Canadian Journal of Public Health (2020) 111:117–124
https://doi.org/10.17269/s41997-019-00258-5

QUANTITATIVE RESEARCH

Risk factors associated with group A *Streptococcus* acquisition in a large, urban homeless shelter outbreak

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Received: 11 March 2019 / Accepted: 28 August 2019 / Published online: 11 October 2019

Abstract

Objective Group A *Streptococcus* (GAS) is a frequent cause of outbreaks in healthcare institutions, yet outbreak reports in the literature from homeless shelters are less common, despite an increased risk of severe GAS infection in homeless populations. In 2016, we conducted a case-control study to identify significant risk factors associated with GAS acquisition in a protracted, 19-month outbreak of GAS in a large, urban men's homeless shelter in Ontario, Canada.

Methods Cases (individuals with either clinical GAS *emm*74 infection or asymptomatic carriers of GAS *emm*74) and controls were identified from shelter residents from February to September 2016. Information on demographics, clinical presentation, pre-existing health conditions, and risk factors for GAS transmission were collected for all study participants from a variety of sources, including the public health notifiable disease information system, electronic health records, the shelter electronic information system, and interviews with client services workers.

Results From the multivariable logistic regression model, younger individuals (OR 9.1; 95% CI 1.57–52.9), those with previous skin conditions (OR 56.2; 95% CI 2.73–1160), and those with recent wounds (with wound care: OR 51.5, 95% CI 8.86–299, and without wound care: OR 77.4, 95% CI 7.38–812) were found to be at increased risk of acquiring GAS in this outbreak.

Conclusion The outbreak investigation clearly demonstrated the need for improved wound care and infection prevention and control practices, for early screening and detection of skin and soft tissue infections, and for a comprehensive, integrated electronic information system in homeless shelters.

Résumé

Objectif Les streptocoques du groupe A (SGA) constituent une cause fréquente d'éclosions dans les établissements de soins, mais les éclosions dans les refuges pour sans-abri sont moins communément abordées dans la presse scientifique malgré le risque accru d'infections à SGA invasives dans les populations sans abri. Nous avons mené en 2016 une étude cas/témoins pour déterminer les facteurs de risque significatifs associés à l'acquisition du SGA lors d'une éclosion prolongée (sur 19 mois) survenue dans un grand refuge pour hommes sans-abri en milieu urbain en Ontario, au Canada.

Méthode Les cas (les personnes ayant une infection clinique à SGA de type *emm*74 ou les porteurs asymptomatiques du SGA de type *emm*74) et les témoins ont été recensés entre février et septembre 2016 parmi les résidents du refuge. Les données démographiques, le tableau clinique, l'état de santé préexistant et les facteurs de risque de transmission du SGA ont été obtenus pour tous les participants de l'étude à partir de sources diverses : le système d'information du service de santé publique sur les maladies à signalement obligatoire; les dossiers médicaux électroniques; le système d'information électronique du refuge; et des entretiens avec les préposés du service à la clientèle.

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Résultats Selon notre modèle de régression logistique multivariée, les jeunes sujets (RC 9,1; IC de 95% 1,57–52,9), les sujets ayant une affection cutanée antérieure (RC 56,2; IC de 95% 2,73–1160) et les sujets ayant des plaies récentes (traitées : RC 51,5; IC de 95% 8,86–299 et non traitées : RC 77,4; IC de 95% 7,38–812) ont couru un risque accru d'acquérir le SGA durant cette éclosion.

Conclusion L'enquête sur l'épidémie a clairement montré la nécessité d'améliorer le traitement des plaies et les pratiques de prévention et de contrôle des infections, ainsi que le besoin d'un dépistage et d'une détection précoces des infections de la peau et des tissus mous, et d'un système d'information électronique complet et intégré dans les refuges pour sans-abri.

Keywords Group A *Streptococcus* · Homeless shelter · Outbreak · Public health · Risk factor

Mots-clés Streptocoques de groupe A · Refuges pour sans-abri · Flambées de maladies · Santé publique · Facteur de risque

Introduction

While group A *Streptococcus* (GAS) infections commonly manifest as uncomplicated throat, skin, or soft tissue infections, invasive GAS (iGAS) infections can cause more severe outcomes, such as necrotizing fasciitis, streptococcus toxic shock syndrome, meningitis, and death (Heymann 2008). Increased risk for infection has been shown for older individuals, young children, those living in long-term care facilities, individuals with underlying conditions such as human immunodeficiency virus (HIV) or cancer, persons who inject drugs, and under-housed populations (Public Health Agency of Canada 2006; Dooling et al. 2013; Bundle et al. 2017; Mosites et al. 2017; Adebanjo et al. 2018).

In March 2016, a clinical infection of invasive GAS *emm*74 was detected in a resident of a large, urban men-only homeless shelter in Toronto. This *emm* type was rare at the time, having been reported only once in this particular region of Ontario between 2002 and March 2016. Subsequent identification of this *emm* type across the province and Canada has been documented (Dickson et al. 2018; Teatro et al. 2018; Pilon et al. 2019). After additional clinical infections with the same iGAS *emm* type were detected among other residents in this shelter, the Toronto Public Health Department (TPH) declared an outbreak of GAS in the shelter and a large-scale outbreak investigation and response effort was initiated. TPH implemented multiple case finding and outbreak control measures, including enhanced environmental cleaning, infection prevention and control audits, screening of shelter residents and staff, *emm* typing of all GAS infections, use of antibiotic chemoprophylaxis, and antibiotic treatment of all individuals with clinical infection or asymptomatic carriage with subsequent test of cure screenings (Finkelstein et al. 2017). Despite these efforts, transmission continued in the shelter and prompted a systematic investigation into risk factors associated with transmission in this setting.

Previous investigations of outbreaks among under-housed populations (Sierra et al. 2006; Cady et al. 2011; Athey et al. 2016; Bundle et al. 2017; Mosites et al. 2017; Adebanjo et al. 2018) and in long-term care facilities (Arnold et al. 2006; Jordan et al. 2007; Thigpen et al. 2007; Dooling et al. 2013) have identified host, behavioural, and environmental risk factors associated with GAS transmission and infection. However, there is little published literature about risk factors most significantly associated with infection or transmission in a homeless shelter setting. There are national and provincial guidelines published by the Public Health Agency of Canada (PHAC) and the Ontario Ministry of Health and Long-Term Care (MOHLTC) for infection prevention and control of GAS and management of GAS outbreaks, but these are difficult to apply in a homeless shelter setting as they primarily focus on healthcare facilities (Public Health Agency of Canada 2006; Population and Public Health Division 2014).

This paper describes a case-control study aimed to identify significant risk factors associated with GAS acquisition during an outbreak in a large men's homeless shelter.

Methods

The affected shelter is a 520-bed facility with three residential floors: a hostel-style floor (floor A), a longer-stay floor for housing men requiring additional clinical care in the infirmary program or access to the shelter's alcohol management program (floor B), and a long-term-stay floor which serves individuals with more complex healthcare needs who cannot otherwise be admitted to a long-term care facility (floor C). Staff, including client service workers, counsellors, healthcare providers, and visiting community agencies, provide care for permanent and transient residents with a range of healthcare requirements.

Individuals with clinical infection were defined as individuals staying at the shelter at any time between 1 February 2016 and 23 September 2016 with laboratory-confirmed (invasive or non-invasive) GAS *emm*74 and at least one of the following clinically compatible signs and symptoms of GAS: (i) pharyngitis (with fever and/or tonsillar exudates and/or enlarged cervical lymph nodes and/or associated ear/nose/throat infections); (ii) skin and soft tissue infection (erysipelas, impetigo, necrotic skin lesions); (iii) pneumonia; (iv) streptococcal toxic

shock syndrome/bacteremia; or (v) meningitis. Carriers were defined as above but with no signs or symptoms. Individuals with clinical infection and asymptomatic carriers were combined as cases for the purpose of this case-control analysis to focus on acquisition of GAS as an outcome. Controls were defined as individuals staying at the shelter at any time between 1 February 2016 and 23 September 2016 with only negative laboratory results for GAS during the outbreak investigation period. Controls were randomly selected from all residents who were never identified as cases, with proportional numbers of cases and controls by floor where possible. Screening of all residents, via throat and wound swabs, occurred in August 2016 on floors B and C and in September 2016 on floor A. Reinfection was defined as an individual with clinical infection or a carrier who completed treatment successfully with three successive negative swab results at 4 to 17 days post-treatment, 18 to 31 days post-treatment, and 32 or more days post-treatment, and was subsequently infected with clinical infection or as an asymptomatic carrier.

Residents with positive GAS laboratory results for non-*emm*74 infections during the outbreak period ($n = 52$) were excluded from the study. There were no deaths due to iGAS during this outbreak.

A list of possible risk factors for GAS transmission in this setting was compiled a priori from a scan of existing published literature (Factor et al. 2003; Sierra et al. 2006; Bargh et al. 2007; Jordan et al. 2007; Dooling et al. 2013; Athey et al. 2016; Hancock-Allen et al. 2016), including epidemiological outbreaks of GAS in institutional facilities (e.g., long-term care facilities) and outbreaks in under-housed populations, and consultation with TPH staff supporting the outbreak and national and international subject matter experts.

Case identifiers, GAS *emm* type, onset date, invasive GAS status, and floor of residence were extracted from the province of Ontario's mandated reportable disease information system (integrated Public Health Information System, iPHIS), and information on underlying health conditions, wounds, wound care, and healthcare utilization for cases and controls was extracted from physician electronic health records. Information on residence location in the shelter, wounds, and healthcare utilization was extracted from an electronic shelter management information system. Information on substance use and activities of daily living was obtained from interviews with counsellors and client service workers. Data from wound care logs and the alcohol management program supplemented these data sources.

The sample size was dictated by the availability of cases. All available cases were recruited, and controls were oversampled to the extent possible based on resource constraints in an outbreak situation. Working on the assumption of 43 cases, a minimum ratio of one control per case, $\alpha = 0.05$, and $\beta = 0.8$, the study had a sufficient sample size to detect a minimum odds ratio of approximately 3 for control group exposure probabilities of at least 0.1. Descriptive statistics were generated for all variables. Statistical comparisons between cases and controls were performed using chi square or Fisher exact tests for categorical variables and standard unpaired *t* tests for continuous variables. Univariable logistic regression quantified the associations of each risk factor variable with GAS acquisition ($n = 20$ variables assessed). Variables with a $p \leq 0.2$ were included in multivariable model building using backwards selection (non-automated) principles. Main effects remained in the model at $p \leq 0.05$. Variables were considered confounders if their removal caused a >30% change in the coefficient of any significant variable. All data were collected and stored in Microsoft Excel 2010 (Microsoft Corporation One Microsoft Way, Redmond, WA, 98052, USA) and analyzed in Stata/IC 13.1 (StataCorp 4905 Lakeway Drive, College Station, TX, 77845, USA) software.

Results

A total of 43 cases (34 individuals with GAS clinical infection and nine carriers) and 62 controls were identified for inclusion in the case-control study. Basic descriptive characteristics of individuals with GAS clinical infection and asymptomatic carriers did not differ (Table 1). Most individuals with clinical infection and carriers (44% each) were among residents of the non-medical section of floor B. The mean age of all cases was 52.5 years, ranging from 30 to 77 years, with a median value of 52 years. Among cases with clinical infection, there were two instances of invasive disease, three hospitalizations, and

Table 1 Characteristics of individuals with GAS *emm*74 clinical infection and asymptomatic carriers in the homeless shelter from 1 February 2016 to 23 September 2016

	Clinical infections ($n = 34$)	Carriers ($n = 9$)
Sex (male)	34 (100%)	9 (100%)
Age (years)	Mean 52.1 Range 30 to 76	Mean 54.3 Range 36 to 77
Location in shelter		
Floor A	4 (12%)	2 (22%)
Floor B—medical	10 (29%)	1 (11%)
Floor B—non-medical	15 (44%)	4 (44%)
Floor C	5 (15%)	2 (22%)
iGAS	2 (6%)	–
Reinfection	2 (6%)	1 (11%)[a]
Hospitalizations	3 (9%)	–
Deaths	0 (0%)	–

iGAS invasive group A *Streptococcus* infection

[a] One resident was infected first as an asymptomatic carrier and then reinfected as an individual with clinical infection after successful treatment and negative clearance swab for the carrier status

no deaths due to GAS. Three cases had reinfections during the study period of which one case was first reported as an asymptomatic carrier and subsequently as a case with clinical infection. Univariable regression of risk factors for acquisition of *emm*74 GAS (Table 2) showed that residents in the youngest age quartile; those with staff-reported alcohol, cigarette, or illicit drug use; those with healthcare encounters in the month prior to onset; and those with mobility challenges preventing any departures from the shelter were at increased risk for GAS infection. Several risk factors associated with skin integrity, such as any history of a physician-diagnosed skin condition; documented evidence of lice, bedbugs, or scabies in the month prior to onset; and the presence of a wound in the month prior to onset, were significantly associated with increased risk of GAS. No other chronic underlying health conditions were significant in the univariable analysis.

The multivariable model (Table 3) showed cases in the youngest-age quartile had 9.1 times higher odds (95% CI 1.57–52.9) of acquiring GAS compared to those in the oldest-age quartile, and residents with a history of a physician-diagnosed skin condition had 56 times the odds of acquiring GAS compared to those without (95% CI 2.73–1160). Presence of a wound, for those with (OR 51.5; 95% CI 8.86–299) or without (OR 77.4; 95% CI 7.38–812) associated wound care in the month prior to onset of their GAS infection or being screened for GAS, was significantly associated with an increased risk of GAS.

When shelter residents with only GAS clinical infection (i.e., no carriers) were analyzed, the main difference in the results was that hepatitis C infection was significantly associated with GAS clinical infection, but with lower odds ratios than the other factors of interest.

Discussion

To our knowledge, this is the first report of a case-control investigation conducted during an outbreak of GAS affecting a homeless shelter. The study focused on the 34 individuals with clinical infection and nine asymptomatic carriers of GAS *emm*74 who were identified from 1 February to 23 September 2016, the early part of a 19-month outbreak in a large, urban men's homeless shelter in Toronto, Canada. Younger individuals, those with previous skin conditions, and those with recent wounds were found to be at increased risk of becoming a case in this outbreak.

This study confirmed the important and well-documented association between poor skin integrity and GAS acquisition. Significant increased risk of GAS infection was found for both the presence of a wound in the month prior to symptom onset and having a physician-diagnosed skin condition. These results are consistent with findings from a previous description of this shelter population in 2000 that identified higher rates of GAS carriage in residents with symptomatic skin lesions (Bargh et al. 2007). Many of the residents with wounds were receiving care either from primary care providers practising at the shelter or a community wound care nursing service that made regular visits to the shelter. Evidence of transmission of GAS infections in a wound care clinic or by wound care practices has previously been reported (Hancock-Allen et al. 2016; Ahmed et al. 2018; Palladino et al. 2019); however, there was no indication of transmission associated with wound care services from infection prevention and control inspections and audits. While there is a trend toward decreased risk of GAS infection for those receiving wound care, this was not statistically significant. This suggests the risk of GAS infection for those with wounds may be high regardless of wound care.

Non-intact skin—a well-known portal of entry for GAS bacteria—has been identified as a risk factor in community and long-term care facility outbreaks of GAS (Shwartz and Ussery 1992; Factor et al. 2003; Arnold et al. 2006; Adebanjo et al. 2018; Ahmed et al. 2018) and among persons using drugs and experiencing homelessness (Valenciano et al. 2019). Here, we have shown clear evidence extending this link between non-intact skin and GAS infection into the shelter setting. It is not known to what extent a reduced capacity to maintain suitable levels of hygiene (e.g., bathing and regular changes into clean clothes) or a high prevalence of alcohol and illicit substance use (e.g., individuals with increased exposure to violence or falls related to inebriation) may contribute to poor skin integrity in a shelter setting (Raoult et al. 2001). This finding reinforces the importance of focusing on maintaining skin integrity of homeless clients to improve their resistance to GAS infection.

The presence of ectoparasites such as lice can also lead to significant deterioration in skin integrity if left untreated. Previous studies have found lice and scabies can be associated with GAS skin infections in marginalized populations affected by poverty and poor housing conditions—a factor that may also be important for this population (Carapetis et al. 1992; Cook et al. 2007). Just prior to the detection of this outbreak, an outbreak of skin lice in shelter residents was being treated by the on-site medical staff. They reported that traditional topical anti-lice treatments at times caused additional damage to the skin of clients, making them reluctant to use these treatments repeatedly. The possibility of an added cause for decreased skin integrity may have contributed to the initiation and the difficulty faced in controlling the outbreak. Later in the outbreak response, the on-site medical staff initiated the widespread use of an oral anti-parasite medication (ivermectin), which had previously been used effectively in a shelter in France (Foucault et al. 2006). This new treatment coincided with the cessation of GAS circulation and may have further contributed to other implemented control strategies that eventually reduced the number of outbreak-associated cases.

Table 2 Univariable analysis of risk factors associated with acquisition of *emm*74 GAS among shelter residents from 1 February 2016 to 23 September 2016

	Cases ($n = 43$) (%)[a]	Controls ($n = 62$) (%)[a]	OR (95% CI)	p value
Age (years)	Mean 52.5	Mean 58.3	0.95 (0.91–0.99)	0.01*
Location in shelter				
Floor A	6 (14.0)	7 (11.3)	Ref	0.08
Floor B—medical	11 (25.6)	7 (11.3)	1.82 (0.43–7.77)	
Floor B—non-medical	19 (44.2)	26 (41.9)	0.85 (0.25–2.95)	
Floor C	7 (16.3)	22 (35.5)	0.37 (0.09–1.48)	
Chronic health conditions				
Diabetes	5 (11.6)	11 (17.7)	0.61 (0.20–1.90)	0.39
Cancer	3 (7.0)	3 (4.8)	1.48 (0.28–7.68)	0.65
HIV	0 (0)	0 (0)		
Hepatitis C virus	10 (23.3)	8 (12.9)	2.04 (0.73–5.70)	0.17
Cardiac[b]	4 (9.3)	7 (11.3)	0.81 (0.22–2.94)	0.74
Respiratory[c]	7 (16.3)	11 (17.7)	0.90 (0.32–2.55)	0.84
Skin[d]	7 (16.3)	1 (1.6)	11.9 (1.40–100)	< 0.01*
Shelter health clinic encounters[e, f]				
0	9 (20.9)	24 (38.7)	Ref	0.03*
1–2	18 (41.9)	12 (19.4)	4.00 (1.39–11.5)	
≥ 3	16 (37.2)	26 (41.9)	1.64 (0.61–4.40)	
Healthcare encounters documented in the shelter management system[e, f]				
0	23 (53.5)	44 (71.0)	Ref	0.05*
1	13 (30.2)	7 (11.3)	3.55 (1.25–10.1)	
≥ 2	7 (16.3)	11 (17.7)	1.22 (0.42–3.56)	
Mobility (leaves shelter during day)	32 (74.4)	56 (91.8)	0.26 (0.08–0.81)	0.02*
Resident has personal service worker	6 (14.0)	6 (9.8)	1.49 (0.45–4.96)	0.52
Poor hygiene[g]	18 (41.9)	16 (25.8)	2.07 (0.90–4.75)	0.09
Lice, bedbugs, or scabies[e]	9 (20.9)	2 (3.2)	7.94 (1.62–38.9)	< 0.01*
Wound[e]				
No wound	11 (25.6)	50 (80.7)	Ref	< 0.01*
Wound without care	11 (25.6)	2 (3.2)	25.0 (4.84–129)	
Wound care	21 (48.8)	10 (16.1)	9.50 (3.52–25.9)	
Substance use				
Alcohol	34 (79.1)	38 (61.3)	2.39 (0.97–5.84)	0.05*
Cigarette	38 (88.4)	45 (72.6)	2.87 (0.97–8.51)	0.04*
Illicit drug	22 (51.2)	20 (32.3)	2.20 (0.99–4.90)	0.05*
Injection drug use	1 (2.3)	3 (4.8)	0.47 (0.05–4.66)	0.50

OR odds ratio, *CI* confidence interval, *Ref* reference, *HIV* human immunodeficiency virus

*$p \leq 0.05$

[a] Unless otherwise specified

[b] Cardiac conditions included Wolff-Parkinson-White syndrome, tachycardia, ablation, peripheral artery disease, coronary artery disease, congestive heart failure, myocardial infarction, non-ischemic cardiomyopathy, atrial fibrillation, right ventricular dysfunction, ischemic heart disease

[c] Respiratory conditions included asthma and COPD

[d] Skin conditions included lichen simplex chronicus, seborrheic dermatitis, severe asteototic dermatitis, eczema, psoriasis, dry gangrene, burns

[e] In month prior to onset (individuals with clinical infection) or in month prior to screening collection date (carriers and controls)

[f] Shelter health clinic encounters were defined as any encounter with the primary health clinic provided in the shelter, whereas health encounters documented in the shelter management system was any evidence of a healthcare encounter outside of the shelter, such as emergency department visits, specialist appointments, external primary care, etc.

[g] Poor hygiene was indicated either on the shelter management system intake form or during interviews with counsellors and client service workers about residents' abilities to regularly perform activities of daily living (bathing, laundering)

Table 3 Multivariable analysis of risk factors associated with acquisition of *emm*74 GAS among shelter residents from 1 February 2016 to 23 September 2016

	OR	Standard error	*p* value	95% CI
Age (years)				
0–50	9.10	8.17	0.01	1.57–52.9
51–55	1.13	1.15	0.90	0.16–8.22
56–59	0.23	0.24	0.17	0.03–1.85
≥ 60	Ref	Ref	Ref	Ref
Skin condition[a]	56.2	86.7	0.01	2.73–1160
Healthcare encounters documented in the shelter management system[b, c]				
0	4.92	4.45	0.08	0.83–29.0
1	18.3	19.9	0.01	2.15–155
≥ 2	Ref	Ref	Ref	Ref
Wound[b]				
No wound	Ref	Ref	Ref	Ref
Wound without care	77.4	92.9	< 0.01	7.38–812
Wound with care	51.5	46.2	< 0.01	8.86–299

OR odds ratio, *CI* confidence interval, *Ref* reference

[a] Skin conditions included lichen simplex chronicus, seborrheic dermatitis, severe asteotic dermatitis, eczema, psoriasis, dry gangrene, burns

[b] In month prior to onset (individuals with clinical infection) or in month prior to screening collection date (carriers and controls)

[c] Health encounters documented in the shelter management system were any evidence of a healthcare encounter outside of the shelter, such as emergency department visits, specialist appointments, external primary care, etc.

Our study found individuals in the youngest-age quartile had increased odds of disease acquisition relative to those in the oldest quartile. While literature suggests that older age can be associated with increased risk of disease transmission (Jordan et al. 2007), our findings are consistent with the GAS carriage study previously conducted in this shelter, which found that those in the lowest-age quartile of shelter residents were 11.5 times more likely to be GAS carriers relative to those in older quartiles (Bargh et al. 2007). A possible explanation for our result is that the outbreak began in the section of this large shelter which had a younger population when compared to other areas, leading to younger clients being preferentially exposed to the bacteria. Additionally, older individuals may preferentially report or be diagnosed with skin integrity issues, resulting in more care by medical staff or other service workers.

Associations between substance use and increased risk of GAS are well documented (Public Health Agency of Canada 2006; Bundle et al. 2017; Sierra et al. 2006; Factor et al. 2003). In our study, however, the univariable associations between alcohol and illicit drug use with GAS acquisition were both borderline statistically significant and did not remain significant when controlling for other factors in the multivariable model. This may be due to the power of this study to detect the effect size or to a lack of specificity in the data collected for certain variables. There was a lack of specificity in the data collected for staff-reported alcohol consumption which prevented classifying it as alcohol abuse versus non-problematic consumption. Consequently, it was not possible to test the association between alcohol abuse and the risk of GAS acquisition.

While a previous study of outbreaks of non-invasive GAS in nursing homes reported increased risk of disease for those requiring assistance with activities of daily living (RR 3.85; 95% CI 1.06–14.29), the closest comparator in our population—having a personal service worker—was not significantly associated with acquiring GAS (McNutt et al. 1992). This further supports that risks for shelter populations sufficiently differ from those of long-term care facility residents in that the type of assistance was not comparable and/or the underlying health conditions differed. Similarly, some data were available on the location of residence in the shelter but there was not sufficient specificity to assess possible increased risk of GAS transmission among close contacts, as has been documented in previous long-term care facility outbreaks (Greene et al. 2005; Jordan et al. 2007).

There are several limitations to this study. The lack of an integrated information system capturing comprehensive health-related data for residents made it difficult to acquire the data needed to assess all possible risk factors. Moreover, multiple care providers from multiple agencies were operating at the shelter and in the community to support this population and, consequently, consistent and comprehensive records were not available for many residents. There was an electronic shelter management information system designed for administrative purposes, such as intake and discharge, tracking resident interactions, appointments, and progress notes, but it ultimately lacked detail and consistent application to the study population. Consequently, to overcome these challenges of completeness, data had to be collated from multiple sources. Additionally, as it was not feasible to conduct individual client interviews, behavioural information (e.g., mobility and hygiene) was obtained from interviews with shelter staff and was subject to inaccuracies, subjectivity, and recall biases. The potential for recall bias may have been higher for controls as staff had less engagement with these individuals compared to cases who were extensively followed up for treatment and screening. Additionally, the case-control study was conducted on a relatively small sample size, limiting possible stratifications and the power to detect small differences between the comparison groups. Upon analysis of the final multivariable model residuals, there were several observations identified that exerted high leverage and influence on the model. The model was assessed with and without the influential observations, and ultimately, investigators did not feel they should be removed from the reported final model, as they did not affect the magnitude or direction of any of the associations.

Conclusion

The results from this study should be used to inform investigations and responses to future outbreaks of GAS in shelter settings. This study was conducted in part to fill a gap related to guidelines and protocols for the control of GAS transmission and outbreaks in non-medical congregate settings, such as homeless shelters. Given the vulnerable nature and complex needs of shelter populations, these guidelines should be prioritized by either national public health authorities who have the resources to undertake this work or by expert bodies with a deep knowledge of infection prevention and control, particularly in non-healthcare settings. The outbreak investigation clearly demonstrated the need for improved wound care and infection prevention and control practices, for early screening and detection of skin and soft tissue infections, and for a comprehensive, integrated electronic information system. Shelters require sufficient funding to successfully implement the measures needed to prevent further outbreaks of preventable infectious diseases such as GAS.

Acknowledgements Toronto Public Health would like to acknowledge the support of Toronto's Shelter Support and Housing Administration division, staff at the shelter, the TPH investigation team, Dr. Elizabeth Rea, the Inner City Family Health Team, Inner City Health Associates, the Public Health Agency of Canada, and content experts Drs. Allison McGeer and Edward Kaplan.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This project was determined by Toronto Public Health to be non-research public health practice; a formal Institutional Review Board review was not required.

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