An outbreak of Legionnaires' disease in Gloucester

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SUMMARY

Fourteen people living in or near the city of Gloucester fell ill with Legionnaires' disease caused by *Legionella pneumophila* serogroup (SG) 1 between 27 August and 27 October 1986. Another patient had fallen ill on 30 May. Nine of the 15 were diagnosed retrospectively during a case finding exercise. There were three deaths. Three cases of Pontiac fever were also diagnosed.

The source was probably one or more wet cooling towers. Nineteen premises in the city with such towers were identified, and three just outside Gloucester. Samples from 11 of the 22 premises grew *Legionella* spp.; from nine of these *L. pneumophila* SG 1 (Pontiac) was isolated. The efficacy of regular addition of biocide in addition to hypochlorite added at the time of disinfection in inhibiting the growth of *Legionella* spp. was demonstrated.

A survey of patients' movements during their likely incubation period showed that there was no single building that all patients had visited, but there were two areas of the city which nearly all had visited or passed through by car. A case-control study demonstrated an association with one of these areas.

Cooling towers near both areas may have been sources but the evidence is insufficient to incriminate any single one. The unexpected finding of *L. pneumophila* SG 1 (Pontiac) in nine towers supports the hypothesis that there may have been multiple sources. Cooling towers may have been contaminated by mains water or by drift from other towers.

INTRODUCTION

Each year in England and Wales about 150–200 cases of Legionnaires' disease are reported to the Public Health Laboratory Service Communicable Disease Surveillance Centre, of which approximately 40% are associated with foreign

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travel. The disease accounted for 2% of community acquired pneumonias in a recent survey [1].

The city of Gloucester (population approximately 91000) is an important industrial and commercial centre. The county of Gloucestershire (population 517000) is served by two health authorities. Serological investigation of respiratory disease for the whole county is undertaken at the Gloucester Public Health Laboratory. Between 1981 and 1984 all sera tested from patients with respiratory disease were also tested for antibodies to *Legionella pneumophila* SG 1. From 1984 onwards only sera from patients with clinical or radiological evidence of pneumonia were tested. One case of Legionnaires' disease was diagnosed in each of the three years 1982–4 and none in 1985. Two of these three patients were thought to have acquired their illness abroad, and none lived in or near the city of Gloucester. Approximately 4000 sera were tested during the 4-year period 1982–5.

Five cases of Legionnaires' disease were diagnosed in Gloucester residents during October and early November 1986, and one had been diagnosed in June. A point source outbreak was therefore suspected. None of those affected had travelled abroad, and most had not been outside Gloucester during the incubation period (2–10 days) and no single building had been visited by all of them. A colonized wet cooling tower or other aerosol generating equipment was, therefore, suspected as the source of the outbreak.

An *ad hoc* committee was established to investigate the outbreak and to instigate control measures.

METHODS
Case finding

Retrospective studies

To identify unrecognized cases, which in other outbreaks have been found to outnumber index cases [2–4], case notes of all medical and geriatric hospital admissions occurring between 1 August and 31 October in the county were examined for cases of pneumonia with radiological evidence of consolidation, which could not be ascribed to any specific cause. General practitioners were asked to report such cases, with or without radiological confirmation, who had been treated at home.

A diagnosis of Legionnaires' disease was accepted if there was a fourfold rise in rapid microagglutination test (RMAT) titre [5] to 16 or more, or a single titre of 32 or higher, or if there was a fourfold rise in indirect fluorescent antibody test (IFAT) titre [6] to 64 or higher, or a single titre of 128 or higher. The diagnosis was excluded only if antibody was not demonstrated in any sample including one obtained at least 4 weeks after the onset of symptoms. Post-mortem lung tissue from patients who had died of pneumonia was examined by immunofluorescent microscopy using monoclonal antibodies [7] and an immunoperoxidase technique [8].

Pontiac fever was defined as a short-lived self-limiting febrile illness without clinical evidence of lung consolidation and fulfilling the same serological criteria as those for Legionnaires' disease.

Prospective surveillance

It was agreed that samples of blood for legionella culture and serology should be taken from newly incident cases of pneumonia, and that if bronchoscopy was carried out on such patients, the aspirates should be cultured. Prospective surveillance continued until 19 December 1986.

Case-control studies

One case lived some 20 miles from Gloucester and denied visiting the city. Of the remaining 14, 10 had walked along a major shopping street near the city centre ('central area') and another had passed through by car. Six of the 14 had walked along a major road on the periphery of the city ('peripheral area') and a further 6 had passed along it by car.

Two case-control studies were undertaken; each tested the hypothesis that cases were more likely than controls to have visited the central or the peripheral area either on foot or by car. Pneumonia patients in whom Legionnaires' disease had been excluded were used as controls.

Study 1. One control per case, matched for sex, age (within 10 years) and place of residence (closest available, all within one mile).

Study 2. Two controls per case, matched for sex and age (within 10 years). No geographical matching, but only cases and controls resident in Gloucester City eligible.

One case was excluded from Study 1 because no control could be found; one was excluded from Study 2 because he lived just outside the city; two further cases had not been identified when the studies were undertaken.

Statistical analysis was performed by calculating exact binomial probabilities [9].

Environmental studies

Environmental health officers and an engineering adviser visited retail, commercial and industrial premises to locate cooling water systems, humidifiers, and other equipment likely to produce aerosols. A brief initial assessment was made of use, condition, maintenance, and any other treatment carried out during the previous 3 months. Water and slime samples were taken from all cooling water systems and from other selected systems for filtration and culture at the Public Health Laboratory Service Centre for Applied Microbiology and Research. Immediate cleaning and disinfection of towers were requested, and a schedule recommended (Table 1) which has since been reviewed [10].

Subsequent letters repeated these instructions, requested confirmation that cleaning and disinfection had taken place, advised repeating this procedure every 6 months, advocated the regular use of biodispersants during routine maintenance and the use of water treatments including corrosion inhibitors, anti-scaling, and continuous chlorination or other anti-microbial treatments. Attention was drawn to existing [11, 12] and forthcoming [13] guidance on cooling water system maintenance.

Wind speed and direction data were obtained from Staverton Airport, 5 miles northeast of the city centre, and from the Environmental Services Department, about a quarter of a mile southwest of the city centre, where records are kept for

Table 1. *Instructions for cleaning and disinfection of cooling towers*

    (1) Chlorinate using sodium hypochlorite solution to
        a minimum concentration of 15 mg/l (parts per million)
        free residual chlorine
    (2) Circulate for at least 2 h
    (3) Drain off, refill, circulate and drain off again
    (4) Clean the inside of the tower, including filler
        pack and drift eliminators by hosing down, and
        remove all scale, sludge, algae and slime
    (5) Refill and chlorinate to at least 5 mg/l
    (6) Circulate for 3 h
    (7) Drain off
    (8) Refill for further operation

odour control purposes. Daily temperature records (single readings taken at 09.00 Greenwich Mean Time) were obtained from the Parks Department in Cheltenham, 8 miles northeast of Gloucester.

RESULTS

The outbreak

One hundred and fifty-two cases of pneumonia were identified, of whom seven, in addition to the six index cases, had serological evidence of recent legionella infection.

A further two patients who had died in September, were shown to have *L. pneumophila* SG 1 in post-mortem lung tissue samples.

Legionella blood culture and serology were negative in every case of pneumonia identified prospectively in the 6 weeks after the start of the investigation. No bronchoscopy was carried out on these patients. No isolate from a human case was therefore ever made.

With the exception of one case who became ill on 30 May, the dates of onset of the 15 cases were between 27 August and 27 October, with a peak of six cases between 18 and 23 September (Fig. 1). There were 11 males aged 38–66 years (median 59) of whom 3 died, and 4 females aged 33, 39, 40 and 71 years. All but 1 of the 15 patients lived in the city or very close to it. There was no clustering of home addresses.

Serological testing of samples from patients with other illnesses identified three cases of Pontiac fever, two men aged 39 and 43, and a woman aged 29 years.

Case-control studies (Tables 2 and 3)

Study 1, which included 11 case-control pairs, failed to show any association with visiting or passing through any area of the city. Study 2 showed cases were more likely than controls to report visiting the peripheral area on foot or by car.

Of the two cases later identified by post-mortem studies, one had worked in the peripheral area, and the other had visited this area 6 days before onset of symptoms. Relatives thought a visit to the central area was unlikely in either case, although one had crossed the end of the central area by car at the earliest limit of his possible incubation period.
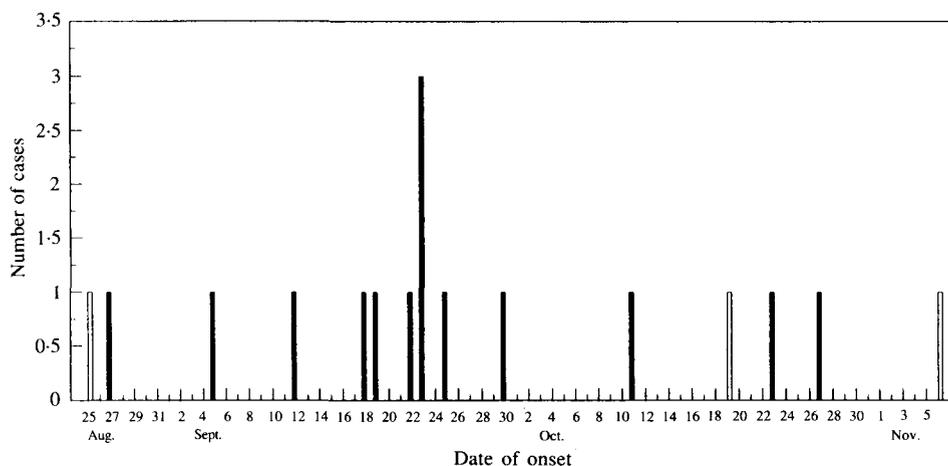
Fig. 1. Cases of legionellosis. ■, Legionnaire's disease; □, Pontiac fever. One case
who fell ill in May not shown.

Table 2. *Study 1 (matched pairs)*

| | | Control | | | |
		+	−	?	P (exact 2-tailed)
Central area	Case +	7	3	0	0·25
(on foot)	Case −	0	1	0	
Central area	Case +	8	1	1	1·00
(on foot/car)	Case −	0	1	0	
Peripheral area	Case +	3	1	0	0·5
(on foot)	Case −	2	5	0	
Peripheral area	Case +	5	3	1	0·625
(on foot/car)	Case −	1	1	0	

Pairs of cases and controls classified according to whether case and control did (+) or did not
(−) recall visiting areas, or were uncertain (?).

Table 3. *Study 2 (two controls per case)*

| | | Controls | | | | | |
		+ +	+ −	+ ?	− ?	− −	P (exact 2-tailed)
Central area	Case +	5	3	0	0	1	0·66
(on foot)	Case −	0	2	0	0	0	
Central area	Case +	6	3	0	1	0	0·54
(on foot/car)	Case −	0	1	0	0	0	
Peripheral area	Case +	1	2	0	0	2	0·46
(on foot)	Case −	0	2	0	0	4	
Peripheral area	Case +	1	4	2	0	3	0·054
(on foot/car)	Case −	0	1	0	0	0	

Groups of cases and controls classified according to whether cases and controls did (+) or did
not (−) recall visiting areas or were uncertain (?).

Table 4. *Recovery by culture of* Legionella pneumophila *from cooling towers in relation to regular biocide treatment*

	Number		
	Examined	Containing *L. pneumophila*	Containing serogroup 1 (Pontiac)
With biocides	33	1 (3 %)	1
No biocides	23	18 (78 %)	8

The man excluded from Study 2 because he lived outside Gloucester regularly visited the central area. Of the three cases of Pontiac fever, one lived close to the peripheral area, but the other two lived in Cheltenham and denied visiting Gloucester.

Environmental studies

Cooling towers were found at 19 premises within Gloucester and three on its outskirts. *Legionella* spp. were identified in samples from 11 premises.

L. pneumophila SG 1 (Pontiac) was isolated from water samples from 9 of these premises in the first round of sampling, and *L. pneumophila* SG 1 (Olda) was also isolated from samples from 4 of these 9. *L. pneumophila* SG 1 (Bellingham) was isolated from samples from one site and *L. pneumophila* SG 5 from another.

Towers which had been treated with biocide during the previous 3 months (i.e. regular addition of biocide in addition to any hypochlorite added at the time of disinfection) were less likely ($P < 0.001$) to yield *Legionella* spp. (Table 4).

The tower closest to the central area appeared well maintained and *Legionella* spp. were never recovered from it despite careful sampling on three occasions. Water samples from two towers at premises some 300 yards to the north grew *L. pneumophila* SG 1 (Pontiac) at concentrations of up to 1.4×10^3 colony forming units (c.f.u.) per litre (and *L. bozemanii* at 3×10^2 c.f.u. per litre).

Water samples from towers at 3 of 6 sites in or near the peripheral area did not yield *Legionella* spp. Samples from 2 towers at 2 other sites yielded *L. pneumophila* SG 1 at concentrations of 5×10^2 (Pontiac) and 3×10^7 (Pontiac) c.f.u. per litre respectively. Samples from 1 of 2 towers at the other site near the peripheral area yielded *L. pneumophila* SG 1, *L. pneumophila* SG 9 and *L. longbeachii* at a total concentration of $\geqslant 10^5$ c.f.u. per litre.

Water samples from 2 ornamental pools, 6 humidifiers, 2 water curtains in paint spray booths, and a puddle from a dry cooling tower all failed to yield *Legionella* spp.

There were 34 wind recordings taken at Staverton Airport between 12 and 18 September of which 28 were in the quadrant 000–090 degrees, four calm, one variable, and one 350 degrees. Seven patients who fell ill between 18 and 25 September may have been infected during this period. Apart from 24–25 September, when 13 out of 16 recordings were in the quadrant 000–090 degrees, only one such wind direction was recorded in the whole of the rest of September. Wind from the northeast might have carried aerosol to the central area from the towers 300 yards to the north of it, or along the line of the major road (peripheral
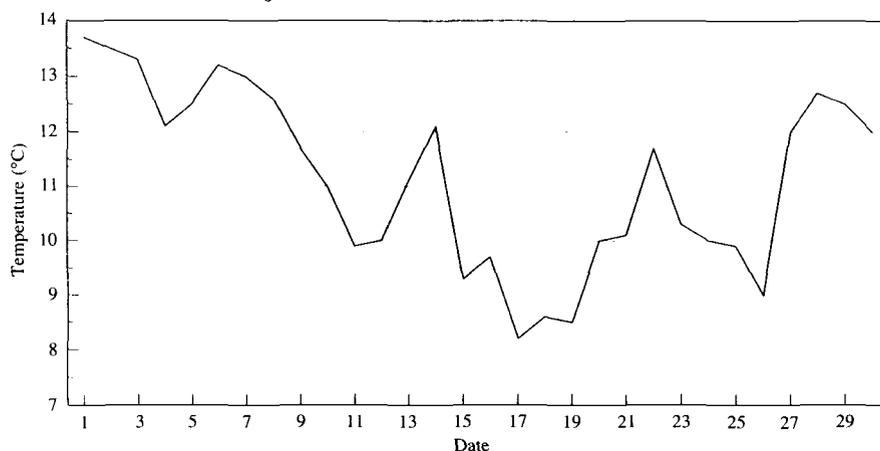
Fig. 2. Temperature (dry bulb). Single daily readings taken at 09.00 GMT,
September 1986. (Source: Cheltenham Parks Department.)

area) exposing car occupants to the maximum risk of infection. The relation
between wind direction at the two areas and that recorded at Staverton is
unknown, and wind records made by the Environmental Services Department
showed variable wind directions between 12 and 18 September.

Temperatures were lower between 15 and 19 September than any other day that
month except one (Fig. 2).

On 20 September the temperature and relative humidity rose. Four cases fell in
on 22 and 23 September, and another on the 25.

DISCUSSION

Investigations of outbreaks of Legionnaires' disease have led to the identifi-
cation of various sources of infection and routes of transmission. Domestic hot-
water systems in large buildings such as hotels and hospitals have been shown to
be important sources [14], but at the time of the Gloucester outbreak water
cooling towers had been implicated in three outbreaks in England and Wales
[15–17] and two in Scotland [18, 19].

Legionella spp. may be present in many cooling water systems and domestic hot-
water systems, but only rarely does this result in human infection. Their growth
may be minimized by cleaning and disinfection at least twice a year; continuous
chlorination or regular treatment with biocide has been recommended [20]. Our
results confirm the efficacy of such treatment. Dry heat rejection devices cannot
disseminate *Legionella* spp. but are larger than wet devices and considerably more
expensive to install and to operate.

The presence of the Pontiac sub-type of *L. pneumophila* SG 1 in 9 of 11 premises
with towers colonized by *Legionella* spp. was unexpected in view of previous
findings that this sub-type accounted for only a small proportion of environmental
isolates, but a large proportion of clinical isolates of *Legionella* spp. [7]. Restriction
fragment length polymorphism (RFLP) analysis [21] showed that all isolates of
the Pontiac sub-type of *L. pneumophila* were of RFLP type 1. In one study [21],
10 of 33 environmental isolates of *L. pneumophila* SG 1 were of this RFLP type.

This finding raises the possibility that towers may become colonized either as a result of contamination by drift from another tower or *via* mains water. The apparently random distribution of colonized and non-colonized towers did not provide support for the former hypothesis; it appears that maintenance is the most important factor in determining whether a tower becomes detectably colonized.

The variable severity of the disease was apparent – 3 patients died, but 3 survivors of Legionnaires' disease and the 3 cases of Pontiac fever did not need hospitalization. It was also confirmed that many cases of Legionnaires' disease remain unrecognized unless specific serology is performed, 9 of the 15 cases having only been diagnosed during the case finding exercise.

It has been suggested [15] that, for *Legionella* spp. in cooling tower drift to remain viable until they reach ground level, there must be light surface winds and high humidity. Neither condition obviously prevailed between 12 and 18 September, when northeasterly wind directions were recorded, and when the seven cases who fell ill between 18 and 25 September may have been infected. These days were cooler than the rest of the month but were otherwise unremarkable.

Alternatively, the five cases with dates of onset of illness between 22 and 25 September may have been infected on or soon after 20 September. On that date a rise of temperature and humidity occurred after 5 cold days. It is possible that thermostatically controlled fans in cooling towers that had been inactive during the cold spell may have started working again on that date, with increased aerosol production as a result.

Intensive epidemiological and microbiological investigation failed to incriminate any single cooling system as the source of infection. Three factors suggest that more than one source may have been involved: the finding of several colonized cooling systems; the fact that neither of the suspect areas had been visited by all cases; and the diagnosis of two cases of Pontiac fever in patients living nine miles distant from Gloucester who denied visiting Gloucester at any time during the month before they became unwell. If this was indeed a multiple source outbreak, local meteorological conditions favouring simultaneous dissemination of aerosol drift from more than one tower may have been an important factor.

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