The burden of Legionnaires' disease in New Zealand (LegiNZ): a national surveillance study

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Summary

Background Legionnaires' disease is under-diagnosed because of inconsistent use of diagnostic tests and uncertainty about whom to test. We assessed the increase in case detection following large-scale introduction of routine PCR testing of respiratory specimens in New Zealand.

Methods LegiNZ was a national surveillance study done over 1-year in which active case-finding was used to maximise the identification of cases of Legionnaires' disease in hospitals. Respiratory specimens from patients of any age with pneumonia, who could provide an eligible lower respiratory specimen, admitted to one of 20 participating hospitals, covering a catchment area of 96% of New Zealand's population, were routinely tested for legionella by PCR. Additional cases of Legionnaires' disease in hospital were identified through mandatory notification.

Findings Between May 21, 2015, and May 20, 2016, 5622 eligible specimens from 4862 patients were tested by PCR. From these, 197 cases of Legionnaires' disease were detected. An additional 41 cases were identified from notification data, giving 238 cases requiring hospitalisation. The overall incidence of Legionnaires' disease cases in hospital in the study area was 5·4 per 100 000 people per year, and *Legionella longbeachae* was the predominant cause, found in 150 (63%) of 238 cases.

Interpretation The rate of notified disease during the study period was three-times the average over the preceding 3 years. Active case-finding through systematic PCR testing better clarified the regional epidemiology of Legionnaires' disease and uncovered an otherwise hidden burden of disease. These data inform local Legionnaires' disease testing strategies, allow targeted antibiotic therapy, and help identify outbreaks and effective prevention strategies. The same approach might have similar benefits if applied elsewhere in the world.

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Introduction

Legionella bacteria are considered to be uncommon causes of pneumonia,[1] but the true incidence has not been rigorously assessed. Specific laboratory tests are required for diagnosis because pneumonia caused by legionella (Legionnaires' disease) cannot be clinically or radiographically distinguished from pneumonia of other causes.[2,3] However, most of the world has little, if any, data for the incidence of Legionnaires' disease simply because diagnostic testing is not done in all hospital admissions. When testing is done in acute disease, sole reliance on urinary antigen tests that only detect *Legionella pneumophila* serogroup 1, combined with limitations of other diagnostic tests and their inconsistent deployment, means there is likely to be a substantial hidden burden of undiagnosed disease. This hidden burden results in a misleading understanding of Legionnaires' disease epidemiology and undue reliance on empirical treatment. Empirical treatment can cause poorer patient outcomes from adverse effects and overuse of antimicrobial agents.[4,5] An accurate

understanding of the burden of Legionnaires' disease is also important given that it is potentially preventable, with key sources of infection being contaminated water and soil or compost.[1]

In the Canterbury region of New Zealand, where legionellae have long been recognised as important causes of community-acquired pneumonia,[6,7] testing for Legionnaires' disease has been more intensive than elsewhere in the country. As a result, Canterbury has the highest reported incidence of Legionnaires' disease in New Zealand, accounting for about a third of all national case notifications, even though the region has less than 10% of the country's total population.[8] Previously, the diagnostic testing strategy for case detection in Canterbury involved routine legionella culture of all lower respiratory tract specimens from patients admitted to hospital with pneumonia. In 2010, culture was replaced by PCR testing as the primary diagnostic technique because of greater sensitivity and shorter reporting time than culture.[7] This change in strategy led to a four-times increase in case detection

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Research in context

Evidence before the study
We searched MEDLINE, PubMed, and Google Scholar using
the search terms "legionella diagnostics", "legionella PCR",
"routine legionella PCR", "diagnosis of Legionnaires' disease",
and "Legionnaires' disease incidence rates" that were published
from database inception until Dec 31, 2017. Review of the
articles and citations, which included two systematic reviews,
showed that most studies did not implement routine PCR
testing as part of normal clinical practice, were retrospective,
and involved comparing the utility of PCR versus culture and
urinary antigen tests for detecting cases. The few studies in
which active surveillance was done with a routine PCR testing
algorithm were either restricted to individuals with severe
pneumonia or did not cover a large percentage of a population
or country's geographical area. These few studies include our
previous study that covered only the Canterbury region of
New Zealand.

Added value of this study
We did the first near-nationwide study using routine systematic
PCR testing to assess the incidence of Legionnaires' disease in
patients in hospital over a 1-year period. We showed that when
systematically sought, there was a substantial increase in cases,
indicating a previously hidden burden of disease. New findings

included high incidence of Legionnaires' disease in regions
that had previously reported few cases. We confirmed the
importance of *Legionella longbeachae* in New Zealand,
and that it caused the majority of legionella cases.
However, our incidence of detected *Legionella pneumophila*
disease is also one of the highest in the world.

Implications of all the available evidence
The true burden of Legionnaires' disease globally is unknown
because diagnostic testing in many parts of the world is either
non-existent or erratically deployed, and also largely
ignores the role that non-*L pneumophila* species might have.
This underdiagnosis can lead to an inaccurate and misleading
picture of local disease epidemiology, have an impact on the
clinical management of cases, and also overlook the public
health implications of a positive diagnosis. Routine PCR testing
provides a rapid and reliable tool for the diagnosis and
surveillance of Legionnaires' disease. It is a valuable addition to
front-line diagnostic laboratories. When used in a systematic
way, it substantially increases case finding (especially
non-*L pneumophila* disease), clarifies local epidemiology,
promotes awareness, and can help to inform disease
prevention strategies.

and has been maintained as standard practice in the
region ever since.

Following the success of Canterbury's enhanced
systematic testing strategy, we rolled out the same
strategy across most of New Zealand with the objective
of more accurately estimating the national and regional
incidence of Legionnaires' disease among patients
who are admitted to hospital with pneumonia. We
hypothesised that many cases of Legionnaires' disease
are undiagnosed and there would be a marked increase
in case detection following the introduction of this
strategy.

Methods

Study design

LegiNZ was a prospective surveillance study, in which
active case-finding through routine legionella PCR test-
ing of lower respiratory tract specimens was used to
maximise the identification of cases of Legionnaires'
disease in hospitals across New Zealand.

The study took place between May 21, 2015, and
May 20, 2016. Laboratories serving 20 secondary and
tertiary hospitals in 17 of the country's 20 District Health
Boards (DHBs) participated. The catchment area covered
96% of New Zealand's population.[9]

A case of Legionnaires' disease was defined as a
patient with pneumonia who had a positive PCR,
culture, or urinary antigen test for a legionella species,
or fourfold or more increase in reciprocal legionella
antibody titres. This definition is the same as that for

confirmed cases used in New Zealand for surveillance
purposes.

Participants

LegiNZ participants were patients of any age, admitted to
hospital at a study site, who had provided an eligible
lower respiratory specimen (figure 1). On receipt of a
specimen, the hospital laboratory used the information
provided on the accompanying request form to identify
eligible specimens, and referred them to one of four
participating specialist laboratories for legionella PCR
testing. PCR-positive specimens were also cultured
for legionella at either the testing laboratory or at
the Legionella Reference Laboratory (Institute of
Environmental Science and Research, Porirua, New
Zealand; figure 1).

Legionella urinary antigen tests and serology also
continued to be requested at the discretion of attending
clinicians. All cases of Legionnaires' disease in
New Zealand are notified to public health units and to
the national Legionella Reference Laboratory. At the end
of the study, the laboratory provided information on all
cases of Legionnaires' disease notified in the participating
DHBs over the study period. From this information,
additional patients in hospital in whom diagnosis was
made through urinary antigen or serological testing were
identified.

The study protocol was approved by the Central Health
and Disability Ethics Committee (14/CEN/114). Individual
patient consent was not required because PCR testing of

lower respiratory specimens for legionella was regarded as part of usual clinical care.

Procedures

Eligible lower respiratory specimens were sent to one of four participating laboratories for legionella real-time PCR testing (Middlemore Hospital Laboratory, South Auckland, New Zealand; LabPlus, Auckland, New Zealand; Wellington Hospital Laboratory, Wellington, New Zealand; Canterbury Health Laboratories, Christchurch, New Zealand). Specimens were liquefied as required with dithiothreitol (Sputasol, Oxoid, Cambridge, UK) in a 1:1 ratio to obtain a homogeneous solution for nucleic acid extraction. The isolation of DNA from specimens at Middlemore Hospital, LabPlus, and Wellington Hospital laboratories was done with the MagNA Pure DNA nucleic acid extractor and gDNA isolation kit (Roche, Basel, Switzerland) as recommended by the manufacturer, whereas at Canterbury Health Laboratories it was done with the NucliSENS easyMag (Biomérieux, Marcy-l'Étoile, France) nucleic acid extractor and gDNA extraction kit. At Auckland LabPlus and Canterbury Health Laboratories, the presence of legionella DNA was detected with primers and probes to the *ssrA* gene,[10] whereas at Wellington Hospital Laboratory the 16S gene target was used,[11] and at Middlemore Hospital Laboratory the Easyplex Pneumonia Panel (AusDiagnostics, Mascot, Australia) was used as per the manufacturer's instructions. Species identification at Middlemore, Wellington, and Auckland LabPlus laboratories was done with high resolution melt analysis.[11] Confirmation of PCR-positive specimens and speciation at Canterbury Health Laboratories was done with *ITS* gene PCR with specific probes to detect *L pneumophila* and *Legionella longbeachae*,[7,12] while other legionella species were identified through sequencing of the PCR amplicons. Inhibitor controls were used to validate negative results.

A quality assurance programme was established to ensure that the legionella PCR testing across the four laboratory sites was consistent. Before the start and at 6 months of study, 12 specimens containing various quantities of legionella (including specimens containing no legionella) were tested by individuals masked to the legionella quantity at each of the four testing laboratories. Correct and consistent results were achieved from all sites.

Culture of legionella PCR-positive specimens was done on buffered charcoal yeast extract-based agar, with and without modified Wadowski-Yee supplement, and incubated at 35°C for 7 days. Isolates were identified by MALDI-TOF MS analysis (Bruker Daltonik GmbH, Bremen, Germany) or referred to the Legionella Reference Laboratory for identification and serotyping.

Age, gender, date of specimen collection or testing, admitting hospital, and legionella test results were documented from the specimen request form and testing laboratory data. Information from specimen request forms was linked to routinely collected demographic, hospitalisation, and mortality data by the New Zealand
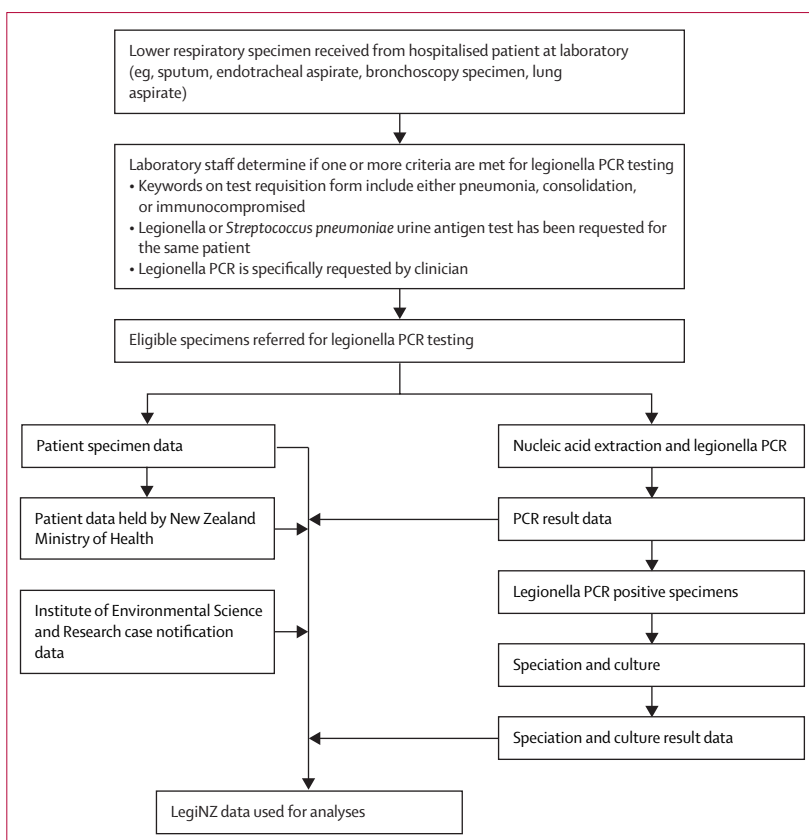

Figure 1: LegiNZ legionella testing algorithm and data collection

Ministry of Health, anonymised, and provided to the researchers (figure 1). These data included ethnicity, New Zealand deprivation index, length of hospital stay, previous hospital admissions and their reasons in the 5 years before the index admission, and readmission to hospital and all-cause mortality in the 3 months after the admission. The first admission during the study period in which a participant had provided an eligible specimen was included in the analysis. When there was more than one specimen provided within a hospital admission, the information provided with the first specimen was used to characterise the patient, unless the patient had Legionnaires' disease, in which event the specimen that was positive for legionella was used as the index specimen for that episode.

The 2013 New Zealand deprivation index was used to characterise patients' socioeconomic status. This index characterises the socioeconomic deprivation of small geographical areas on the basis of data from the census.[13] Respiratory and cardiovascular causes of previous hospital admissions were categorised on the basis of International Classification of Diseases 10 codes (appendix).

See **Online** for appendix

Outcomes

The primary outcomes for the study were the number of cases and population incidence of Legionnaires' disease
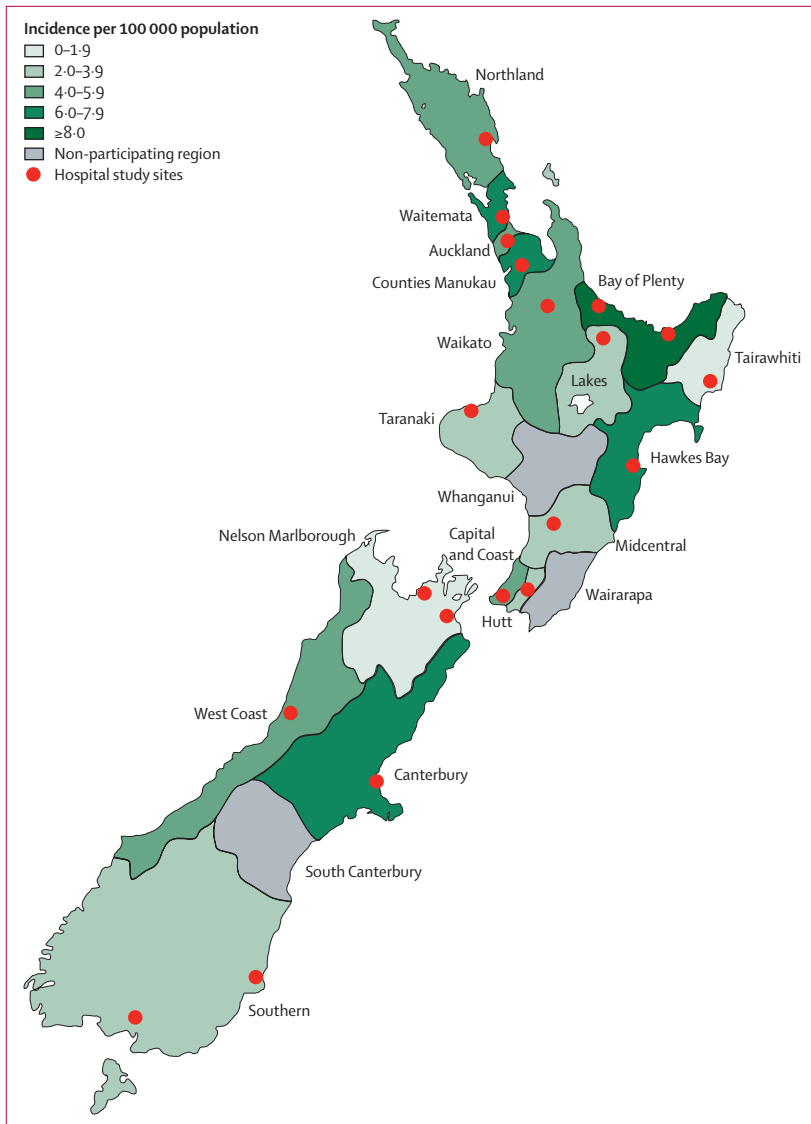
Figure 2: Age-standardised incidence of legionellosis in hospitals participating District Health Board regions during the study period with study sites

Incidence was not calculated for the three non-participating District Health Board regions (Wanganui, Wairarapa, and South Canterbury), which are coloured grey. The red circles denote the 20 hospital study sites (Whangarei Hospital, North Shore Hospital, Auckland City Hospital, Middlemore Hospital, Waikato Hospital, Tauranga Hospital, Rotorua Hospital, Whakatāne Hospital, Gisborne Hospital, Taranaki Base Hospital, Hawke's Bay Hospital, Palmerston North Hospital, Hutt Hospital, Wellington Hospital, Wairau Hospital, Nelson Hospital, Grey Base Hospital, Christchurch Hospital, Dunedin Hospital, and Invercargill Hospital).

in hospital. This outcome was calculated for DHB region, age, season, socioeconomic deprivation, ethnicity, and legionella species, and per sample tested. Statistics New Zealand projected population data[14] for 2015 were used for the incidence denominators (except for socioeconomic status, for which only 2013 data were available). Incidence by DHB, deprivation, and ethnicity was age-standardised to the overall population of the included regions.

Secondary outcomes included mortality, prevalence of intensive care unit (ICU) admission, and length of hospital stay among Legionnaires' disease cases. Because of concerns about regional variability in the proportion of patients with pneumonia for whom a specimen was tested by LegiNZ, we compared the number of LegiNZ participants in each DHB with data reported by the Ministry of Health on the total number of hospital admissions with pneumonia from July 1, 2014, to June 30, 2015, the latest reported.[15]

Statistical analysis

Poisson exact CIs were calculated for counts. To estimate the effect of the LegiNZ strategy on Legionnaires' disease detection, incidence during LegiNZ was compared with rates of notified Legionnaires' disease reported by national surveillance in previous years.[16] Because routine national surveillance data includes patients who would not meet LegiNZ inclusion criteria, we added such cases that were notified from the study area during the study period to the LegiNZ case numbers for this purpose. For comparison, the non-Canterbury incidence for 2012–14 was calculated, because Canterbury had been using the LegiNZ testing algorithm since 2010.[7] Case numbers for 2012–14 were obtained from annual notified diseases reports[16] and population numbers from Statistics New Zealand.[14] All statistical analyses were done with Stata IC (version 15.1).

Role of the funding source

The funders of the study had no role in study design, data collection, analysis, or interpretation, or writing of the manuscript. DRM had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results

In total, 6034 specimens were tested for legionella by PCR. Of these, 5622 were eligible specimens taken during 5153 hospital admissions of 4862 patients. Figure 2 shows the locations of the participating regions and hospitals, and table 1 shows the characteristics of patients whose respiratory specimens were included in the study. Most patients had only one specimen tested, whereas a small proportion had three or more. About two-thirds of index admissions were during winter and spring, and more than half of patients were aged 65 years or older. Patients who lived in more socioeconomically deprived areas were over-represented, with nearly a third living in areas with the highest quintile of deprivation. Although most patients had been admitted to hospital during the previous 5 years, fewer than half had been admitted for respiratory disease, and less than a quarter had previously been admitted for pneumonia (table 1). The number of patients by DHB is shown in the appendix.

Of 5622 eligible specimens, 197 specimens from 197 patients were positive for legionella by PCR. A further 41 cases of Legionnaires' disease, in which a respiratory specimen was not available for PCR testing, were

Table 1

	Number of patients (N=4862)
Number of LegiNZ specimens tested per patient	
1	4287 (88%)
2	447 (9%)
3	90 (2%)
4	28 (<1%)
≥5	10 (<1%)
Season	
Autumn (March–May)	886 (18%)
Winter (June–Aug)	1738 (36%)
Spring (Sept–Nov)	1334 (27%)
Summer (Dec–Feb)	904 (19%)
Sex	
Female	2154 (44%)
Male	2708 (56%)
Age, years	
0–14	131 (3%)
15–24	184 (4%)
25–39	353 (7%)
40–64	1510 (31%)
65–79	1666 (34%)
≥80	1018 (21%)
Socioeconomic deprivation*	
1–2 (least deprived)	601 (12%)
3–4	770 (16%)
5–6	782 (16%)
7–8	1100 (23%)
9–10 (most deprived)	1574 (32%)
Missing	35 (<1%)
Ethnicity†	
Māori	867 (18%)
Pacific	592 (12%)
Asian	284 (6%)
Other	3068 (63%)
Missing	51 (1%)
Hospital admissions in the 5 years before index admission	
Any hospital admissions	3849 (79%)
Previous admission for pneumonia	1116 (23%)
Previous admission for any respiratory disease	2009 (41%)
Previous admission for cardiovascular disease	1375 (28%)

Data are n (%). *New Zealand deprivation index 2013 quintiles. †Prioritised ethnicity; when a patient identified with more than one ethnic group, we assigned their ethnicity to a single ethnic group based on the ethnicities they identified with, in the prioritised order of Māori, Pacific, Asian, and European or Other.

Table 1: Characteristics of patients that contributed eligible specimens to LegiNZ

Table 2

	Number of cases	Incidence per 100 000 per year (95% CI)	Age-standardised incidence per 100 000 people per year* (95% CI)
Age, years			
0–14	1	0·1 (0·0–0·6)	..
15–24	1	0·2 (0·0–0·9)	..
25–39	5	0·6 (0·2–1·4)	..
40–64	92	6·5 (5·2–7·9)	..
65–79	92	18·9 (15·2–23·2)	..
≥80	47	30·3 (22·3–40·3)	..
Season†			
Autumn (Mar–May)	54	1·2 (0·9–1·6)	..
Winter (June–Aug)	27	0·6 (0·4–0·9)	..
Spring (Sept–Nov)	71	1·6 (1·3–2·0)	..
Summer (Dec–Feb)	86	1·9 (1·6–2·4)	..
Socioeconomic deprivation‡			
1–2 (least deprived)	48	5·6 (4·2–7·5)	5·6 (4·0–7·2)
3–4	43	5·2 (3·8–7·0)	5·1 (3·6–6·6)
5–6	42	5·2 (3·8–7·1)	5·2 (3·6–6·7)
7–8	58	7·3 (5·6–9·5)	7·3 (5·4–9·2)
9–10 (most deprived)	46	5·8 (4·2–7·7)	6·7 (4·8–8·7)
Ethnicity§			
Māori	14	2·0 (1·1–3·4)	3·6 (1·5–5·7)
Pacific	10	3·4 (1·6–6·3)	5·9 (1·8–10·0)
Asian	8	1·4 (0·6–2·7)	1·8 (0·5–3·2)
Other	201	7·0 (6·1–8·1)	5·8 (5·0–6·6)
Legionella species†			
Legionella pneumophila	52	1·2 (0·9–1·5)	..
Legionella longbeachae	150	3·4 (2·9–4·0)	..
Other	24	0·5 (0·3–0·8)	..
Not speciated	12	0·3 (0·1–0·5)	..

*Ethnicity age standardised to the total population of the study areas at 2015, ages 0–14, 15–24, 25–39, 40–64, 65–79, and ≥80 years; socioeconomic deprivation age standardised to total population at 2013, ages 0–14, 15–24, 25–64, 65–74 and 75+ years due to data restrictions. †Not age standardised because the same denominator was used for each calculation. ‡Quintiles of NZDep13 index, one case had missing deprivation data. §Prioritised ethnicity (see table 1 footnote), five cases had missing ethnicity data.

Table 2: Incidence rate of Legionnaires' disease by age, season, deprivation, ethnicity, and legionella species

diagnosed through urinary antigen or serological testing. These cases were identified through notification data, giving 238 cases of Legionnaires' disease in hospital in participating DHBs that met our diagnostic criteria over the study period, an overall incidence of 5·4 per 100 000 people per year (95% CI 4·7–6·1). Positive test combinations are shown in the appendix (p 3). All the Legionnaires' disease cases had community-acquired pneumonia, and none had more than one episode of Legionnaires' disease. Table 2 shows disease incidence by age, season, socioeconomic deprivation, ethnicity, and legionella species. *L longbeachae* was the cause of disease in 150 (63%) of 238 cases, with the incidence of *L longbeachae* disease nearly three-times that of disease caused by *L pneumophila* (table 2). Legionnaires' disease incidence increased with age, and was similar across quintiles of socioeconomic deprivation. Most cases of *L longbeachae* were diagnosed in the spring and summer (September to March; figure 3).

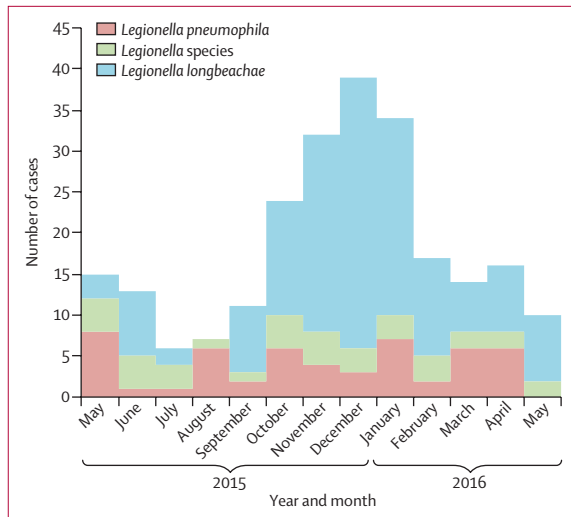Regional unadjusted incidence ranged from 0 in Tairawhiti, to 10·8 per 100 000 people per year in the

Figure 3: **Monthly number of cases of Legionnaires' disease in hospital during the study period**
The number of cases for May are split over 2015 and 2016 because the study started part-way through the month.

neighbouring Bay of Plenty (figure 2). The 95% CIs of age-standardised incidence largely overlapped with each other and with the overall incidence (figure 2; appendix p 4). There were regional differences in the proportion of specimens sent for testing through LegiNZ. On the basis of 2014–15 DHB admissions data, the proportion of LegiNZ specimens to pneumonia admissions ranged from 12% to 53%, and those regions with a higher proportion had a higher incidence of Legionnaires' disease detected through LegiNZ (data not shown).

38 patients (16%, 95% CI 11·6–21·2) with Legionnaires' disease were admitted to ICUs, and the median length of hospital stay was 6 days (IQR 4–8). Case fatality rates were low, with only seven patients (2·9%; 1·2–6·0) having a cause of death listed as Legionnaires' disease or pneumonia. Six of these patients died within 30 days of admission to hospital, and one at 33 days after admission. Over a 90-day period after admission with Legionnaires' disease, 39 patients were readmitted to hospital (12 with pneumonia), and eight patients died.

A further 18 patients who met our diagnostic criteria but were not admitted to hospital, and another 50 patients who did not meet our diagnostic criteria, were notified to the public health authorities in the LegiNZ area during the study period. The cases that did not meet our criteria had a diagnosis on the basis of one or more elevated legionella antibody reciprocal titres of 512 or greater without seroconversion, which were classified as probable cases for national surveillance purposes. There were 306 notified cases and an overall notified rate of 6·9 per 100 000 people per year in the LegiNZ area during the study period. The average non-Canterbury notified rate for 2012–14 was 2·4 per 100 000 people per year.

Discussion

Here, we report the first near-nationwide surveillance study to actively estimate the burden of Legionnaires' disease. A pragmatic and systematic PCR testing strategy uncovered a substantial, otherwise undiagnosed, burden of Legionnaires' disease. This finding illustrates that many cases go undetected if diagnostic testing relies solely on clinical discretion. Our approach identified regional variability in both incidence and causative species, including a high incidence of Legionnaires' disease in regions that had previously reported few cases.[16]

Over the 1-year study period, the incidence of Legionnaires' disease cases among patients requiring hospitalisation that met our diagnostic criteria was 5·4 per 100 000 people. The corresponding rate of notified cases per year, including non-hospitalised and probable cases, was 6·9 per 100 000 people, nearly three-times the average non-Canterbury rate of notified disease over the previous 3 years.[16] The relative increase in case detection in this study is similar to the four-times increase we observed following the introduction of routine PCR testing in the Canterbury region in 2010.[7] By comparison, the reported incidence in Australia is 1·3 per 100 000 people, and rates of Legionnaires' disease in Canada, Europe, Japan, and the USA are 0·2–1·1 cases per 100 000 people per year.[1] However, any comparisons need to be made with caution as these incidences are undoubtedly underestimated because of differences in case assessment, diagnostic testing, and reporting practices.

This study also confirms the importance of *L longbeachae* as the predominant cause of Legionnaires' disease in New Zealand.[6,7] Legionella species other than *L pneumophila* are well recognised causes of pneumonia,[17–19] and *L longbeachae* is an important cause of Legionnaires' disease in Australasia and Scotland.[18,20] *L longbeachae* is found in soil and composted plant material,[18,20] and people at greatest risk are those involved in gardening.[18,21] However, the significance of *L longbeachae* for most of the world is uncertain as few diagnostic laboratories routinely test for species other than *L pneumophila*. Consequently, *L longbeachae* is likely to be underdiagnosed as a cause of Legionnaires' disease worldwide. It is unknown whether the high incidence of *L longbeachae* disease in New Zealand is because of more rigorous testing for this species or something specific to the New Zealand environment. However, the high incidence of Legionnaires' disease in New Zealand is not simply because of *L longbeachae* disease; New Zealand also has one of the highest reported incidences of Legionnaires' disease caused by *L pneumophila*,[1] and our findings are relevant to all legionella species and regions of the world.

PCR is arguably the test of choice for diagnosing Legionnaires' disease. It has high sensitivity and high specificity for legionella species, detects all species and serogroups, and can increase case detection by more than 30% over other methods such as culture and urinary

antigen testing.[22–24] Serology is now of limited use because of the need to obtain convalescent sera. Routine PCR testing of respiratory specimens for legionella allows early detection within a clinically relevant time frame.[7,25] The technique also detects a greater proportion of less severe disease, with evidence that such cases have lower bacterial loads.[7,26] A large portion of the world uses Legionnaires' disease testing strategies that rely almost solely on urinary antigen testing that consequently systematically fail to detect most legionella species and serogroups, and potentially distort regional epidemiological data.

Our study design was intentionally pragmatic and has several limitations. Our reliance on obtaining respiratory specimens means that for individuals who cannot produce sputum (ie, up to half of patients with Legionnaires' disease[27–29]) testing will not be done and cases will be missed. Although this can be overcome partly by sputum induction,[30] not all patients can tolerate or undergo this procedure. We also depended on appropriate recording of clinical information on specimen request forms to trigger testing. Cases will have been missed because inadequate clinical details were provided. Other testing algorithms mitigate this requirement by testing patients from specific units (eg, ICUs),[25] but this testing of patients in ICUs limits testing to severe pneumonia. Regional incidences of Legionnaires' disease varied widely, although this might partly be explained by regional variability in the proportion of patients with pneumonia who provided respiratory specimens for testing, probably as a result of differences in hospital-specific thresholds for specimen collection. Also, small numbers in some regions and random fluctuations over time mean that identification of regions with consistently higher rates will require longer-term data. By including most hospitals nationally, we aimed to minimise bias that might occur if a less representative sample of patients had been included. A clear algorithm was used at the participating hospital laboratories to determine which specimens would be tested by LegiNZ to minimise bias that might have been introduced by clinicians' judgment about which patients were most likely to have Legionnaires' disease.

This study is not a study of the causes of pneumonia. The focus was on the detection of cases of Legionnaires' disease and, consequently, there was no testing for pathogens other than legionellae, and it is possible that some of the Legionnaires' disease cases had polymicrobial infections. However, detection of legionellae as part of polymicrobial infection is almost always regarded as clinically meaningful, especially as no evidence exists that these bacteria are colonisers of the respiratory tract. There was also no intention to examine risk factors for Legionnaires' disease, as this subject has already been studied extensively.

Despite its limitations, our routine PCR testing strategy provides a rapid and reliable tool for the diagnosis and surveillance of Legionnaires' disease and our findings have several practical clinical and public health implications that extend beyond New Zealand. First, our testing algorithm is a practical epidemiological tool for better characterising the burden of Legionnaires' disease anywhere. Developing a more comprehensive approach to testing was a main driver for our study, as historical testing for Legionnaires' disease in most regions of New Zealand was ad hoc at best. Systematic case detection leads to better characterisation of Legionnaires' disease epidemiology and, in turn, further informs local disease testing strategies, promotes awareness, and helps identify effective prevention strategies. For example, following this study, recognition of Legionnaires' disease in regions where it previously was considered rare prompted changes in protocols for the management of pneumonia and refocused prevention efforts (mainly around gardening behaviour). Legionnaires' disease is a preventable form of pneumonia, and opportunities for prevention will be missed or compromised if the true burden remains hidden. Second, routine PCR testing for legionella allows targeted antibiotic therapy to be given in a timely manner, thereby influencing patient prognosis and outcome, while improving antibiotic stewardship.[4,5] Even in regions of the world where Legionnaires' disease is thought to be rare, concern about Legionnaires' disease is a major reason for the inclusion of broad-spectrum empirical antibiotic regimens in community-acquired pneumonia treatment guidelines.[31,32] We believe our findings support testing for Legionnaires' disease in all patients admitted to hospital with community-acquired pneumonia to better target therapy. Third, PCR testing has the potential to quickly identify outbreaks due to all legionella species and serogroups, thus improving the public health response and surveillance of Legionnaires' disease.

Although our study provides only a 1-year snapshot, it clearly illustrates that active case finding through more rigorous testing increases case detection and better clarifies regional epidemiology of Legionnaires' disease. The findings from this study have already prompted changes to Legionnaires' disease testing and clinical management strategies and improvements in public-health messaging to promote awareness and disease prevention in New Zealand. The same approach might have similar benefits if applied elsewhere in the world.

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