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Cancer incidence and mortality in serving whole-time Scottish firefighters 1984–2005

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Background Firefighters may encounter uncontrolled exposure to carcinogens in their working environment.

Aims To determine the incidence of, and mortality from, cancer in a cohort of ~2200 serving firefighters.

Methods Service medical records were scrutinized for reports of malignancies. Age at recruitment and diagnosis was calculated, and annual incidence and mortality rates per 100 000 population were derived and compared with age-matched male Scottish populations.

Results Overall mean annual cancer incidence and mortality rates were lower in the firefighters (86.5 versus 123.7, $P < 0.01$, 95% confidence interval [CI] −290.3 to −209.7 and 20.4 versus 59.9, $P < 0.001$, 95% CI −57.5 to −22.5, respectively). The incidences of melanoma and kidney cancer were higher (13.6 versus 7.7, $P < 0.001$ 95% CI 3.0 to 8.8 and 9.1 versus 4.4, $P < 0.01$, 95% CI 2.4 to 6.7) as was mortality from kidney cancer (6.5 versus 1.9, $P < 0.01$, 95% CI 2.8 to 6.4). Testicular cancer occurred more frequently than expected (9.1 versus 8.1), but did not reach statistical significance. Large bowel (9.1 versus 13.8), lung cancer (6.8 versus 20.4) and lymphoma (9.1 versus 11.0) all had a lower than expected incidence. This was significant regarding large bowel ($P < 0.01$, 95% CI −7.7 to −1.7) and lung ($P < 0.001$, 95% CI −7.7 to 1.0). Mortality was also lower—large bowel 4.5 versus 6.0, lung 4.5 versus 16.8 and lymphoma 2.3 versus 3.3, but this did not reach significance. Mean age and length of service at diagnosis were 43 years (range 28–54) and 19 years (range 2–31), respectively.

Conclusions These results are generally consistent with other studies of firefighters. The most common tumours were generally those associated with young and middle-aged men.

Key words Cancer; cancer skin; firefighters; local authority; lung cancer; epidemiology.

Introduction

Lees [1], and more recently, Austin *et al.* [2] and Fent and Evans [3] have reviewed some of the chemical hazards, including known carcinogens like benzene and polycyclic aromatic hydrocarbons, faced by firefighters tackling blazes. Other exposures may occur as firefighters become increasingly involved in responding to chemical spills, radiation leaks and urban search and rescue operations. Milham [4] suggests that non-ionizing radiofrequency radiation may also be an underestimated hazard. Appropriate firefighting techniques, combined with personal protective equipment (PPE), reduces these risks. Unfortunately, PPE can be uncomfortable, interferes with communication etc, hence it is often removed at the earliest opportunity, e.g. the overhaul phase of firefighting, when the blaze has been extinguished and firefighters search for potential sources of re-ignition. However, harmful substances can still be detected [5], producing measurable short-term spirometric and biochemical changes [6]. As canister respirators may not always give adequate protection, it may be necessary to continue to use self-contained breathing apparatus [7].

There has been extensive research into carcinogenesis and cancer in firefighters. A PubMed search using 'Firefighters AND cancer' yielded 50+ hits, with the oldest study showing a reduced standardized mortality ratio (SMR) overall, and to cardiovascular disease and cancer in particular [8]. In 1959, Mastromatteo [9] expressed concern about the increase in cardiovascular/renal deaths.

Two main approaches were adopted: identifying and following up a cohort of firefighters [10,11]; and using a cancer registry to identify a particular tumour/tumours and then exploring the associated occupations [12,13]. Much of the work originated in North America with contributions also from Australia [14,15], New Zealand [16], Sweden [17], Denmark [18], Germany [19,20], France [21], the UK [22] and Korea [23]. Papers prior to 1995 were reviewed by Golden *et al.* [24].

Generally, firefighter all-cause and broad diagnostic category mortality compares well—sometimes extremely so—with control groups. Donnan [22], Deschamps [21] and Wagner *et al.* [20] cited overall SMRs for English, French and German firefighters of 63, 52 and 78, respectively, for example. Because reference groups are usually drawn from the general population, this finding is often due to the 'healthy worker effect' operating both at enlistment and during careers. Examining incidence and/or mortality from organ-specific tumours not infrequently shows above average rates, although it is unusual for them to attain statistical significance, or for findings to be consistently replicated by other researchers.

If the reference population is selected from another group of workers, then Massachusetts firefighters may be shown to have an increased incidence of bladder cancer and non-Hodgkin's lymphoma, with standardized mortality odds ratios (MORs) of 211 and 327, respectively [10], compared with Massachusetts policemen. This finding is relevant because firefighters and police are recruited from similar social backgrounds, and have comparable terms and conditions of service, thus reducing significant confounders. Differences also emerge when comparisons are made between firefighters of different ethnic extraction. Ma *et al.* [25] found that, while both white and black firefighters had raised MORs for prostate cancer, whites had increased MORs for sites such as the lip, non-Hodgkin's lymphoma and Hodgkin's disease, whilst for blacks, the oesophagus, colon and brain were the only ones which attained significance.

The chances of finding an increased incidence or mortality from cancer may also depend on the number of tumour sites included in the analysis. However, the greater the number of sites, the more likelihood of purely chance associations arising. Ma's study [25] examined the incidence of cancers at 29 sites, finding raised rates in 20 sites, but only three sites attained statistical significance. Furthermore, eight sites in whites and six sites in blacks had three or fewer cases. Assembling a sufficiently large population to accurately reflect the incidence of rare diseases is always a problem. Some researchers have dealt with this by assembling a large historical cohort, thus Musk *et al.* [8], Tornling *et al.* [17], Wagner *et al.* [20] and Guidotti [26] gathered cases over 50–60 years. However, during such long periods, the background incidence of diseases can fluctuate, medical classifications, exposures and firefighting techniques can all change, making interpretation of results more difficult. Others, such as LeMasters *et al.* [27], have used meta-analysis. Although this produces large numbers, it is designed to maximize information available from existing data, rather than presenting new findings.

As inhalation is the principal source of entry to the body of most occupational toxins, it is surprising that the studies have not shown a sustained statistically significant excess of cancers of the lung, larynx or sinuses. However, increased incidences of cancers affecting the brain, haematopoietic/lymphatic, genitourinary and digestive systems and skin cancers appear consistently in many of these studies, and for malignancies of the large bowel, prostate, brain and multiple myeloma, significance is usually attained. An International Agency for Research on Cancer (IARC) review in 2010 allocated firefighting to category 2B, suggesting that occupational exposures during firefighting were possibly carcinogenic to humans [28].

At the time of writing, Strathclyde Fire and Rescue Service (SF&RS), with ~2200 whole-time firefighters, was the second largest of the 58 local authority fire and rescue services in the UK. It serves a population of ~2.3 million who live in urban, rural and island areas of ~14 000 kms^2 in west central Scotland. The large majority of the firefighters in SF&RS are recruited from, and live in, this area. It also has some of the poorest health indices in the UK. It accounts for roughly half the whole-time firefighters in Scotland. During the period of this study, firefighters were enlisted between the ages of 18–30 years and could retire at any time after their 50th birthday, to a pension that reached its maximum value after 30 years' service. Very few were permitted to serve beyond their 55th birthday.

The large majority of papers draw on mixed populations of serving and retired/dead firefighters, usually without distinguishing between the two. However, it was the sickness absence, premature retirement and deaths in service, which were among the most pressing concerns for senior managers in fire and rescue services. This study describes the previously unreported cancer morbidity and mortality solely of a cohort of serving firefighters. This study aimed to examine the incidence and outcomes of cancer in the serving firefighters between 1984 and 2005; to compare their experience with local reference populations, the null hypothesis was that there was no difference between rates of disease and death between the two groups; and to compare these findings with existing research.

Methods

Each firefighter's medical history was updated when attending for medical examinations involving routine triennial screening, initial issue or renewal of large goods vehicle driving licences, sickness absence or when referred because of concerns expressed by their commander. Notes of those leaving because of maximum service, ill-health retirement, death, transfer to other fire and rescue services and resignation were searched, and relevant details transferred to a database whose construction for the purposes of providing data for research had been approved by the local research ethics committees of the four (later reduced to three) health boards whose areas covered the same geographical areas as SF&RS. There was a yearly request to headquarters for copies of death certificates, which are publicly available, of deceased serving members. All serving firefighters gave formal written consent to the information being obtained from their doctors. Dates of birth, enlistment, tumour diagnosis and retirement/death (if appropriate) were entered onto an Excel 2003 spreadsheet, along with the histological nature of the cancer, independently sought from the firefighter's oncologist and/or general practitioner. Other information included employment prior to joining the SF&RS, current tobacco and alcohol habits and hobbies. This data were then anonymized.

The denominators of the reference populations comprised men between 20 and 54 years from Scotland and the west of Scotland (the area now covered by Ayrshire and Arran, Dumfries and Galloway, Greater Glasgow and Clyde and Lanarkshire Health Boards), derived from the mid-year estimates of the years in question from the Annual Reports of the General Register Office, Scotland. The numerators were cancer cases from men of the same age range, obtained from data published by Information Services Division, NHS National Services Scotland. Because of concerns about data quality in the years 1984 and 2005, these years were excluded from analysis from Table 2 onwards.

Descriptive statistics were calculated using the Excel spreadsheet, while differences between two proportions were calculated using Minitab (MINITAB Inc., LEAD Technologies version 16.2.2., State College, PA, USA). Statistical significance was regarded as $P \leq 0.05$.

Results

Throughout the study, mean personnel strength was 2213 (range 2173–2308). Nineteen (<1%) were female, who were excluded from the analysis. Thirty-eight firefighters developed 39 tumours. Age at diagnosis ranged from 28 to 54 years, mean and median 43 years (SD 6.3, interquartile range [IQR] 34–47). Service duration ranged from 2 to 31 years, mean 19 years (SD 6.6) and median 20 (IQR 14–23).

Data were available on pre-fire service jobs in 50% (19/38), alcohol in 89% and tobacco habits in 97%, dates of enlistment in 95%, birth, and diagnosis of tumours and nature/site of tumour in 100%. Regarding tobacco habit, 33% were current smokers, 50% claimed never to have smoked and the remaining 17% had abstained for at least a year. For those who gave a precise alcohol consumption, five were tee-total and three drank ≥28 units/week. Of the lung cancer cases, two out of three had exposure to asbestos, one before joining (he was a joiner) and two were current smokers.

Table 1 summarizes the number of tumours in each year, the mean being 1.77 over 22 years and 1.9 per year over 20 years (see Discussion). Seven years (mode) had a single case, 5 years had none and 1 year had five cases, so the annual rate varied quite widely from 0 to $227.0/10^5$ (mean $81.8/10^5$). Age-matched Scottish male rate varied between 110.0 and $135.0/10^5$, mean $12.3/10^5$ (SD 7.9), $P < 0.001$, 95% confidence interval (CI) −0.0007 to −0.0001 and median 12.4 (IQR 11.7–12.8).

Table 2 aggregates the number of cases and deaths into quinquennia, after removing the first and last years of the study. Further removing the three non-melanoma skin cancers changes the mean rate to $7.9/10^5$. The numbers of cases increased in the last two 5 year periods. As the incidence of cancers rises with age, this would be in keeping with the cohort ageing. Nine firefighters died while serving, from widespread metastases. The maximum number of deaths per year was two, mean rate 4.1 and $4.5/10^5$ per year over 22 and 20 years, respectively.

Table 3 ranks the tumours in order of frequency. There were 15 different types of cancers identified, but melanomas, lymphomas and testicular cancers, commonest in young and middle-aged men, constituted 38% (15/39) of the total burden, 42% if the basal cell carcinomas are excluded.

Table 1. Numbers of cancers diagnosed in each year of the survey, and annual rates for all tumours per 100 000 population

Number of cancers/year (all malignancies)	Years	Annual rate/10^5 (all malignancies)
0	1991–93, 1998, 2005	0
1	1984–88, 1999, 2003	45
2	1989, 1994, 2001, 2002[a], 2004[a]	91
3	1992, 1996[a], 1997	136
4	1990, 2000	182
5	1995	227

[a]One tumour in these years was a non-melanoma skin cancer (basal cell carcinoma). They were removed from subsequent calculations.

Table 2. Types of cancers and numbers of deaths aggregated into quinquennial periods

Years	1985–89	1990–94	1995–99	2000–04	Total
Number of cancers	6	7	13 (1)	12 (2)	38 (3)
Type of cancer	Melanoma, lymphoma ×2, testicle, squam, osteosarcoma	Lymphoma +, kidney +, melanoma, testicular, lung ×2 ++, colon +	Melanoma ×2, colon ×3 +, testicular ×2, adenoca +, kidney +, squam ×2 +, brain (BCC)	brain ×2, kidney ×2, lung, bladder ×2, lymphoma, melanoma ×2 (BCC ×2)	
Mean annual rate per 10^5 (all tumours)	54.0	63.0	117.0	108.0	
Mean annual rate per 10^5 (less N-MSC/BCC)	54.0	63.0	108.0	90.0	

Adenoca, adenocarcinoma, unknown primary; N-MSC/BCC, non-melanoma skin cancer/basal cell carcinoma; squam, squamous cell carcinoma.

Numbers in brackets refer to N-MSC/BCC, not included in subsequent calculations. + indicates one death.

Table 3. Ranking of cancers, tumour type and number of cases

Rank	Tumour type	Number of cases (%)
1	Malignant melanoma	6 (15)
2	Lymphomas	5 (13)
3=	Testicular, colon, kidney	4 (10)
6=	Lung, N-MSC/BCC	3 (8)
8=	Brain, bladder	2 (5)
10	Miscellaneous others	6 (15)
Total		39

N-MSC/BCC, non-melanoma skin cancer/basal cell carcinoma.

Other tumours: adenocarcinoma with unknown primary, melanocytic meningeal tumour, osteosarcoma of thigh, squamous cell carcinomas of penis, right pleura and left tonsil. Percentages do not add up to 100 because of rounding.

Table 4 shows that overall incidence and mortality rates from cancer were considerably less than the age-matched reference groups with the lowest rates. However, incidence rates for specific tumour sites—kidney, melanoma, lymphoma and testicle—were higher by ~200, 121, 177 and 113%, respectively, with kidney and melanoma attaining statistical significance. Renal tumour mortality in firefighters was almost quadrupled, also reaching significance ($P < 0.01$ in all cases). To enhance anonymity, only mean data were presented for tumours represented by two cases. For the same reason, no tumours with just one case were included. In addition, it was difficult to obtain reliable incidence and mortality data on very rare tumours. All four kidney cancers were clear cell adenocarcinomas, three occurring in a 3 year period. The two bladder cancers also occurred in adjacent years. Four of five lymphomas occurred in the first half of the period. All data were analysed over the 20 year period, to avoid constructing the hypothesis after the data had been gathered and analysed.

Twelve firefighters were prematurely retired on ill-health grounds (nine because of the cancer). Of these, one subsequently died, but another rejoined. Six others completed maximum service. The remainder were still serving at the end of the study period. The nine who died constituted 24% of all serving firefighter deaths during this period (n = 37), very similar to the proportion of cancer deaths in the age-matched general Scottish male population (21%). The difference did not reach statistical significance. However, for all-cause annual mortality, the median rate among the firefighters was $67.0/10^5$, compared with $305/10^5$ for the reference population. This was significant ($P < 0.001$, 95% CI 186 to 249).

Discussion

In this study, the overall annual incidence of, and mortality from, cancer in this population was less than expected (86.5 versus $123.7/10^5$, $P < 0.01$ and 20.4 versus $54.1/10^5$, $P < 0.01$, respectively). However, there was a statistically significant increase in melanoma incidence (13.6 versus $8.1/10^5$, $P < 0.01$) and kidney cancer (9.1 versus $4.4/10^5$, $P < 0.01$). Mortality from kidney cancer was also significantly higher (6.5 versus $1.8/10^5$). Incidence of testicular cancer was also greater than expected (9.1 versus $7.7/10^5$), but this did not attain statistical significance. This contrasts with Donnan's findings—the only other study involving British firefighters—in which all tumour types showed reduced incidence and mortality [22].

This study has a number of weaknesses. First, the population was small. This is a problem with rarely occurring diseases because the population may not be large enough to generate any cases. Alternatively, should they occur, they may cast a disproportionately large effect. However, in LeMasters *et al.*'s publication [27], 13 of the 32 studies cited had smaller populations (including three case control studies), 2 were similar size and 10 were of shorter duration (median 8.5 years, IQR 4–14 years). Second, it is possible that all not cases of malignancy that occurred during the period in question were counted. The author had no access to files prior to 1985 and from mid-September 2005 so data were incomplete for the year at the end of the survey

Table 4. Range and means [SD] of age (years), length of service (years) at diagnosis, annual incidence and mortality rates of cancers, compared with age-matched male controls 1985–2004 (95% CIs)

Tumour type	n	Age at diagnosis (years)	Length of service (years)		Incidence rate/10^5/year [SD]	Mortality rate/10^5/year [SD]
All cancers	38	28–54	2–31	FF	86.5 [64.2]	20.4 [27.4]
Mean [SD]		43 [6.3]	19 [6.6]	WS	337.0 [25.3]*** (−290.3 to −209.7)	59.9 [6.0]*** (−57.5 to −22.5)
				S	123.7 [7.9]*** (−65.4 to −8.55)	54.1 [3.9]*** (50.8 to −17.1)
Melanoma	6	31–49	2–26	FF	13.6 [21.4]	Nil
Mean [SD]		43 [6.2]	21 [4.5]	WS	7.7 [2.3]*** (−3.0 to −8.8)	1.5 [0.5]*** (−2.2 to −74.10)
				S	8.1 [1.8]*** (−2.61 to −8.4)	1.4 [0.3]*** (−2.13 to 66.66)
Lymphoma	4	28–47	4–23	FF	9.1 [18.7]	2.3 [10.2]
Mean [SD]		41 [7.4]	18 [8.3]	WS	11.2 [1.6], NS, (−4.89 to 69.23)	3.1 [0.8], NS, (−2.24 to 40.3)
				S	11.5 [13], NS, (−5.21 to 41.30)	3.3 [0.7], NS, (−2.47 to 46.77)
Testicle	4	29–38	9–18	FF	9.1 [18.7]	Nil
Mean [SD]		34 [4.5]	13 [3.8]	WS	7.7 [2.3], NS, (−1.1 to 3.9)	1.5 [0.5]** (−2.3 to −74.0)
				S	8.1 [1.8], NS, (−1.57 to 3.57)	1.4 [0.3]** (−2.1 to −6.7)
Kidney	4	41–52	21–27	FF	9.1 [18.7]	6.5 [16.3]
Mean [SD]		47 [4.9]	26 [4.3]	WS	4.4 [1.2]*** (2.4 to 6.9)	1.9 [0.5]*** (2.8 to 6.4)
				S	4.4 [1.2]*** (2.4 to 6.9)	1.8 [0.4]*** (2.9 to 6.5)
Large bowel	4	41–52	15–29	FF	9.1 [18.7]	4.5 [13.9]
Mean [SD]		46 [5.0]	23 [5.8]	WS	13.8 [2.0]** (−7.7 to −1.7)	6.0 [1.2], NS, (−3.5 to 5.0)
				S	13.8 [2.0]** (−7.7 to −1.7)	5.6 [0.8], NS, (−3.01 to 8.7)
Lung	3	43–54	15–28	FF	6.8 [16.7]	4.5 [13.9]
Mean [SD]		45 [8.2]	21 [6.6]	WS	20.4 [3.9]*** (−1.7 to −1.0)	16.8 [3.8]*** (−15.2 to −9.4)
				S	17.1 [2.8]*** (−1.33, −7.27)	13.9 [2.7]*** (−12.1 to −6.7)
Basal cell carcinoma	3	36–47	17–25	FF	6.8 [16.7]	Nil
Mean [SD]		41 [5.7]	20 [3.1]	WS	7.0 [2.3], NS, (−2.5 to 2.1)	Not available
				S	26.7 [8.3]*** (−2.4 to −1.6)	0.2 [0.09], NS, (−0.5 to 0.8)
Bladder	2	52	27	FF	4.8 [13.7]	Nil
[SD]		[3.5]	[0.7]	WS	5.2 [2.4], NS, (−2.4 to 1.6)	9.6 [4.4]*** (−115.0 to −768.0)
				S	5.0 [2.3], NS, (−2.1 to 1.7)	8.0 [3.0]*** (−975.0 to −625.0)
Brain	2	42	16	FF	4.8 [13.7]	Nil
[SD]		[3.6]	[1.4]	WS	5.0 [1.2], NS, (−3.8 to 38.4)	3.6 [0.9]*** (−4.8 to −2.4)
				S	6.5 [0.9], NS, (−3.7 to 38.3)	3.9 [0.6]*** (−5.1 to −2.7)

**$P < 0.01$, ***$P < 0.001$. NS, not significant; FF, firefighters; WS, West of Scotland; S, Scotland;

and unreliable for the year at the beginning. Also, not all cases may be ascertained—two cancers, both basal cell carcinoma, were discovered co-incidentally, one during a routine medical and the other during correspondence with a general practitioner about an unrelated matter. As day surgery becomes more common, and earlier detection and treatment of some malignancies reduce the need for sickness absence to receive adjuvant therapies, then recall of diagnosis and treatment by the employee will become less reliable as time passes. Finally, the cancer experience of the 164 men who left between 1985 and 1994 because of transfer to other fire and rescue services, resignation or dismissal is unknown—in order to estimate the magnitude and direction of bias, it would be necessary to know their age and length of service at the time of their departure. It has also been assumed that the age profile of the firefighters reflected that of the reference populations. In fact, this was not the case. Unfortunately, data for age structure of the firefighters were only available for 2001–05. This showed that the 20–24 age group comprised between 2% and 4% of the cohort during this time. This steadily rose to 18–22% in the 45–49 quinquennium, before falling steeply to 8–9% in the 50–54 group. By contrast, the corresponding quinquennia in the all-Scotland reference group varied much less, being 10–14%, 14–15% and 14%, respectively, while the west of Scotland rates were very similar. All these differences reached statistical significance ($P < 0.001$). The likely reason for the peculiar age structure of the firefighter population is that, from 1972 to 1978, the UK firefighters contracted weekly hours of work fell from 56 to 42. This required augmentation of the existing workforce of ~1700 with an influx of ~500 additional recruits, practically all of whom would have been aged between 18 and 30 years. From 2002 onwards, these members would have begun to retire. Also, the age range of the firefighters overlapped the reference populations at both ends. However, in each of the 4 years, the numbers <20 varied between zero and three and for the >55s between two and five, so the likely effect is small.

The firefighters who attended the site of the World Trade Centre (WTC) after the collapse of the twin towers were exposed to substantial quantities of carcinogens and toxins, particularly if they arrived within the first 24 hours. A comparison of cancer rates between this population and age-matched male Americans and non-exposed firefighters showed that the WTC cohort had an ~10% rise in the cancer incidence ratio compared with the age-matched male controls, and 32% compared with non-exposed firefighters. These increases affected all types of tumours, and 95% CIs all included 1, so a chance effect cannot be excluded [29].

Further research in this area should examine the incidence of cancers in populations of firefighters, in comparison to temporal trends of the disease. Because ultraviolet radiation and trichloroethylene are established environmental risk factors for melanoma and kidney cancer, respectively, it would be helpful to postulate what other exposures in the firefighting environment may also give rise to these tumours, thus improving protection. Also, eight firefighters who retired on maximum service from Strathclyde Fire Brigade had chest X-rays, which showed pulmonary fibrosis. Examination of enlistment medicals showed that at least four had worked in jobs with the potential for significant exposure to fibrogenic agents, such as silica and asbestos (shipyards, quarries and foundries) [30]. Hence on this basis, study of pre-firefighting employment, or perhaps even leisure activities, may also provide an insight into the causes of cancers in these populations, particularly for firefighters recruited later in life, having had a longer opportunity for these exposures.

In conclusion, this study of cancer incidence and mortality in a previously unreported population of firefighters confirms earlier internationally derived research, which shows a significant decrease of overall incidence and death from cancer, although there is a significant increase in specific tumour types, such as melanoma and clear cell adenocarcinoma of the kidney.

Key points

- This study suggests that, despite the potential for uncontrolled exposures to carcinogens at work, the overall cancer incidence in a cohort of firefighters is lower than expected, compared with an age- and sex-matched population.
- Despite this, specific organ and site-specific tumours may occur more frequently than expected, occasionally reaching statistical significance.
- It is necessary to use a variety of clinical, data gathering and administrative approaches to ensure that all existing tumours are identified for inclusion in surveys.

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Conflicts of interest

None declared.

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