*Epidemiology and Infection*, Estimating the burden of illness caused by domestic waterborne Legionnaires’ disease in Canada: 2015-2019

Carrie K.M. McMullen, Brendan Dougherty, Diane T. Medeiros, Gordon Yasvinski, Deepak Sharma, and M. Kate Thomas

**SUPPLEMENTARY MATERIAL**

SUPPLEMENTARY TABLE S1. Comparison of the modelling approaches and inputs used in this (HC-PHAC) model versus those used in the U.S. CDC [1] model to estimate the burden of illness caused by Legionnaires’ disease

|  |  |  |
| --- | --- | --- |
|   |   | **Data sources**  |
| **Model input**  | HC-PHAC**1**  | U.S. CDC  |
| **Estimating illnesses** | Total population  | Canada’s population estimate as a cumulative distribution by year (2015-2019) [2]  | U.S. 2014 population   |
| Reported number of illnesses (of legionellosis) | Canadian Notifiable Disease Surveillance System (CNDSS, 2015-2019) [3] | CDC’s National Notifiable Diseases Surveillance System (NNDSS, 2008–2014) [4]  |
| Proportion travel-related**2**  | Used Collier et al. [1] value (source: CDC’s Supplemental Legionnaires’ Disease Surveillance System [4])  |
| Serogroup proportion  | Assessment broken down into the proportion of LD caused by *Legionella pneumophila* serogroup 1 (Lp1) and the proportion caused by other serogroups and species (non-serogroup 1 *L. pneumophila* and non-*L. pneumophila*) (non-Lp1) [5]  | Assessed LD caused by *Legionella* as one group |
| Underreporting: Reports local to national   | All cases assumed to be reported  |
| Proportion severe   | All cases assumed to be severe  |
| Care seeking  | Used Collier et al. [1] value (source: CDC’s Active Bacterial Core surveillance program 2011-2013 [6]) |
| Test requested2  | Based on three studies, including the one used by Collier et al. [1]. Resulted in a different distribution, with low value derived from Decker et al. [7], and modal and high values from Hollenbeck et al. [8], and Henry et al. [9], respectively  | Captured as “Specimen submission”, and based on only one study [7]  |
| Specimen submitted  | Based on expert feedback  | Not included  |
| Selected lab test2 | Considered three test methods: Urine Antigen Test (UAT), culture and polymerase chain reaction (PCR)   | Based solely on the use of UAT   |
| Selected lab test sensitivity2 | Considered test sensitivities associated with UAT, culture and PCR   | Considered only the test sensitivity of UAT  |
| Proportion waterborne**2** | Used Collier et al. [1] value (source: [10]) |
| **Estimating hospitalizations** | Reported hospitalizations  | Average annual number of hospitalizations with ICD10 codes (A48.1) reported in the Canadian Institute for Health Information Discharge Abstract Database (DAD) (2015-2019) [11] and Hospital Morbidity Database (HMDB) (2006-2010)**3** [12] | Proportion hospitalized in cases reported to CDC’s Active Bacterial Core surveillance program, 2011–2013 [6] |
| Under- and Over-capture multiplier  | Approach used by Thomas et al. [13] | Not included  |
| Underdiagnosis multiplier | Used Illness multipliers for test requested and selected lab test/test sensitivity | Assumed to be the same as for illnesses |
| **Estimating deaths** | Reported deaths  | Average annual number of hospitalizations with ICD10 codes (A48.1) reported in the DAD (2015-2019) [11] that were discharged as deaths **3**  | Proportion of case-patients who died, reported to CDC’s Active Bacterial Core surveillance program, 2011–2015 [6]   |
| Under- and Over-capture multiplier  | Approach used by Thomas et al. [13] | Not included  |
| Underdiagnosis multiplier  | Used Illness multipliers for test requested and selected lab test/test sensitivity | Assumed to be the same as for illnesses  |

**1**Model input values are available in Table S3; **2**Also applies to hospitalization and death estimates; **3**Data for the province of Québec were unavailable in the DAD, so the national hospitalizations and deaths had to be estimated as described by Glass-Kaastra et al. [14].

SUPPLEMENTARY APPENDIX S2. Outline and elaboration of methodology for estimating the burden of Legionnaires’ disease illness in Canada, 2015-2019

|  |
| --- |
| Estimating the annual number of illnessesThe number of annual illnesses of Legionnaires’ disease (LD) in Canada was estimated using the multiplier and schematic approach developed by Scallan et al. [15, 16] and Thomas et al. [17] (Figure 1). The data included in this model were sourced from the Canadian Notifiable Disease Surveillance System (CNDSS) (2015-2019) [3], Public Health Ontario Laboratory, CDC’s Supplemental Legionnaires’ Disease Surveillance System, among other peer-reviewed publications.Observed in surveillanceUsing a cumulative distribution, the reported average annual number of legionellosis illnesses to the CNDSS from 2015-2019 was 437.80 [3]. As an addition to the work carried out for the United States by Collier et al. [1], we applied an estimate of the proportion of cases in two subgroups to partition the model into two streams: *Legionella pneumophila* serogroup 1 (**Lp1**), and other serogroups and species (non-serogroup 1 *L. pneumophila* and non-*L. pneumophila)* (**non-Lp1**). This breakdown was derived from Ontario laboratory surveillance data [5] and was due to differences between the proportion of illnesses diagnosed in each subgroup, and variation in diagnostic testing sensitivities.Proportion travel-relatedCollier et al. [1] reported the proportion of persons with Legionnaires’ disease within the CDC’s Supplemental Legionnaires’ Disease Surveillance System (2014-2015) who reported travel outside of the United States within 10 days of illness was about 1% [4]. This value was removed at the top of the model, with the following assumptions: the model inputs do not differ for an internationally acquired case compared to a domestically acquired case; the model inputs, specifically “Care seeking” and “Test requested”, include only domestically acquired cases; and the proportion of Lp1 versus non-Lp1 does not differ among illnesses acquired internationally compared to domestically.Estimated serogroup breakdownThis model parameter refers to the number of domestically acquired Legionnaires’ disease illnesses reported nationally each year, separated by Lp1 and non-Lp1 subgroups [5]. Mathematically, this line accounts for those illnesses observed in surveillance that were not acquired internationally.Lp1After accounting for proportion of illnesses that were travel-related within the number of legionellosis cases observed in surveillance, there were 413.73 estimated reported domestically acquired Lp1 illnesses each year.Non-Lp1After accounting for proportion of illnesses that were travel-related within the number of legionellosis cases observed in surveillance, there were 19.57 estimated reported domestically acquired non-Lp1 illnesses each year.Underreporting multiplierLegionellosis is a nationally notifiable disease in Canada, whereby only laboratory-confirmed cases of disease should be notified to the federal level [18]. A confirmed case of legionellosis is defined as clinical illness with laboratory confirmation of infection, such as a) isolation of *Legionella* species or detection of the antigen from respiratory secretions, lung tissue, pleural fluid, or other normally sterile fluids; or b) a significant (*e.g.,* fourfold or greater) rise in *Legionella* species IgG titre between acute and convalescent sera; or c) IgG titre greater than 1:128 against *Legionella* species; or d) demonstration of *L. pneumophila* antigen in urine [18]. Legionnaires’ disease is defined as a serious respiratory illness that results in severe pneumonia, and may lead to death, whereas Pontiac fever, a milder form of legionellosis that results in flu-like symptoms, does not cause pneumonia [19]. Therefore, this model assumed that, based on its severity and high rate of medical care seeking behaviour, all reported legionellosis cases were Legionnaires’ disease. All confirmed cases of Legionnaires’ disease were assumed to be reported from the laboratory to local public health, and from local public health to provincial public health and to the CNDSS. Therefore, our model assumed there was no underreporting within the health-care system for Legionnaires’ disease.Underdiagnosis multiplierCare seeking behaviour in those with a severe disease, like Legionnaires’ disease, was assumed to be high. In cases reported to the CDC’s Active Bacterial Core surveillance program (2011-2015), 98% were hospitalized [1, 6], which demonstrates the severity of this disease and, therefore, likely a high rate of medical care seeking behaviour (>98%).Test requested refers to the proportion of true legionellosis cases that would have been tested with a laboratory diagnostic test for *Legionella* under standard testing guidelines (*i.e.*, those that have met the Infectious Disease Society of America-American Thoracic Society (IDSA-ATS) criteria for testing). This model input was based on three published studies, one of which was also referenced by Collier et al. [1]. The authors of the first study reported 56% of true legionellosis cases would have been tested with a diagnostic test under standard testing guidelines [7]; this represented the low distribution value in the model. The authors of the second study reported 59% of true legionellosis cases would have been tested with a diagnostic test under standard testing guidelines [8]; this represented the modal distribution value in the model. The authors of the third study reported 64.7% of patients with *Legionella* met the IDSA-ATS criteria for severe pneumonia [9]; this represented the high distribution value in the model. The standard testing guidelines referred to here are the five criteria in the IDSA-ATS consensus guidelines: history of alcohol abuse, recent travel within 2 weeks (assumed to exclude international travel), pleural effusion upon admission, admission to ICU for pneumonia, and failure of outpatient antibiotics [20]. Canadian guidelines suggest similar criteria in routine investigation of severe community-acquired pneumonia, such as ordering a *Legionella* urine antigen test, especially in those admitted to the ICU [21]. Further, experts at the expert review session confirmed similar testing guidelines to the IDSA-ATS are used in clinical settings in Canada.Specimen submission refers to the proportion of cases that submitted a specimen if a physician requested a test. From the expert review, it was discussed that about 5-10% of specimens do not arrive at the laboratory or are not properly tested once at the laboratory; therefore, we estimated this value to be 90-100%.Authors of a study analyzing data from Public Health Ontario Laboratory (2010-2014) reported the diagnostic testing methods used as part of routine clinical testing for legionellosis [5]. Of 28,965 patients tested for *Legionella* during the study, 81% were tested with a urinary antigen test (UAT), 13% were tested with culture, and 13% were tested with PCR [5]. In this study, the proportion of tests used is greater than 100% due to some (7.2%) patients being tested by more than one method [5]. Prior to the expert review session, we included the following values: selected lab test (UAT) (80%), selected lab test (culture) (10%), and selected lab test (PCR) (10%), approximated based on this reference and breakdown between the three different testing practices. However, in 2012, Public Health Ontario changed their testing methodology for *Legionella* such that a new PCR test was implemented, and routine culture isolation was to only be used for PCR positive samples [22]. In confirmation, the experts identified culture is used less often in clinical practice today and PCR is more common. Therefore, we adjusted these values to represent distributions. Selected lab test UAT was input as a 70-90% distribution, and the reciprocal (10-30%) was divided amongst selected lab test (culture) (5% of reciprocal) and selected lab test (PCR) (15% of reciprocal).Lp1The selected lab test proportions remained the same regardless of case subgroup. The test sensitivities used within the model to diagnose Lp1 were >70% UAT [23], 60% for culture [24, 25], and 83% for PCR [25].Non-Lp1The selected lab test proportions remained the same regardless of case subgroup. However, the test sensitivities used within the model to diagnose non-Lp1 differ from the test sensitivities for Lp1 because UAT can only diagnose Lp1 [18, 23]. This means in the non-Lp1 subgroup, the selected lab test sensitivity for UAT becomes 0%; therefore, non-Lp1 cases are only diagnosed using culture or PCR. Within this model we have estimated that 5% of patients are tested using culture, and 15% are tested using PCR, for a total of 20%. This represents 100% of the testing used to diagnose non-Lp1 cases. To account for the inability of UAT to detect non-Lp1 cases, we apply a multiplier of 5 (range 3.33-10 depending on the reciprocal value of ‘selected lab test (UAT)’).*For example, if 20 non-Lp1 cases present to a physician, 16 (range 14-18) patients will be tested for legionellosis by UAT, 1 patient will be tested by culture, and 3 patients will be tested by PCR. The patients tested by culture and PCR will be accounted for in the surveillance system, but the 16 patients tested by UAT will be missed. This means we need to account for these missed patients by applying a multiplier of 5 (20/4=5).*Proportion waterborneThis distribution comes from an expert judgement panel, referenced by Collier et al. [1]; 97% (95% UI: 67-100%) of legionellosis cases were estimated to be waterborne [10]. |

SUPPLEMENTARY TABLE S3. Estimation and uncertainty model inputs and assumptions included in the model to estimate the burden of illness of Legionnaires’ disease (LD) in Canada, 2015-2019 based on the schematic and multiplier approach of Thomas et al. [17]

|  |
| --- |
| **Pathogen: *Legionella*** |
| **Model input** | **Data sources** | **Distribution1** | **Parameters** |
| Total population | Canada’s population estimate as a cumulative distribution by year (2015-2019) [2] | Cumulative | By year: 35 702 908, 36 109 487, 36 545 236, 37 065 084, 37 601 230 |
| Reported number of cases | Incidence of *Legionella* infection resulting in legionellosis reported to Canadian Notifiable Disease Surveillance System (CNDSS, 2015-2019) [3]. All reported cases of legionellosis were assumed to be Legionnaires’ disease (LD) based on the percentage of cases reported to the CDC’s Supplemental Legionnaires’ Disease Surveillance System, which found 97-98% of legionellosis cases were in fact LD [4]. | Cumulative | By year: 328, 315, 426, 635, 655 |
| \*Proportion travel-related | Collier et al. [1]: Proportion of persons with LD who reported travel outside the United States within 10 days of illness onset (2014-2015) in CDC’s Supplemental Legionnaires’ Disease Surveillance System [4]. Uncertainty within this proportion (1%) was based on a 50% relative increase/decrease from 0.01 on an odds scale [1] | PERT | Low, modal, high values: 0.0067, 0.01, 0.0149 |
| **Reason for inclusion:** We are using a U.S. reference as we do not have this data available at the national level in Canada. By removing proportion of cases that are acquired internationally, we can estimate the burden of legionellosis that can be prevented within Canada. |
| **Assumptions:** We are assuming that the model inputs do not differ for an internationally acquired case compared to a domestically acquired case, that the serogroup distributions (95% Lp1, 5% non-Lp1) do not differ outside of Canada, and that “Care seeking” and “Test requested” model inputs include only domestically acquired cases. |
| Serogroup proportion2 | Proportion of *Legionella pneumophila* serogroup 1 (Lp1) identified among legionellosis cases, compared to other serogroups and species (non-serogroup 1 *L.* *pneumophila* and non-*L. pneumophila*) (non-Lp1) based on a laboratory study of specimens tested for *Legionella* at Public Health Ontario Laboratory (PHOL), 2010-2014 [5]*Low value* The low distribution value accounts for confirmed Lp1 cases divided by total *Legionella* cases (680/725=0.938) [5]*Modal value* The modal distribution value accounts for Lp1 divided by *Legionella* cases that were serotyped, or cases that were speciated as non-*L. pneumophila* (680/(725-15)=0.958) [5]*High value* The high distribution value accounts for confirmed cases of Lp1 plus *L. pneumophila* not serotyped divided by total *Legionella* cases ((680+15)/725=0.959) [5] | PERT | Lp1: Low, modal, high values: 0.938, 0.958, 0.959 |
| **Reason for inclusion:** Testing practices within Canada are biased towards the use of Urine Antigen Tests (UAT), which can only diagnose Lp1. By separating our model into two streams, Lp1 versus non-Lp1, we hope to account for this biased testing practice to provide a more holistic perspective on legionellosis in Canada. |
| **Assumptions:** We are assuming the testing practices (e.g., proportion of UAT, culture, or PCR selected) in Ontario are the same across Canada. The proportion of Lp1 is an assumption based on the high frequency at which UAT is selected as the lab test to diagnose LD in Ontario. |
| Underreporting |
| Reports local to national | All cases assumed reported from laboratory to local public health and from local public health to provincial public health | Constant | 100% |
| Underdiagnosis |
| Proportion severe | All cases assumed severe | Constant | 100% |
| \*Care seeking | Collier et al. [1] under “*Medical care seeking”*: Assumed to have a high rate of medical care seeking (97.9% hospitalized in cases reported to CDC’s Active Bacterial Core surveillance program, 2011-2013) [6]. The high rate of hospitalization in these cases represents the severity of LD, thus, an even higher proportion of cases are assumed to seek medical care (>98%) [1]. | PERT | Low, modal, high values: 0.99, 0.995, 1.0 |
| **Reason for inclusion:** A Canadian reference for this data could not be found. People with LD are assumed to seek care because it is a severe disease, compared to people with Pontiac Fever, a milder form of legionellosis, who may not seek care and thus infection will not be reported. |
| **Assumptions:** We are assuming this U.S. reference includes hospitalization data for only domestically acquired cases. |
| Test requested | *Low value* Collier et al. [1] under “*Specimen submission”*: In a healthcare system where universal testing of patients with community-acquired pneumonia for LD was implemented, 56% of patients with LD would have been tested using standard guidelines [7]*Modal value* Hollenbeck et al. [8] completed a retrospective chart review of patients diagnosed with pneumonia to determine the sensitivity of *Legionella* testing criteria, which showed that 59% of patients with LD would have been tested using standard guidelines. *High value* Henry et al. [9] conducted a retrospective cohort study of patients admitted to a single centre in Texas between 2001 and 2013 to determine the incidence of *Legionella*. In an area of low incidence of *Legionella*, 64.7% of patients with *Legionella* met the IDSA-ATS criteria for severe pneumonia. | PERT | Low, modal, high values: 0.56, 0.59, 0.65 |
| **Reason for inclusion:** In patients with community-acquired pneumonia (CAP), a causative agent is not always identified because antimicrobials prescribed for severe CAP often cover *Legionella* [21]. Therefore, we needed to account for the possible underdiagnosis multiplier that if a patient with LD presented to a physician, what is the likelihood they would receive a test to diagnose LD (i.e., UAT, culture, PCR). |
| **Assumptions:** These references are based on standard testing guidelines for LD in the US, developed by the Infectious Diseases Society of America (IDSA) – American Thoracic Society (ATS) [20]. Canadian guidelines suggest similar criteria for routine investigation of severe CAP, including *Legionella* urine antigen testing, especially in those admitted to the ICU [20]. We are assuming these guidelines are the same as guidelines that are used in Canada to diagnose LD. We are also assuming “recent travel within 2 weeks” refers to domestic travel only.IDSA-ATS Guidelines for *Legionella* testing in severe community-acquired pneumonia cases [20]:- History of alcohol abuse- Recent travel within 2 weeks- Pleural effusion upon admission- Admission to the ICU for pneumonia- Failure of outpatient antibiotics |
| Specimen submitted | Estimated that 90-100% of samples provided by patients arrive at the laboratory for testing (Source: Canadian Expert Review Session3) | PERT | Low, modal, high values:  0.90, 0.95, 1.0 |
| **Reason for inclusion:** This multiplier means if a sample was requested by a physician (e.g., a urine sample for UAT), then the patient would submit the sample to the care team and the sample would be submitted to the lab 90-100% of the time. This model input is based on expert review wherein agreement was reached that 5-10% of samples do not reach the laboratory for testing. |
| Selected lab test (UAT) | Of patients tested for *Legionella* at PHOL from 2010-2014, 81% were tested using urinary antigen test [5] | PERT | Low, modal, high values:0.70, 0.80, 0.90 |
| **Reason for inclusion:** As mentioned above, testing practices in Canada favour use of the UAT. By including multipliers for various testing methods for LD, we hope to provide a more accurate representation of LD cases in Canada, and the proportion of cases caused by both Lp1 and non-Lp1. |
| **Assumptions:** We are assuming these values are consistent across Canada, and that the tests that are ordered to diagnose LD follow an approximate distribution of 80% UAT, 5% culture, 15% PCR, while acknowledging other tests are available (e.g., Direct Fluorescent Antibody [26]). |
| Selected lab test sensitivity (UAT) | >70% based on PHOL guidelines for Binax ICT Abbott Urine Antigen test. Urinary antigen testing is only capable of detecting *Legionella pneumophila* serogroup 1; therefore, the sensitivity of UAT when used to diagnose non-Lp1 cases is 0% [23] | PERT | Lp1: Low, modal, high values:0.70, 0.80, 0.90Non-Lp1: Low, modal, high values:0, 0, 0 |
| Selected lab test (culture) | Of patients tested for *Legionella* at PHOL from 2010-2014, 13% were tested using culture [5]. Based on expert review and changes in testing practices at PHOL in 2012, we estimate the distribution of culture as the selected laboratory test to be 5% | Constant | 5% of remainder of selected lab test UAT (1-0.90, 1-0.80, 1-0.70) |
| Selected lab test sensitivity (culture) | 60% based on studies reporting sensitivity of culture test for *Legionella* [24, 25] | PERT | Low, modal, high values: 0.50, 0.60, 0.70 |
| Selected lab test (PCR) | Of patients tested for *Legionella* at PHOL from 2010-2014, 13% were tested using PCR [5]. Based on expert review and changes in testing practices at PHOL in 2012, we estimate the distribution of PCR as the selected laboratory test to be 15% | Constant | 15% of remainder of selected lab test UAT (1-0.90, 1-0.80, 1-0.70) |
| Selected lab test sensitivity (PCR) | 83% (95% CI: 0.79-0.87) based on a meta-analysis providing the pooled sensitivity of PCR compared to the reference standard of culture [25]. The real-time PCR used at PHOL has two targets, one that detects all *Legionella* species, and another that detects *Legionella pneumophila* [22] | PERT | Low, modal, high values: 0.70, 0.80, 0.90 |
| **Assumptions:** We are assuming, alike the PCR used at PHO, that PCR tests used at health-care facilities across Canada can identify all *Legionella* species. |
| Adjustment for UAT failure | Urinary antigen testing cannot detect disease when used to diagnose non-Lp1 cases [23]. Therefore, 5% of cases diagnosed using culture and 15% of cases diagnosed using PCR (20% total) represents 100% of testing used to diagnose the non-Lp1 cases. To account for this underdiagnosis, a median multiplier of 5 (reciprocal of 20/100) is used | Constant | Dependent upon selected lab test UAT:3.33 at 0.705 at 0.8010 at 0.90 |
| **Reason for inclusion:** This multiplier needs to account for the underdiagnosis we experience when non-Lp1 LD patients are tested solely with UAT, which can only diagnose *L. pneumophila* serogroup 1. Using our model inputs for the selected lab tests, 20% of non-Lp1 patients would be tested with a test method that can accurately diagnose non-Lp1 (i.e., culture and PCR). This adjustment accounts for the preferential testing practices of selecting UAT more often that we see in Canada. |
| **Assumptions:** We are assuming the same selected lab test distribution is true for both Lp1 and non-Lp1 patients, and the selected lab test sensitivities do not differ between the serogroups and species. Additionally, we are assuming there are no other commonly used test methods in Canada that would change the distribution of selected lab tests from 80% UAT, 5% culture, and 15% PCR. |
| \*Proportion waterborne | Collier et al [1]: Structured expert judgement estimate for Legionnaires’ Disease [10] | PERT | Low, modal, high values: 0.67, 0.97, 1.00 |

\*Proportion travel-related, Care seeking, and Proportion waterborne model inputs were from the U.S. CDC model [1]; 1Distributions [1]: PERT, Program Evaluation and Review Technique; 2A distinction was made between *Legionella pneumophila* serogroup 1 (Lp1) and non-Lp1 serogroups and species (non-Lp1) due to important differences in test sensitivities and nationally reported clinical infections. Non-Lp1 includes both non-serogroup 1 *L.* *pneumophila* and non-*L. pneumophila* serogroups and species; 3An expert review session with Legionnaires’ disease experts from across Canada was used to validate the modelling approach and model inputs with that which might occur in clinical practice.

SUPPLEMENTARY TABLE S4. Estimation and uncertainty model inputs included in the model to estimate the burden of Legionnaires’ disease (LD) on hospitalizations and deaths in Canada, 2015-2019 based on the schematic and multiplier approach of Thomas et al. [13]

|  |
| --- |
| **Pathogen: *Legionella*** |
| **Model input** | **Data source** | **Distribution1** | **Parameters** |
| Reported hospitalizations | Annual number of hospitalizations with ICD10 codes (A48.1) reported in the DAD (DAD, 2015-2019) [11]  | Cumulative | By year (2015-2019): 140, 161, 214, 313, 345 |
| Reported deaths | Annual number of hospitalizations with ICD10 codes (A48.1) reported in the DAD that were discharged as deaths (2015-2019) [11] | Cumulative | By year (2015-2019): 9, 13, 10, 2, 0 |
| Multiplier to account for Québec | This model input was derived using the approach of Glass-Kaastra et al. [14]. Annual number of hospitalizations for the province of Québec were estimated from the reported number in the HMDB from 2006-2010 [12]. The proportion of hospitalizations reported in the HMDB, compared to that reported in DAD, was used to create a multiplier for Québec. This value was also used to estimate the national LD deaths | Constant | 1.6352657 |
| Under-capture in DAD  | We estimated that 88.9% (and 95% CI) of hospitalizations are captured in the DAD based on medical chart review of significant diagnoses codes for ICD10 ‘Bacterial, unspecified and aspiration pneumonia as significant non-post admit comorbidity’ category as part of DAD Reabstraction Study 2009-2010 [27, pp.62]. Any abstract with ICD-10-CA code (J13 (M, 1 or W, X, Y) or J14 (M, 1 or W, X, Y) or J15.^ (M, 1 or W, X, Y) or J16.^ (M, 1 or W, X, Y) or J18.^ (M, 1 or W, X, Y) or J85.1 (M, 1, or W, X, Y) or [J69.0 (M, 1, W, X, or Y) with B95.^ (3) or B96.^ (3)]) | PERT | Low, modal, high values:0.81, 0.889, 0.97 |
| Over-capture in DAD | We estimated that 11.6% (and 95% CI) of hospitalizations captured in the DAD are not identified in the medical charts based on analysis of significant diagnoses codes for ICD10 ‘Bacterial, unspecified and aspiration pneumonia as significant non-post admit comorbidity’ category as part of DAD Reabstraction Study 2009-2010 [27, pp.62]. Any abstract with ICD-10-CA code (J13 (M, 1 or W, X, Y) or J14 (M, 1 or W, X, Y) or J15.^ (M, 1 or W, X, Y) or J16.^ (M, 1 or W, X, Y) or J18.^ (M, 1 or W, X, Y) or J85.1 (M, 1, or W, X, Y) or [J69.0 (M, 1, W, X, or Y) with B95.^ (3) or B96.^ (3)]) | PERT | Low, modal, high values:0.09, 0.116, 0.14 |
| Underdiagnosis |
| Test requested | *Low value* Collier et al. [1] under “*Specimen submission”*: In a healthcare system where universal testing of patients with community-acquired pneumonia for LD was implemented, 56% of patients with LD would have been tested using standard guidelines [7]*Modal value* Hollenbeck et al. [8] completed a retrospective chart review of patients diagnosed with pneumonia to determine the sensitivity of *Legionella* testing criteria, which showed that 59% of patients with LD would have been tested using standard guidelines *High value* Henry et al. [9] conducted a retrospective cohort study of patients admitted to a single centre in Texas between 2001 and 2013 to determine the incidence of *Legionella*. In an area of low incidence of *Legionella*, 64.7% of patients with *Legionella* met the IDSA-ATS criteria for severe pneumonia | PERT | Low, modal, high values: 0.56, 0.59, 0.65 |
| Laboratory testing UATLaboratory testing cultureLaboratory testing PCR | Of patients tested for *Legionella* at Public Health Ontario Laboratory (PHOL) from 2010-2014 [5], we estimated the following laboratory testing distributions are used to diagnose Legionnaires’ disease:80% (and 95% CI)5%15% | PERT | Low, modal, high values:0.70, 0.80, 0.9025% of remainder of selected lab test UAT [1-PERT(0.70, 0.80, 0.90)]\*[1-PERT(0.50, 0.75, 1.00)]75% of remainder of selected lab test UAT [1-PERT(0.70, 0.80, 0.90)]\*[1-PERT(0.50, 0.75, 1.00)] |
| Test sensitivity UATTest sensitivity cultureTest sensitivity PCR | We estimated a most likely UAT laboratory test sensitivity of >70% for *L. pneumophila* serogroup 1 based on PHOL guidelines for Binax ICT Abbott Urine Antigen test. Urine antigen testing is only capable of detecting *Legionella* *pneumophila* serogroup 1; therefore, the sensitivity of UAT when used to diagnose non-Lp1 is 0% [23]We estimated a most likely culture laboratory test sensitivity of 60% to diagnose *Legionella* based on published literature [24, 25]We estimated a most likely PCR laboratory test sensitivity of 83% (and 95% CI) based on published literature [25] | PERT | Low, modal, high values:0.70, 0.80, 0.900.50, 0.60, 0.700.70, 0.80, 0.90 |
| Proportion travel-related | Estimated to be 1% (and 95% CI) based on surveillance data from the CDC’s Supplemental Legionnaires’ Disease Surveillance System [4]. This is reported as the proportion of persons with LD who reported travel outside of the United States within 10 days of illness onset from 2014-2015. Uncertainty within this proportion (1%) was based on a 50% relative increase/decrease from 0.01 on an odds scale [1] | PERT | Low, modal, high values:0.0067, 0.01, 0.0149 |
| Proportion waterborne | Estimated to be 97% (and 95% CI) based on a structured expert judgement estimate for Legionnaires’ disease [10] | PERT | Low, modal, high values:0.67, 0.97, 1.00 |

1Distributions [1]: PERT, Program Evaluation and Review Technique

**References**

[1] **Collier SA, *et al*.** (2021) Estimate of burden and direct healthcare cost of infectious waterborne disease in the United States. *Emerging Infectious Diseases;* **27**: 140-149. doi:10.3201/eid2701.190676.

[2] **Statistics Canada.** (2022) Estimates of population (2016 Census and administrative data), by age group and sex for July 1st, Canada, provinces, territories, health regions (2018 boundaries) and peer groups: 2015-2019. *Government of Canada*: Ottawa, Canada. Accessed 10 September 2022. (https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1710013401&cubeTimeFrame.startYear=2015&cubeTimeFrame.endYear=2019&referencePeriods=20150101%2C20190101).

[3] **Public Health Agency of Canada.** (2023) Large data extract – Notifiable disease on-line: Legionellosis, 1924-2020. *Canadian Notifiable Disease Surveillance System, Government of Canada*: Ottawa, Canada (https://diseases.canada.ca/notifiable/charts?c=ppd).

[4] **Shah, P., *et al*.** (2019) Legionnaires’ disease surveillance summary report, United States (2014-2015). *Division of Bacterial Diseases, National Center for Immunization and Respiratory Diseases, Centers for Disease Control and Prevention*: Atlanta, Georgia (https://www.cdc.gov/legionella/health-depts/surv-reporting/2014-15-surv-report-508.pdf).

[5] **Peci A, Winter A-L, Gubbay JB.** (2016) Evaluation and comparison of multiple test methods, including real-time PCR, for Legionella detection in clinical specimens. *Frontiers in Public Health*; **4**: Article 175. doi:10.3389/fpubh.2016.00175.

[6] **Dooling KL, *et al*.** (2015) Active bacterial core surveillance system for Legionellosis – United States, 2011-2013. *Morbidity and Mortality Weekly Report (MMWR)*; **64**: 1190-1193. doi:10.15585/mmwr.mm6442a2.

[7] **Decker BK, *et al*.** (2016) Improving the diagnosis of *Legionella* pneumonia within a healthcare system through a systematic consultation and testing program. *Annals of the American Thoracic Society*; **13**: 1289-1293. doi:10.1513/AnnalsATS.201510-715BC.

[8] **Hollenbeck B, Dupont I, Mermel LA.** (2011) How often is a work-up for Legionella pursued in patients with pneumonia? A retrospective study. *BMC Infectious Diseases*; **11**: Article 237. doi:10.1186/1471-2334-11-237.

[9] **Henry C, *et al*.** (2017) Clinical utility of testing for *Legionella* pneumonia in Central Texas. *Annals of the American Thoracic Society*; **14**: 65-69. doi:10.1513/annalsats.201606-501bc.

[10] **Beshearse E, *et al*.** (2021) Attribution of illnesses transmitted by food and water to comprehensive transmission pathways using Structured Expert Judgement, Unite States. *Emerging Infectious Diseases*; **27**: 182-195. doi:10.3201/eid2701.200316.

[11] **Canadian Institute for Health Information (CIHI).** Discharge Abstract Database (DAD) [metadata] 2015-2019. Accessed 10 September 2022.

[12] **Canadian Institute for Health Information (CIHI).** Hospital Morbidity Database (HMDB) [metadata], 2006-2010. Accessed 10 September 2022.

[13] **Thomas MK, *et al*.** (2015) Estimates of foodborne illness-related hospitalizations and deaths in Canada for 30 specified pathogens and unspecified agents. *Foodborne Pathogens and Disease*; **12**: 820-827. doi:10.1089/fpd.2015.1966.

[14] **Glass-Kaastra S, *et al.*** Estimated reduction in the burden of nontyphoidal *Salmonella* illness in Canada circa 2019. *Foodborne Pathogens and Disease*; **19**: 744-749. Published online: 1 November 2022. doi:10.1089/fpd.2022.0045.

[15] **Scallan E, *et al*.** (2011a) Foodborne illness acquired in the United States – Major pathogens. *Emerging Infectious Diseases*; **17**: 7-15. doi:10.3201%2Feid1701.P11101.

[16] **Scallan E, *et al*.** (2011b) Foodborne illness acquired in the United States – Unspecified agents. *Emerging Infectious Diseases*; **17**: 16-22. doi:10.3201%2Feid1701.P21101.

[17] **Thomas MK, *et al*.** (2013) Estimates of the burden of foodborne illness in Canada for 30 specified pathogens and unspecified agents, circa 2006. *Foodborne Pathogens and Disease*; **10**: 639-648. doi:10.1089%2Ffpd.2012.1389.

[18] **Public Health Agency of Canada.** (2008) National case definition: Legionnaires’ disease and Pontiac fever (Legionellosis). Legionella, Infectious diseases. *Government of Canada:* Ottawa, Canada (https://www.canada.ca/en/public-health/services/infectious-diseases/legionella/health-professionals/national-case-definition.html).

[19] **Green D, *et al.*** (2018) *Legionella* – Who’s addressing the risks in Canada? *National Research Council of Canada, Health Canada and Public Services and Procurement Canada*: Ottawa, Canada (https://nrc.canada.ca/sites/default/files/2019-03/legionella\_e.pdf).

[20] **Mandell LA, *et al.*** (2007) Infectious Disease Society of America/American Thoracic Society consensus guidelines on the management of community-acquired pneumonia in adults. *Clinical Infectious Diseases*; **44 (Suppl. 2)**: S27-72. doi:10.1086/511159.

[21] **Mandell LA, *et al*.** (2000) Canadian guidelines for the initial management of community-acquired pneumonia: an evidence-based update by the Canadian Infectious Diseases Society and the Canadian Thoracic Society. The Canadian Community-Acquired Pneumonia Working Group. *Clinical Infectious Diseases*; **31**: 383-421. doi:10.1086/313959.

[22] **Public Health Ontario (PHO).** (2012) Legionella – Change in testing methodology to real-time PCR testing. *Public Health Ontario*: Toronto, Canada (https://www.publichealthontario.ca/-/media/Documents/Lab/lab-sd-084-legionella-realtime-pcr-testing.pdf?la=en&sc\_lang=en&hash=709EAECE747EB78071049AE7C5599541).

[23] **Public Health Ontario (PHO).** (2020) Legionella – Urine antigen. *Public Health Ontario*: Toronto, Canada (https://www.publichealthontario.ca/en/laboratory-services/test-information-index/legionella-urine-antigen).

[24] **Fields BS, Benson RF, Besser RE.** (2002) Legionella and Legionnaires’ disease: 25 years of investigation. *Clinical Microbiology Reviews*; **15**: 506-526. doi:10.1128%2FCMR.15.3.506-526.2002.

[25] **Cristovam E, *et al*.** (2017) Accuracy of diagnostic tests for Legionnaires’ disease: A systematic review. *Journal of Medical Microbiology*; **66**: 485-489. doi:10.1099/jmm.0.000454.

[26] **Pierre DM, *et al.*** (2017) Diagnostic testing for Legionnaires’ disease. *Annals of Clinical Microbiology and Antimicrobials*; **16**: 59. doi:10.1186/s12941-017-0229-6

[27] **Canadian Institute for Health Information (CIHI).** (2012)CIHI data quality study of the 2009-2010 Discharge Abstract Database. *Canadian Institutes for Health Information*: Ottawa, Canada, pp. 62 (https://secure.cihi.ca/free\_products/Reab%202009-2010%20Main%20Report%20FINAL.pdf).