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 significantly 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.

Keywords: hazardous materials; firefighters; medical surveillance

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:          |              |                     |                 |
| Exposed                  | 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.

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 (98.83)     | 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—such as year 1 vs year 3—were examined with paired t tests. Differences in proportions were compared with the standard (Pearson’s) \( \chi^2 \) 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 (ANOVs) 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 \( p < 0.05 \)).

\( \chi^2 \) 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% (\( \chi^2 \), \( p = 1.000 \), 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 1 | Technicians | Support | p  Value |
|---------------------------------|--------|-------------|---------|---------|
| **Liver function tests:**       |        |             |         |         |
| Alkaline phosphatase (U/l)      | Year 1 | 82 (21)     | 84 (22) | 0.491   |
|                                 | n=266  | n=70        |         |         |
|                                 | Year 3 | 82 (20)     | 84 (19) | 0.339   |
|                                 | n=266  | n=63        |         |         |
| Aspartate aminotransferase (U/l)| Year 1 | 25 (10)     | 24 (9)  | 0.360   |
|                                 | n=266  | n=71        |         |         |
|                                 | Year 3 | 25 (10)     | 25 (9)  | 0.805   |
|                                 | n=266  | n=63        |         |         |
| Alanine aminotransferase (U/l)  | Year 1 | 36 (20)     | 35 (21) | 0.652   |
|                                 | n=266  | n=71        |         |         |
|                                 | Year 3 | 36 (18)     | 38 (18) | 0.418   |
|                                 | n=266  | n=62        |         |         |
| **Renal function tests:**       |        |             |         |         |
| Blood urea nitrogen (mmol/l)*   | Year 1 | 5.7 (1.4)   | 5.7 (1.4)| 0.999 |
|                                 | n=268  | n=71        |         |         |
|                                 | Year 3 | 5.3 (1.4)   | 5.7 (1.4)| 0.145 |
|                                 | n=269  | n=63        |         |         |
| Creatinine (µmol/l)†            | Year 1 | 97 (18)     | 97 (18) | 0.161  |
|                                 | n=268  | n=71        |         |         |
|                                 | Year 3 | 88 (18)     | 88 (18) | 0.938  |
|                                 | n=266  | n=63        |         |         |
| **Haematological tests:**       |        |             |         |         |
| White blood cells (×10^9/l)      | Year 1 | 6.6 (2.2)   | 6.6 (1.4)| 0.876 |
|                                 | n=266  | n=71        |         |         |
|                                 | Year 3 | 6.3 (1.7)   | 6.7 (1.6)| 0.682 |
|                                 | n=266  | n=63        |         |         |
| Packed cell volume (fraction)   | Year 1 | 0.45 (0.02)| 0.45 (0.03)| 0.698 |
|                                 | n=266  | n=71        |         |         |
|                                 | Year 3 | 0.46 (0.03)| 0.46 (0.03)| 0.165 |
|                                 | n=269  | n=63        |         |         |
| Platelet count (×10^9/l)        | Year 1 | 239 (51)    | 252 (58)| 0.099  |
|                                 | n=268  | n=70        |         |         |
|                                 | Year 3 | 231 (53)    | 246 (52)| 0.053  |
|                                 | n=266  | n=63        |         |         |

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

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

RENAAL FUNCTION TESTS
We detected no significant differences between hazmat technicians and support controls when comparing either the mean blood urea nitrogen or creatinine concentrations at year 1, year 3 (table 3). We also found no significant differences in either mean blood urea nitrogen or creatinine values in independent sample t tests at years 1 and 3 (table 3). We also found no significant 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) vs 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 cell 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).

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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).

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

| Variable                   | Year 1 (1996–7) | Year 3 (1998) | p Value |
|----------------------------|-----------------|---------------|---------|
| Liver function tests:      |                 |               |         |
| Alkaline phosphatase (U/l)| 83 (21)         | 83 (20)       | 0.721   |
| Support (n=53)             | 87 (23)         | 85 (20)       | 0.206   |
| Aspartate aminotransferase (U/l) | 25 (10) | 25 (10) | 0.982   |
| Support (n=54)             | 24 (10)         | 26 (9)        | 0.273   |
| Alanine aminotransferase (U/l) | 36 (20) | 37 (18) | 0.364   |
| Support (n=54)             | 38 (23)         | 39 (18)       | 0.646   |
| Renal function tests:      |                 |               |         |
| Blood urea nitrogen (mmol/l) | 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)†       | 97 (18)         | 88 (8.8)      | 0.000   |
| Support (n=54)             | 97 (18)         | 88 (18)       | 0.005   |
| Haematological tests:      |                 |               |         |
| White blood cells (×10⁹/l) | 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): | 106 (18) | 97 (8.8) | 0.007   |
| Technicians (n=244)        | 106 (18)        | 97 (8.8)      | 0.007   |
| Support (n=54)             | 106 (18)        | 97 (8.8)      | 0.007   |

*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 vs 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)         | 74 (20)       | 0.093   |
| Support (n=12)             | 74 (20)         | n=12          |         |
| Aspartate aminotransferase (U/l) | 23 (5) | 22 (7) | 0.535   |
| Support (n=12)             | 22 (7)          | n=12          |         |
| Alanine aminotransferase (U/l) | 23 (9) | 24 (16) | 0.695   |
| Support (n=12)             | 24 (16)         | n=12          |         |
| Renal function tests:      |                 |               |         |
| Blood urea nitrogen (mmol/l) | 6.4 (1.8) | 5.7 (1.1) | 0.065   |
| Support (n=12)             | 6.4 (1.8)       | n=12          |         |
| Creatinine (µmol/l)†       | 106 (18)        | 97 (8.8)      | 0.007   |
| Support (n=12)             | 106 (18)        | n=12          |         |
| Haematological tests:      |                 |               |         |
| White blood cells (×10⁹/l) | 6.8 (1.7)       | 6.3 (1.3)     | 0.458   |
| Support (n=12)             | 6.8 (1.7)       | n=12          |         |
| Packed cell volume (fraction): | 0.44 (0.03) | 0.44 (0.03) | 0.428   |
| Support (n=12)             | 0.44 (0.03)     | n=12          |         |
| Platelet count (×10⁹/l)    | 292 (47)        | 227 (53)      | 0.003   |
| Support (n=11)             | 292 (47)        | n=11          |         |

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

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) | 78 (16) | 77 (18) | 78 (17) | 78 (19) | 0.770         |
| Support (n=35)             | (n=34) | (n=34) | (n=34) | (n=34) | (n=34) |               |
| Aspartate aminotransferase (U/l) | 26 (11) | 25 (13) | 29 (13) | 24 (7) | 27 (16) | 0.560         |
| Support (n=35)             | (n=34) | (n=34) | (n=34) | (n=34) | (n=34) |               |
| Alamine aminotransferase (U/l) | 24 (8) | 26 (8) | 28 (17) | 27 (14) | 28 (14) | 0.571         |
| Support (n=35)             | (n=34) | (n=34) | (n=34) | (n=34) | (n=34) |               |
| Renal function tests:      |      |      |      |      |      |               |
| Blood urea nitrogen (mmol/l) | 6.0 (1.1) | 5.7 (1.4) | 6.0 (1.4) | 5.7 (1.4) | 6.0 (1.8) | 0.886         |
| Support (n=35)             | (n=34) | (n=34) | (n=34) | (n=34) | (n=34) |               |
| Creatinine (µmol/l)†       | 114 (8.8) | 114 (8.4) | 106 (8.8) | 106 (8.8) | 97 (8.8) | 0.000         |
| Support (n=35)             | (n=34) | (n=34) | (n=34) | (n=34) | (n=35) |               |
| Haematological variables:  |      |      |      |      |      |               |
| White blood cells (×10⁹/l) | 7.1 (1.6) | 6.3 (1.6) | 6.7 (1.6) | 6.8 (1.5) | 6.5 (1.4) | 0.237         |
| Support (n=35)             | (n=34) | (n=34) | (n=34) | (n=34) | (n=34) |               |
| Packed cell volume (fraction): | 0.45 (0.02) | 0.45 (0.03) | 0.45 (0.02) | 0.45 (0.02) | 0.44 (0.02) | 0.164         |
| Support (n=35)             | (n=34) | (n=34) | (n=34) | (n=34) | (n=35) |               |
| Platelet count (×10⁹/l)    | 237 (42) | 247 (54) | 242 (48) | 220 (44) | 210 (40) | 0.004         |
| Support (n=35)             | (n=34) | (n=34) | (n=34) | (n=34) | (n=35) |               |

*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 tech-
nicians 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 experi-
enced no notable chemical exposures. Minor
musculoskeletal injuries were reported in a sin-
gle 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 medi-
cal examinations of hazardous materials work-
ers,17,18 and firefighters.19,20

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 materi-
als, as more controls had increased creatinine
values than technicians. Also, we found no dif-
fferences 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 longitudi-
unal 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 cre-
tinine decreased (improved) in support work-
ers as well as technicians, and we found no dif-
fferences 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 hospi-
tals 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 differ-
ces 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 cohort4
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 19954 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 poten-
tial problems that ongoing surveillance pro-
grammes may have when hospital contractual
obligations mandate changes in reference labo-
ratories. 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 techni-
cians, as they do not enter the hot or contami-
nated 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 differ-
ences would be expected to bias the study
towards finding worse results for the techni-
cians. Despite the fact that the technicians were

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reported exposures.16–18 Most irritant and corrosives are the most commonly reported exposures during work with 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 sub-cohort 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 variance or other clinical factors.

We thank the members of Massachusetts Hazardous Materials Response Teams, and the Massachusetts Hazardous Materials Response Program for their participation and support. We also thank the examining physicians: Drs David Artzermanian, Thomas Gassett, Howard Hu, Karl Kelsey, and Charles Sweet, the staff of the examining hospitals, and Ms Dianne Plantamura for their continuing support of this research, and Jeffery M Hill for his assistance with the revisions. Funding was provided for SNK by NIOSH OH00156 and NIOSH OH03729 and for DCC by NIOSH OH03729, NIH ES00002 and ES05947. The involvement of human subjects in this study was approved by the Institutional Review Boards of the Harvard School of Public Health and Cambridge Hospital. This work was supported by: NIOSH OH00156, NIOSH OH03729, NIH ES00002, and ES05947.

Another important consideration in this discussion involves the most likely potential exposures during work with hazardous materials. Irritants and corrosives are the most commonly reported exposures among hazardous materials technicians who wear appropriate personal protective equipment. Therefore, current protective equipment and procedures including decontamination seem to be effective.

We thank the members of Massachusetts Hazardous Materials Response Teams, and the Massachusetts Hazardous Materials Response Program for their participation and support. We also thank the examining physicians: Drs David Artzermanian, Thomas Gassett, Howard Hu, Karl Kelsey, and Charles Sweet, the staff of the examining hospitals, and Ms Dianne Plantamura for their continuing support of this research, and Jeffery M Hill for his assistance with the revisions. Funding was provided for SNK by NIOSH OH00156 and NIOSH OH03729 and for DCC by NIOSH OH03729, NIH ES00002 and ES05947. The involvement of human subjects in this study was approved by the Institutional Review Boards of the Harvard School of Public Health and Cambridge Hospital. This work was supported by: NIOSH OH00156, NIOSH OH03729, NIH ES00002, and ES05947.

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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)    | 27 (14)     | 50 (22)    |
|      | (n=99)     | (n=118)     | (n=120)    |
| 1997 | 31 (12)    | 29 (14)     | 60 (45)    |
|      | (n=89)     | (n=102)     | (n=110)    |
| 1998 | 32 (17)    | 49 (16)     | 48 (15)    |
|      | (n=103)    | (n=111)     | (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) | 26 (8) | 28 (17) | 27 (14) | 48 (14) |
|      | (n=35) | (n=34) | (n=34) | (n=34) | (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 | 0–65 |

Appendix 2  Further analysis of platelet count (×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) | 243 (57) | 0.909 |
|      | Support | 257 (62) | 256 (55) | 0.828 |
| Hospital No 2* | Technicians | 236 (49) | 208 (41) | 0.000 |
|      | Support | 245 (55) | 226 (51) | 0.002 |
| Laboratory used | A | 140–400 |
| Reference range | B | 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 |
|------------|------------|------------|--------------------|
| White blood cells | Year 01 | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| Year 03 | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| Packed cell volume | Year 01 | 2 (0.8) | 1 (1.4) | 2 (0.8) | 2 (2.8) | 0 (0) | 0 (0) | 1 (1.4) | 0.000 |
| Year 03 | 1 (0.4) | 1 (1.6) | 7 (2.6) | 1 (0.4) | 1 (1.4) | 4/265 (1.5) | 4/71 (5.6) | 0.005 |
| Platelet count | Year 01 | 0 (0) | 1 (1.4) | 2 (0.8) | 1 (1.4) | 1 (0.4) | 1 (1.6) | 0 (0) | 2/268 (0.8) | 1/70 (1.4) | 0.000 |
| Year 03 | 0 (0) | 1 (1.6) | 2 (0.8) | 0 (0) | 1 (0.4) | 0 (0) | 0 (0) | 0 (0) | 3/269 (1.1) | 1/63 (1.6) | 0.000 |
| Blood urea nitrogen | Year 01 | 3 (1.1) | 2 (2.8) | 6 (2.2) | 1 (1.4) | 2 (0.8) | 1 (1.4) | 4/265 (1.5) | 4/71 (5.6) | 0.005 |
| Year 03 | 1 (0.4) | 1 (1.6) | 6 (2.3) | 2 (1.3) | 2 (0.8) | 1 (1.4) | 11/268 (4.1) | 4/71 (5.6) | 0.027 |
| 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) | 0.000 |
| 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) | 0.000 |
| Aspartate aminotransferase | 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) | 0.000 |
| 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) | 0.000 |
| Alanine aminotransferase | 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) | 0.000 |
| 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) | 0.000 |

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