differences were found between technicians and support workers at either year 1 or year 3. After adjustment for a change in laboratory, no significant longitudinal changes were found within groups for any of the markers except for creatinine which decreased for both technicians ($p<0.001$) and controls ($p<0.01$).**

***Conclusions*—Health effects related to work are infrequent among hazardous materials technicians. Haematological, hepatic, and renal testing is not required on an annual basis and has limited use in detecting health effects in hazardous materials technicians.**

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Occupational Medicine, Department of Medicine, The Cambridge Hospital, 1493 Cambridge Street, Cambridge, MA 02139, USA
S N Kales
G N Polyhronopoulos
J M Aldrich
P J Mendoza
J H Suh

Harvard Medical School, and Harvard School of Public Health, Department of Environmental Health (Occupational Health Program), Boston, MA, USA
S N Kales
D C Christiani

Pulmonary Critical Care Unit, Massachusetts General Hospital
D C Christiani

Center for Occupational and Environmental Medicine, Massachusetts Respiratory Hospital, Braintree, MA, USA
D C Christiani

Correspondence to:
Dr S N Kales
stefokali@aol.com

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Accidents that involve hazardous materials may potentially occur during the manufacture, transport, storage, sale, use, or disposal of a chemical substance. The United States Agency for Toxic Substances and Disease Registry (ATSDR) has suggested that over 400 000 people in the United States may be involved as first responders to accidents that involve hazardous materials. These include emergency medical technicians, firefighters, police, and others.[1] An increasing number of communities and industries have developed hazardous materials (hazmat) teams composed of people specially trained to respond to chemical spills, fires, and accidents. Also, there are over 1 million people in the United States involved in firefighting.[2] Firefighters have become increasingly involved in the response to accidents that involve hazardous materials.[3 4]

The United States Occupational Safety and Health Administration (OSHA) standard on hazardous waste workers (29 CFR 1910.120) requires medical examinations for hazardous waste workers including members of hazardous materials response teams.[5] An identical United States Environmental Protection Agency (EPA) standard (40 CFR 11) applies to state and municipal employers in states without designated OSHA programmes.[1 6] The OSHA standard requires examinations before starting work as well as periodic examinations at least every 2 years, but the content of the examinations is not specified.

Because of the myriad and mixed nature of the exposures, most medical surveillance programmes have included end organ effect markers (complete blood counts, renal and hepatic function tests, etc) in their examination programmes.[7] These common practices agree with recommendations that such haematological and biochemical testing be considered as part of the medical examination process for hazardous waste workers[1 8 9] and for firefighters.[10–12]

Despite the widespread use of these medical surveillance tests, limited information is available at present on the health effects of work with hazardous materials and the usefulness of monitoring end organ effect markers. A cross sectional study contrasted 55 clinical chemistry, haematological, and urinary variables between workers with more or less exposure to hazardous waste.[13] The only variable that consistently distinguished the two groups was a clinically unimportant one, mean corpuscular volume. In a small, prospective study of 40 hazardous materials firefighters, we found few biochemical abnormalities and none that could be specifically linked to exposures or response to accidents.[14] We did, however, find significant (but not clinically important) changes in paired means testing of some of the indices which warranted longer longitudinal follow up.

The current study was undertaken to further evaluate possible health effects of hazardous materials firefighting work as measured by end organ effect markers in a larger cohort over a period of about 2 years, and in our original cohort over 5 years.

Methods

SUBJECTS

The subjects were 356 members of six regional hazmat response teams of the Commonwealth of Massachusetts who underwent state man-

Table 1 Study population 1996–8

	Total (n (%))	Technicians (n (%))	Support (n (%))
1996/97 Year 1:			
Examined	340 (100)*†	268 (79)	72 (21)
Changes between year 1 and year 3 examinations:			
Dropouts or inactive after initial examination	24 (100)†	19 (79)	5 (21)
New members joined after initial examination	16 (100)*	10 (62)	6 (38)
Position changes‡	14 (100)†	2 (14)	12 (86)
1998 Year 3:			
Examined	332 (100)	269 (81)	63 (19)

*Total examined 1996–8 was 356=340+16.
†Total who were examined in both years and did not change jobs was 302=340−(24+14).
‡12 Support became technicians and two technicians became support.

dated medical surveillance and fitness for duty examinations in either 1996–97 (year 1) or 1998 (year 3) of the primary study. All firefighters were examined on a confidential basis. The review of the medical records of firefighters for research purposes was approved by the institutional review boards of the Harvard School of Public Health and The Cambridge Hospital.

All of the subjects were also members of municipal fire departments as well as their hazmat duty with the state teams. In 1996–97 (year 1) of the primary study, the initial cohort (n=340) included 268 (79%) hazardous materials technicians and 72 (21%) support workers. Most of the technicians were already members of the hazardous materials teams before the start of the study.

Of the initial cohort (n=340), 24 firefighters (19 (79%) hazardous materials technicians and five (21%) support workers) were examined only in year 1. They either left the teams before the 1998 (year 3) examination, became inactive members and were not reexamined in 1998, or their 1998 results (n=2) were missing from the medical record repository. Also, between year 1 and year 3, a total of 16 new members (10 (62%) technicians and six (38%) support workers) joined the teams and were examined only in 1998 (year 3).

Three hundred and sixteen firefighters (249 (79%) hazardous materials technicians and 67 (21%) support workers) were examined in 1996 or 1997 (year 1) and remained active with the team to the 1998 (year 3) examination. However, within these 316 firefighters, 14 changed positions at some point after the year 1 and before the year 3 examination. More specifically, 12 support workers became technicians, and two technicians became support workers. The study population is summarised in table 1.

Therefore, 302 firefighters (247 (82%) hazardous materials technicians and 55 (18%) support workers) were examined in 1996 or 1997 (year 1), remained active with the team to the 1998 (year 3) examination, and did not change positions between 1996 and 1998.

EXPOSURE

Technicians are involved with the actual assessment and mitigation of accidents that involve hazardous materials within the "hot" or contaminated zone of the accident. Most situations are responded to on a "level A" basis which entails the use of vapour tight clothing and a positive pressure self contained breathing apparatus (SCBA). Field decontamination is routinely performed after all accidents unless the hazard poses a threat only by pulmonary absorption—for example, carbon monoxide.

During work with hazardous materials, support workers are presumed to have very limited potential exposure compared with technicians, as they do not enter the hot or contaminated zone of an accident and their role is ancillary. Both technicians and support workers perform regular fire duty with their non-state, local fire departments. As support workers are not exposed in their hazmat duties but do serve as municipal firefighters, they are an ideal control group for the investigation of potential health effects limited to those arising from duty within the contaminated zone of hazmat accidents.

BASELINE AND FOLLOW UP MEDICAL EXAMINATIONS

Year 1 medical surveillance examinations for 340 firefighters were performed at one of three hospitals in 1995 (1%), 1996 (82%), or 1997 (17%) during the first year of a statewide surveillance programme. Less (n=214) were examined during the year 2 examinations in 1997. This was due to an administrative decision by the Commonwealth of Massachusetts in 1997 to have all teams' subsequent examinations conducted within a 2 month period in the autumn of each year. As the year 1 examinations were conducted throughout 1996 and part of 1997 and 16 months is the maximum period allowed between examinations, some firefighters were not re-examined until the autumn of 1998. Nearly all year 3 examinations (98%) were done in September or October of 1998.

Forty technicians from team 1, the major Boston area hazmat team, had baseline examinations conducted at hospital 2, one of the three hospitals already mentioned, between November 1992 and August 1993. Thirty seven technicians from this group had follow up examinations performed in April and May of 1995. We previously reported on the results of their 1992–3 and 1995 examinations.[14] Thirty seven technicians from this original cohort participated in the statewide year 1 (1996–7) and 34 in the year 2 (1997) examinations conducted in the statewide programme. Finally, 35 of the original technicians remained active to year 3 and were examined again in 1998. Therefore, this subgroup (n=35, 10%) of the total cohort (n=356) had longitudinal follow up data over 5 years at 5 time points available for study.

All examinations were conducted in a similar way. Examinations included a detailed medical, smoking, environmental, and occupational history tailored to emergency responders; physical examination; visual and audiometric testing; routine laboratory tests (complete blood count, blood urea nitrogen, creatinine, alkaline phosphatase, aspartate aminotransferase (AST), alanine aminotransferase (ALT), and urinary analysis); and spirometry.

Table 2 Characteristics of technicians versus support (year 1)

	Technicians (n=268)	*Support (n=72)*	*p Value*
Age (mean (SD))	40.60 (6.43)	34.89 (6.89)	<0.001
BMI (mean (SD))	29.10 (4.16)	28.35 (3.61)	0.137
Sex (male) (n (%))	267 (99.63)	69 (95.83)	0.031
Increased blood pressure (n (%))	31 (11.57)	5 (6.94)	0.258
Antihypertensive medication (n (%))	18 (6.72)	2 (2.78)	0.268
Increased blood pressure or antihypertensive medication (n (%))	44 (16.42)	5 (6.94)	0.042
Diabetes mellitus (n (%))	8 (2.98)	0	0.211
Lipid lowering agent(s) (n (%))	8 (2.98)	0	0.211
Cholesterol >6.22 mmol/l (>240 mg/dl) (n (%))*	63 (23.50)	12 (16.67)	0.024

MEDICAL RECORDS REPOSITORY

Summary results of each firefighter's examination were transferred to hospital 2 where they were entered into a statewide computerised medical record repository. The repository facilitates tracking any incident related injuries and exposures requiring transport to a hospital. In such cases, the local treating hospital requests medical information from the repository and each request is dated and logged with the name of the firefighter and the hospital requesting the records. This enables the investigators to obtain additional medical information from the local treating hospital.

STATISTICAL ANALYSES

Differences between groups at a single time point were examined with independent *t* tests and separate variances. Differences in mean values for paired comparisons within groups—for example, year 1 *v* year 3—were examined with paired *t* tests. Differences in proportions were compared with the standard (Pearson's) χ^2 test unless one or more cells contained an expected value less than 5. In that case, we used Fisher's exact test. For the team 1 subcohort, analyses of variance (ANOVAs) were used to look for differences among the means as a factor of time for the 5 years studied. If a significant difference among the 5 years was found, then a paired *t* test was used to compare the 1992–3 mean with the 1998 mean. The level of significance for all analyses was $p < 0.05$, and was two tailed for all tests.

ADJUSTMENT OF 1998 ALT VALUES DUE TO A CHANGE IN REFERENCE LABORATORY

In preliminary analyses, in independent *t* tests between technicians and support workers for both years 1 and 3, we found no differences between groups for ALT. In paired *t* tests, however, ALT increased significantly and to a similar magnitude for both subject groups from year 1 to year 3. Further analyses of ALT values (appendix 1), showed that the increases in 1998 were limited to one hospital that changed its reference laboratory in 1998. The reference interval of this laboratory had the same range but the minimum and maximum normal values were both 20 units higher than the reference interval of the previous laboratory . The mean ALT values at this hospital in 1998 were about 20 units higher than those of previous years but had similar SDs. Therefore, 1998 ALT values obtained from this laboratory were lowered 20 units for each affected subject before the statistical analyses presented here. Values for the other hospitals were not adjusted.

Results

DEMOGRAPHICS: BASELINE AND FOLLOW UP

At year 1 of the study, the cohort of 340 firefighters had a mean (SD, range) age of 40 (6.4, 28–58.) years. At year 3, the follow up cohort of 316 firefighters and the total population of those who were examined in year 3 (n=332) both had a mean (SD, range) age of 41 (6.9, 22–59) years. The population included the same four women (1%) at both time points.

Table 2 summarises the characteristics of the technicians and support controls in year 1. The mean (SD) age of the technicians was significantly greater (p<0.001) than the mean age of the support workers ((n=253) 41 (6.4) versus (n=70) 35 (6.9)). Although both groups were predominantly men, there was a higher proportion of female (4.2%) support controls than female technicians (0.4%, p<0.05). Higher proportions of technicians than support workers had increased blood pressures (systolic>140 or diastolic>90), reported taking antihypertensive medications; had a diagnosis of diabetes mellitus; were on lipid lowering agents, and had increased cholesterol measurements (cholesterol >6.22 mmol/l or >240 mg/dl). These differences were significant for cholesterol >6.22 mmol/l and for increased blood pressure and use of antihypertensives (both p<0.05).

χ^2 Tests showed no differences in the proportions of technicians (78%–81%) and support workers (20%–22%) examined at each of the three hospitals in year 1 (p=0.971). Likewise, these proportions of technicians (77%–84%) and support workers (16%–23%) did not differ significantly among the three hospitals in year 3 (p=0.852).

We found no difference at year 1 between the mean (SD) age of firefighters who remained on the teams (n=303) 39 (6.9) and the mean (SD) age of those who left the teams or were inactive in year 3 (n=20) 40 (8.2). Among the 24 subjects who either left the teams or were inactive in 1998 (year 3), the proportions of technicians and support workers were the same as the rest of the initial cohort: 79% and 21% (χ^2, p=1.000), respectively.

MEDICAL RECORDS REPOSITORY

We had no record requests from outside treating hospitals for assistance in the treatment of any team member. During the study period, no significant injuries or exposures due to work with hazardous materials were reported to the Commonwealth of Massachusetts Office of Hazardous Materials Response, which administers the teams.

LIVER FUNCTION TESTS

We found no significant differences between the liver function tests of technicians and support controls at year 1 (baseline) nor year 3 (follow up, table 3). We also found no differences in liver function tests at year 1 between subjects who remained active to the

Table 3 Cross sectional comparisons of hazmat technicians v support controls at year 1 and year 3 examinations (independent samples t tests)

Variable	*Year*	*Technicians*	*Support*	*p Value*
Liver function tests:				
Alkaline phosphatase (U/l)	Year 1	82 (21) n=266	84 (22) n=70	0.491
	Year 3	82 (20) n=269	84 (19) n=63	0.339
Aspartate aminotransferase (U/l)	Year 1	25 (10) n=266	24 (9) n=71	0.360
	Year 3	25 (10) n=269	25 (9) n=63	0.805
Alanine aminotransferase (U/l)	Year 1	36 (20) n=266	35 (21) n=71	0.652
	Year 3	36 (18) n=269	38 (18) n=62	0.418
Renal function tests:				
Blood urea nitrogen (mmol/l)*	Year 1	5.7 (1.4) n=268	5.7 (1.4) n=71	0.999
	Year 3	5.3 (1.4) n=269	5.7 (1.4) n=63	0.145
Creatinine (μmol/l)†	Year 1	97 (18) n=268	97 (18) n=71	0.161
	Year 3	88 (18) n=269	88 (18) n=63	0.938
Haematological tests:				
White blood cells ($\times 10^9$/l)	Year 1	6.6 (2.2) n=266	6.6 (1.4) n=71	0.876
	Year 3	6.6 (1.7) n=269	6.7 (1.6) n=63	0.682
Packed cell volume (fraction)	Year 1	0.45 (0.02) n=265	0.45 (0.03) n=71	0.698
	Year 3	0.46 (0.03) n=269	0.46 (0.03) n=63	0.165
Platelet count ($\times 10^9$/l)	Year 1	239 (51) n=268	252 (58) n=70	0.099
	Year 3	231 (53) n=269	246 (52) n=63	0.053

*mg/dl=2.81 (mmol/l).
†mg/dl=μmol/(88 l).

Table 4 Comparisons of year 1 data for active (remained active to the end of year 3) v inactive team members (not active in year 3) (independent samples t tests)

Variable	*Active*	*Inactive*	*p Value*
Liver function tests:			
Alkaline phosphatase (U/l)	83 (21) n=313	76 (25) n=23	0.231
Aspartate aminotransferase (U/l)	25 (10) n=313	24 (9) n=24	0.927
Alanine aminotransferase (U/l)	36 (20) n=313	38 (22) n=24	0.694
Renal function tests:			
Blood urea nitrogen (mmol/l)*	5.7 (1.4) n=315	5.7 (1.1) n=24	0.660
Creatinine (μmol/l)†	97 (18) n=315	106 (8.8) n=24	0.102
Haematological tests:			
White blood cells ($\times 10^9$/l)	6.6 (2.1) n=313	6.1 (1.3) n=24	0.078
Packed cell volume (volume fraction)	0.45 (0.02) n=312	0.45 (0.02) n=24	0.256
Platelet count ($\times 10^9$/l)	243 (53) n=314	228 (48) n=24	0.151

*mg/dl=2.81 (mmol/l).
†mg/dl=μmol/(88 l).

year 3 examination and those who did not remain active (table 4).

In paired *t* tests, of year 1 versus year 3 liver function tests no significant changes were found for either hazmat technicians or support controls (table 5). We also made paired comparisons of liver function tests between year 1 and year 3 for the 12 support workers who subsequently became technicians (table 6). Again, we found no significant differences. Finally, we found no significant variation in mean liver function test values as a function of time for the team 1 subcohort over the period of 1993–8 (table 7).

RENAL FUNCTION TESTS

We detected no significant differences between hazmat technicians and support controls when comparing either the mean blood urea nitrogen or creatinine values in independent sample *t* tests at years 1 and 3 (table 3). We also found no differences in either mean blood urea nitrogen or creatinine at year 1 between subjects who remained active to the year 3 examination and those who did not remain active (table 4).

For blood urea nitrogen, no significant differences were found in paired testing (tables 5 and 6). For technicians and for support workers who became technicians, the means for year 3 blood urea nitrogen showed a trend to be lower. Over the period 1993–8, we found no significant variation in mean blood urea nitrogen as a function of time for the team 1 subcohort (table 7).

We did find a significant decrease in mean creatinine concentrations from year 1 to year 3 for both technicians and support cohorts (table 5), and for the 12 support workers who subsequently became technicians (table 6). Moreover, we found a significant longitudinal decrease in creatinine concentrations for the team 1 subgroup from 1993 to 1998 (table 7). The 1998 mean creatinine concentration was lower than the 1993 concentration (114(8.8) *v* 97 (8.8), $p< 0.001$).

Because no differences were found across exposures, subsequent analyses were done for each examining hospital. For two of the hospitals (including one that had changed laboratories) the year 3 mean creatinine was significantly lower (both $p<0.001$), but for the third hospital the year 3 mean creatinine was non-significantly higher ($p=0.177$) (data not shown).

HAEMATOLOGICAL TESTS

For mean white blood count and packed cell volume, we found no significant differences between groups (tables 3 and 4) nor within groups over time (tables 5–7).

Independent *t* tests between the mean platelet count of technicians and support controls at year 1, showed a trend towards a lower mean platelet count for the technicians in both years (table 3). There was no significant difference in mean platelet count between subjects who remained active to the year 3 examination and those who did not remain active (table 4).

Paired *t* tests of platelet count at years 1 and 3 for both technician and support worker subgroups showed significant changes for technicians (n=247): 240 (52) to 232 (54) from baseline to follow up examination ($p< 0.001$; table 5), whereas within support workers the decrease was non-significant. We also found a significant decrease in mean platelet count for the support workers who subsequently became technicians (table 6).

Also, we found significant longitudinal variation in mean platelet counts among the team 1 subgroup from 1993 to 1998 (table 7) as a function of time. The 1998 mean platelet count decreased significantly from the 1993 value of 237 (42) to 210 (40) (n=35; $p< 0.01$).

Table 5 Paired, longitudinal comparisons for hazmat technicians and support members: year 1 v year 3 (paired samples t tests)

Variable	Year 1 (1996–7)	Year 3 (1998)	p Value
Liver function tests:			
Alkaline phosphatase (U/l):			
Technicians (n=246)	83 (21)	83 (20)	0.721
Support (n=53)	87 (23)	85 (20)	0.206
Aspartate aminotransferase (U/l):			
Technicians (n=245)	25 (10)	25 (10)	0.982
Support (n=54)	24 (10)	26 (9)	0.273
Alanine aminotransferase(U/l):			
Technicians (n=245)	36 (20)	37 (18)	0.364
Support (n=54)	38 (23)	39 (18)	0.646
Renal function tests:			
Blood urea nitrogen (mmol/l):*			
Technicians (n=247)	5.7 (1.4)	5.3 (1.4)	0.050
Support (n=54)	5.3 (1.4)	5.7 (1.4)	0.324
Creatinine (μmol/l):†			
Technicians (n=247)	97 (18)	88 (8.8)	0.000
Support (n=54)	97 (18)	88 (18)	0.005
Haematological tests:			
White blood cells ($\times 10^9$/l):			
Technicians (n=245)	6.7 (2.3)	6.6 (1.8)	0.891
Support (n=54)	6.6 (1.3)	6.7 (1.5)	0.635
Packed cell volume (fraction):			
Technicians (n=244)	0.45 (0.02)	0.46 (0.03)	0.332
Support (n=54)	0.46 (0.03)	0.46 (0.03)	0.133
Platelet count ($\times 10^9$/l):			
Technicians (n=247)	240 (52)	232 (54)	0.000
Support (n=54)	254 (60)	248 (55)	0.176

*mg/dl=2.81 (mmol/l).
†mg/dl=μmol/(88 l).

Table 6 Paired, longitudinal comparisons for firefighters who started as hazmat support members and later became technicians by 1998: year 1 v year 3 (paired samples t tests)

Variable	Year 1 (1996–7)	Year 3 (1998)	p Value
Liver function tests:			
Alkaline phosphatase (U/l)	70 (17) n=12	74 (20) n=12	0.093
Aspartate aminotransferase (U/l)	23 (5) n=12	22 (7) n=12	0.535
Alanine aminotransferase (U/l)	23 (9) n=12	24 (16) n=12	0.695
Renal function tests:			
Blood urea nitrogen (mmol/l)*	6.4 (1.8) n=12	5.7 (1.1) n=12	0.065
Creatinine (μmol/l)†	106 (18) n=12	97 (8.8) n=12	0.007
Haematological tests:			
White blood cells ($\times 10^9$/l)	6.8 (1.7) n=12	6.3 (1.3) n=12	0.458
Packed cell volume (fraction)	0.44 (0.03) n=12	0.44 (0.03) n=12	0.428
Platelet count ($\times 10^9$/l)	252 (47) n=11	227 (53) n=11	0.003

*mg/dl=2.81 (mmol/l).
†mg/dl=μmol/(88 l).

Because hospital 2 had changed reference laboratories in year 3, we performed further paired analyses stratified by examination site (appendix 2). For the other two hospitals, we found no differences over time in mean platelet count for either technicians or support workers. For hospital 2, the new reference laboratory had a lower reference interval, and in year 3 both technicians (n=82) and support (n=14) workers had lower mean platelet counts (p<0.001 and p<0.005, respectively).

Of the 12 support workers who became technicians by 1998, 10 (83%) were examined at hospital 2. Thus, the change in laboratories would explain the relative decrease in mean platelet count from 1996 to 1998. Finally, a second ANOVA as a function of time with only the means from the original laboratory (1993–7), showed no longitudinal variation in mean platelet count for the team 1 subcohort (p=0.110).

PROPORTION OF TECHNICIANS AND CONTROLS WITH VALUES OUTSIDE THE EXPECTED RANGE FOR THE COHORT

Comparison of mean values between and within groups did not show any adverse effects associated with work with hazardous materials. Therefore, we also explored the hypothesis that a few hazardous materials technicians might develop significant changes in laboratory variables associated with exposure—that is, depression of haematological test values, or increases in renal or hepatic test values. Thus, we compared the proportion of hazardous materials technicians and support workers with values outside the expected range for the entire cohort. In these analyses, we identified the number of firefighters in both groups with haematological test values of more than two SDs below the mean (technicians and support workers combined), or with renal or hepatic test values of more than two SDs above the overall mean. As each hospital used a different laboratory, we used the mean (SD) for each test at each facility separately to identify the number of firefighters outside the expected ranges. Then, these numbers were summed for

Table 7 5 Year longitudinal time analysis of follow up for the team technician cohort (ANOVA time analysis)

Variable	1993	1995	1996	1997	1998	ANOVA p value
Liver function tests:						
Alkaline phosphatase (U/l)	74 (16) (n=35)	78 (16) (n=34)	77 (18) (n=34)	78 (17) (n=34)	78 (19) (n=35)	0.770
Aspartate aminotransferase (U/l)	26 (11) (n=35)	25 (13) (n=34)	29 (13) (n=34)	24 (7) (n=34)	27 (16) (n=35)	0.560
Alanine aminotransferase(U/l)	24 (8) (n=35)	26 (8) (n=34)	28 (17) (n=34)	27 (14) (n=34)	28 (14) (n=35)	0.571
Renal function tests:						
Blood urea nitrogen (mmol/l)*	6.0 (1.1) (n=35)	5.7 (1.4) (n=34)	6.0 (1.4) (n=34)	5.7 (1.4) (n=34)	6.0 (1.8) (n=35)	0.886
Creatinine (μmol/l)†	114 (8.8) (n=35)	114 (8.8) (n=34)	106 (8.8) (n=34)	106 (18) (n=34)	97 (8.8) (n=35)	0.000
Haematological variables:						
White blood cells ($\times 10^9$/l)	7.1 (1.6) (n=35)	6.3 (1.6) (n=34)	6.7 (1.6) (n=34)	6.8 (1.5) (n=34)	6.5 (1.4) (n=35)	0.237
Packed cell volume (fraction)	0.45 (0.02) (n=35)	0.45 (0.03) (n=34)	0.45 (0.02) (n=34)	0.45 (0.02) (n=34)	0.44 (0.02) (n=35)	0.164
Platelet count ($\times 10^9$/l)	237 (42) (n=35)	247 (54) (n=33)	242 (48) (n=34)	220 (44) (n=34)	210 (40) (n=35)	0.004

*mg/dl=2.81 (mmol/l).
†mg/dl=μmol/(88 l).

technicians and support controls for year 1 and year 3, respectively.

No differences in the proportions of technicians or support controls with test values outside the expected ranges were found with the exception that significantly more controls (7%, (5/71)) had increased creatinine values in year 1 than technicians (1%, (3/268), $p<0.012$). A detailed breakdown of technicians and support controls with values outside the expected ranges for each hospital and year is given in appendix 3.

Discussion

This study was a prospective and cross sectional evaluation of possible health effects of firefighting work with hazardous materials. No clinical health effects of work with hazardous materials were reported during the study period. This is consistent with our previous studies of incidents with hazardous materials responded to by the same six Massachusetts regional teams from 1990 to 1996.[15 16] In analyses of reports of incidents for the first 6 years of work with hazardous materials, hazardous materials team members experienced no notable chemical exposures. Minor musculoskeletal injuries were reported in a single incident. This is also consistent with findings among hazardous waste workers that few notable exposures occur because when the potential for exposure is greatest the workers are usually equipped with the highest levels of personal protective equipment.[7]

To study the possible subclinical health effects of hazardous materials firefighting, we studied liver and renal function tests and haematological indices as markers of end organ effect. Such testing has been recommended as standard or optional components in the medical examinations of hazardous materials workers[1 8 9] and firefighters.[10–12]

We found no significant differences in means for any of the effect markers studied across exposures (hazardous materials technicians versus support controls) at both year 1 and year 3. Also, no differences in the proportions of technicians or support controls with test values outside the expected ranges were found with the exception of creatinine in year 1. In this case, the result was not consistent with an adverse effect of work with hazardous materials, as more controls had increased creatinine values than technicians. Also, we found no differences in any of the variables studied between members of the teams who either left or became inactive and those who remained active to the 3rd year of the study.

Likewise, we found no clinically notable changes within the means for various subject groups over time. We found significant longitudinal changes for only two indices: creatinine and platelets. For all groups studied at two of the hospitals, creatinine decreased significantly over time, at the third hospital, mean creatinine increased non-significantly. Because mean creatinine decreased (improved) in support workers as well as technicians, and we found no differences between groups at either time point, we think that these changes are not related to exposure. The change in reference laboratory in 1998 at one of the hospitals may account for some of the variation.

In initial longitudinal analyses, we did find consistent and significant decreases in platelet values within technician groups and support workers who became technicians. In further analyses, however, the use by one of the hospitals of a new laboratory in year 3 (1998) with a lower reference interval for platelet counts seemed to be the cause. When we stratified the data by hospital, the decrease in platelets was isolated to those tested at a different laboratory in 1998, and was also found in support workers examined at the same site. Also, when platelet data for the team 1 subcohort were examined for 1992–3 to 1997 (excluding 1998 when a different laboratory was used) there was no significant change in platelets over time.

Our results are consistent with those of the study of hazardous waste workers by Favata and Gochfeld ,[13] which failed to find any differences in the same indices that we studied between workers with low and high potentials for exposure. The results are also consistent with our previous study of the team 1 cohort[14] where we found few abnormalities in these indices and none that we could link to specific exposures. Examination of the team 1 data over 5 years showed remarkable stability. This suggests that the clinically unimportant, but significant changes in some of these indices that we found from 1992–3 to 1995[14] were probably due to chance, subtle changes in specimen collection, preparation, or laboratory analyses between the two time points. As expected, over many observation points, such factors not related to exposure are unlikely to affect results in a consistent way.

The major limitation of the current study was imposed by logistical constraints. In a statewide programme, all six teams could not be examined at a single hospital. Further, the investigators could not require the examining hospitals to send all specimens to a single reference laboratory for all teams and all time points. Indeed, this study highlights the potential problems that ongoing surveillance programmes may have when hospital contractual obligations mandate changes in reference laboratories. This limitation was countered by the major strength of our study, the overall study design.

Firstly, we had an excellent control group, the support workers. Both technicians and support workers perform regular fire duty with their non-state, local fire departments. Support members are presumed to have a very limited potential for exposure compared with technicians, as they do not enter the hot or contaminated zone of an accident. Therefore, they are an ideal control group for the investigation of potential health effects limited to those arising from duty within the contaminated zone of hazmat accidents. We found some differences between technicians and control firefighters on several confounding variables, but these differences would be expected to bias the study towards finding worse results for the technicians. Despite the fact that the technicians were older, more likely to have increased blood pressure, increased cholesterol, take antihypertensive or lipid lowering medications, or have diabetes mellitus, we found no significant differences in means for any of the effect markers studied across exposures.

Secondly, the proportions of control workers examined at each of the three hospitals were similar. There were no significant differences in the proportions of technicians to controls among the three hospitals at either year 1 or year 3. This fact justified pooling the data from all three hospitals for most analyses.

Thirdly, our design allowed for multiple methods of looking for possible exposure or work related effects. These included independent, cross sectional comparisons of technicians and controls at two separate time points, comparisons of those who became inactive or left the teams with those who remained active, and prospective follow up comparisons within subjects over time. These prospective comparisons included technicians, support workers who became technicians, and a 5 year time analysis for the team 1 cohort. Although the support workers who became technicians and the team 1 cohort were small, their results support the consistency of the lack of any effect related to exposure or work. Finally, we explored the hypothesis that a few technicians might be adversely affected by examining the proportion of firefighters with results outside the expected range for the cohort as a whole. Again, we found no evidence for an adverse effect of work with hazardous materials on the test values we studied. Given the study's design, it seems unlikely that we would have missed a significant effect related to exposure on the end organ effect markers studied.

Work with hazardous materials has the potential for serious exposures and injuries due to explosions, fires, and other releases of dangerous substances. Among hazardous waste workers it has been found, however, that few significant exposures occur because those with the greatest potential for exposure are usually equipped with the highest levels of personal protective equipment.[7] This study and previous studies of surveillance[13 14] and of a hazardous materials accident database[15 16] also suggest that there are seldom health effects among hazardous materials technicians who wear appropriate personal protective equipment. Therefore, current protective equipment and procedures including decontamination seem to be effective.

Another important consideration in this discussion involves the most likely potential exposures during work with hazardous materials. Irritants and corrosives are the most commonly released hazardous materials, and respiratory exposures to irritants are the most commonly reported exposures.[16–18] Most irritant and corrosive substances would not affect haematological indices, or liver or renal function. On the other hand, common health problems and other non-occupational factors may produce abnormalities. Therefore, the hepatic, renal, and haematological tests used in our investigation cannot be expected to be either sensitive or specific markers of exposure to hazardous materials. In our experience, a further disadvantage of these markers is that firefighters under medical surveillance often misunderstand the limitations of these tests. They tend to overvalue normal results on these variables as ruling out the possibility of present and future health effects related to exposure.

Our results suggest that routine testing of the hepatic, renal, and haematological indices used in our investigation is not required on an annual basis, and that the use of these tests in detecting subclinical health effects is limited. Our current recommendations for haematological, hepatic, and renal indices in the medical surveillance of hazardous materials firefighters and other firefighters will be baseline measurements for comparison after notable exposures, illness, or other changes in clinical state. Because certain laboratory values may vary as a function of age, it seems desirable to retest at some interval. The results of the subcohort followed up over 5 years suggest that in the absence of a known exposure or other clinical indication, it is unnecessary to reassess the indices studied here more often than every 3–5 years. When comparing periodic testing with baseline results, there should also be consideration of variation not related to exposure or illness, but due to changes in laboratories, reference intervals, or testing methods.

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Appendix 1 table 1 Further analysis of alanine aminotransferase (U/l) data by hospital and year of testing

Year	Hospital 1	Hospital 2*	Hospital 3
1996	30 (15) (n=99)	27 (14) (n=118)	50 (22) (n=120)
1997	31 (12) (n=89)	29 (14) (n=102)	60 (45) (n=21)
1998	32 (17) (n=105)	49 (16) (n=111)	48 (15) (n=115)

*Laboratory used in 1996 and 1997 was A, and in 1998 it was B.

Appendix 1 table 2 Analysis of alanine aminotransferase (U/l) data for team one subgroup

Year	1993	1995	1996	1997	1998
Alanine aminotransferase	24 (8) (n=35)	26 (8) (n=34)	28 (17) (n=34)	27 (14) (n=34)	48 (14) (n=35)
Hospital No	2	2	2	2	2
Laboratory used	A	A	A	A	B
Reference range	0–45	0–45	0–45	0–45	20–65

Appendix 2 Further analysis of platelet count ($\times 10^9$/l) data by hospital, position, and year of testing

Hospital	Position	Year 1	Year 3	p Value
Hospital Nos 1 and 3†	Technicians	243 (53) n=164	243 (57) n=164	0.909
	Support	257 (62) n=40	256 (55) n=40	0.828
Hospital No 2*	Technicians	236 (49) n=82	208 (41) n=82	0.000
	Support	245 (55) n=14	226 (51) n=14	0.002
Laboratory used		A	B	
Reference range (K/mm^3)		140–400	130–400	

*Laboratory used in 1996 and 1997 was A, and in 1998 it was B.
†The same laboratories were used in 1996–8.

Appendix 3 Firefighters (n (%)) with hepatic and renal test values 2 SDs above the mean, and haematological test values 2 SDs below the mean**

		Hospital 1				Hospital 2				Hospital 3				Total firefighters				
		Technicians		Support		Technicians		Support		Technicians		Support		Technicians		Support		p Value
White blood cells	Year 01	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0/266	(0)	0/71	(0)	NA
	Year 03	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0/269	(0)	0/63	(0)	NA
Packed cell volume	Year 01	2	(0.8)	1	(1.4)	2	(0.8)	2	(2.8)	0	(0)	1	(1.4)	4/265	(1.5)	4/71	(5.6)	0.065
	Year 03	1	(0.4)	1	(1.6)	7	(2.6)	0	(0)	1	(0.4)	0	(0)	9/269	(3.3)	1/63	(1.6)	0.694
Platelet count	Year 01	0	(0)	1	(1.4)	2	(0.8)	0	(0)	1	(0.4)	0	(0)	2/268	(0.8)	1/70	(1.4)	1.000
	Year 03	0	(0)	1	(1.6)	2	(0.8)	0	(0)	1	(0.4)	0	(0)	3/269	(1.1)	1/63	(1.6)	0.571
Blood urea nitrogen	Year 01	3	(1.1)	2	(2.8)	6	(2.2)	1	(1.4)	2	(0.8)	1	(1.4)	11/268	(4.1)	4/71	(5.6)	0.527
	Year 03	1	(0.4)	1	(1.6)	6	(2.3)	2	(3.1)	1	(0.4)	1	(1.6)	8/269	(3.0)	4/63	(6.3)	0.252
Creatinine	Year 01	1	(0.4)	1	(1.4)	2	(0.8)	4	(5.6)	0	(0)	0	(0)	3/268	(1.1)	5/71	(7.0)	0.012
	Year 03	0	(0)	1	(1.6)	5	(1.9)	2	(3.1)	1	(0.4)	0	(0)	6/269	(2.2)	3/63	(4.8)	0.380
Alkaline phosphatase	Year 01	5	(1.9)	1	(1.4)	0	(0)	0	(0)	6	(2.3)	2	(2.9)	11/266	(4.1)	3/70	(4.3)	1.000
	Year 03	3	(1.1)	1	(1.6)	2	(0.8)	0	(0)	2	(0.8)	1	(1.6)	7/269	(2.6)	2/63	(3.2)	0.681
Aspartate aminotransfe rase	Year 01	2	(0.8)	0	(0)	2	(0.8)	1	(1.4)	3	(1.1)	1	(1.4)	7/266	(2.6)	2/71	(2.8)	1.000
	Year 03	3	(1.1)	0	(0)	2	(0.8)	2	(3.1)	4	(1.5)	0	(0)	9/269	(3.3)	2/63	(3.2)	1.000
Alanine aminotransfe rase	Year 01	2	(0.8)	0	(0)	2	(0.8)	1	(1.4)	5	(1.9)	1	(1.4)	9/266	(3.4)	2/71	(2.8)	1.000
	Year 03	2	(0.8)	0	(0)	3	(1.1)	1	(1.6)	5	(1.9)	1	(1.6)	10/269	(3.7)	2/62	(3.2)	1.000

*Mean is of all subjects tested (technicians and support) at each hospital and time point.

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