Divergences between healthcare-associated infection administrative data and active surveillance data in Canada

Virginie Boulanger[1,2], Étienne Poirier[1,2], Anne MacLaurin[3], Caroline Quach[1,2,4,5]*

Affiliations

[1] Département de microbiologie, infectiologie et immunologie, Faculté de médecine, Université de Montréal, Montréal, QC

[2] Centre de recherche CHU Sainte-Justine, Montréal, QC

[3] Healthcare Excellence Canada

[4] Département clinique de médecine de laboratoire, CHU Sainte-Justine, Montréal, QC

[5] Prévention et contrôle des infections, Département de pédiatrie, CHU Sainte-Justine, Montréal, QC

***Correspondence:**

c.quach@umontreal.ca

Abstract

Background: Although Canada has both a national active surveillance system and administrative data for the passive surveillance of healthcare-associated infections (HAI), both have identified strengths and weaknesses in their data collection and reporting. Active and passive surveillance work independently, resulting in results that diverge at times. To understand the divergences between administrative health data and active surveillance data, a scoping review was performed.

Method: Medline, Embase and Cumulative Index to Nursing and Allied Health Literature along with grey literature were searched for studies in English and French that evaluated the use of administrative data, alone or in comparison with traditional surveillance, in Canada between 1995 and November 2, 2020. After extracting relevant information from selected articles, a descriptive summary of findings was provided with suggestions for the improvement of surveillance systems to optimize the overall data quality.

Results: Sixteen articles met the inclusion criteria, including twelve observational studies and four systematic reviews. Studies showed that using a single source of administrative data was not accurate for HAI surveillance when compared with traditional active surveillance; however, combining different sources of data or combining administrative with active surveillance data improved accuracy. Electronic surveillance systems can also enhance surveillance by improving the ability to detect potential HAIs.

Conclusion: Although active surveillance of HAIs produced the most accurate results and remains the gold-standard, the integration between active and passive surveillance data can be optimized. Administrative data can be used to enhance traditional active surveillance. Future studies are needed to evaluate the feasibility and benefits of potential solutions presented for the use of administrative data for HAI surveillance and reporting in Canada.

Suggested citation: Boulanger V, Poirier E, MacLaurin A, Quach C. Divergences between healthcare-associated infection administrative data and active surveillance data in Canada. Can Commun Dis Rep 2022;48(1):4–16. https://doi.org/10.14745/ccdr.v48i01a02

Keywords: surveillance, healthcare-associated infection, administrative data

Introduction

Each year, many Canadians acquire an infection during their hospital stay that increases morbidity and mortality, and that bears a financial cost to the healthcare system (1). These healthcare-associated infections (HAI) are preventable, measurable, and are the most frequently reported adverse event in healthcare worldwide. Every year, it is estimated that 220,000 Canadian patients develop a HAI (2). Many HAIs are now caused by antimicrobial resistant organisms (AROs), which make them difficult to treat. The Public Health Agency of Canada (PHAC) estimates that approximately 2% of patients admitted to large, academic Canadian hospitals will acquire an infection with an ARO during their hospital stay (3). Surveillance, including monitoring and reporting of HAI, is a critical component of infection prevention and control and needs to be strengthened at the national level. Although coronavirus disease 2019 (COVID-19) did not originate as a HAI, the current pandemic has revealed how critical it is to have reliable and consistent data in order to formulate an effective response to infection. When asked to provide projections regarding the course of COVID-19 virus, Prime Minister Trudeau said that "….the inconsistency in the data from across Canada is part of the delay in offering a nationwide picture" (4).

In Canada, PHAC collects national data on multiple HAIs through the Canadian Nosocomial Infection Surveillance Program (CNISP); a program established in 1994 as a partnership between PHAC, the Association of Medical Microbiology and Infectious Disease Canada and sentinel hospitals from across Canada (5). The objectives of CNISP are to provide national and regional benchmarks, identify trends on selected HAIs and AROs, and provide key information to help inform the development of federal, provincial and territorial infection prevention and control programs and policies (5). At present, the CNISP network comprises 87 acute-care sentinel hospitals from ten provinces and one territory. The network's goal is to have all Canadian acute care hospitals adopt the CNISP HAI surveillance definitions and contribute data to the national surveillance system (2). Despite the desire to expand the surveillance program, CNISP is limited 1) by funding capacity, 2) by lack of human resources available to participate in national surveillance (2) and 3) because most hospitals already report to their provincial government and are unwilling to enter data twice. As a result, CNISP HAI rates may not provide a complete picture and some segments of the Canadian hospital population are underrepresented—such as smaller, community hospitals (6).

National statistics reported by PHAC relating to HAIs only include data from hospitals that participate in CNISP as they all follow standardized case definitions, methods and case reporting. Currently HAI rates reported by provinces and territories or posted by individual hospitals cannot be combined as case definitions, methods of data collections and calculation of rates vary from hospital to hospital and between provinces and territories (2). Active surveillance is done by Infection Prevention and Control (IPC) practitioners and each province, territory, administrative region or hospital can determine their own surveillance protocols based on local epidemiology and resources, making it difficult to evaluate improvement efforts and compare HAI rates in Canadian hospitals (7).

On the other hand, Canada has a wealth of administrative health data including insurance registries, inpatient hospital care, vital statistics, prescription medications and electronic health record system (8). Exploring the potential of integrating these diverse administrative health data sets could provide a more robust picture of HAIs across Canada.

The hospital discharge abstract database (DAD), housed at the Canadian Institute for Health Information (CIHI), collects demographic and clinical information from patient discharge summaries from all acute care facilities in Canada, except in Québec (Québec has its own discharge abstract database—*Maintenance et exploitation des données pour l'étude de la clientele hospitalière (MED-ÉCHO)*—that reports to CIHI's Hospital Morbidity Database) (9). Information is entered in the database by professional coders from all hospitals and is used by CIHI to produce data and analytic reports. The CIHI's Data and Information Quality Program is recognized internationally for its high standard (10). However, discharge summaries are not standardized across the country and reflect only what is entered into the summary by the attending physician. The CIHI could, however, be a potential partner to support data collection and reporting of HAIs for acute care hospital. We conducted a scoping review to identify existing gaps between administrative data and active surveillance data for healthcare-associated infection surveillance and to propose possible integration strategies to optimize data.

Methods

Research question

The main research question was "What are the discrepancies between HAI administrative data and active surveillance data in Canada?". The research sub-questions were: Are administrative data valid for HAI surveillance? For each type of HAI, what are the discrepancies between administrative data and hospital surveillance data? We performed this scoping review following the PRISMA extension for scoping review (11).

For this review, HAI included *Clostridioides difficile* (*C. difficile*; CDI), catheter-associated bloodstream infection (CLABSI) or catheter-associated urinary tract infection (CAUTI) or urinary tract infection (UTI) (CAUTI), methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant Enterococci (VRE), carbapenem-resistant Enterobacteriaceae (CPE), antimicrobial resistant organism (ARO or AMR), bloodstream infection (BSI), surgical site infections (SSI) and ventilator-associated pneumonia (VAP).

Relevant literature

We performed a search developed in collaboration with a medical research librarian. The inclusion criteria consisted of articles evaluating passive surveillance of specific or various HAIs in Canada. We included articles (qualitative, quantitative and mixed-method studies) published between 1995 and November 2, 2020 in Canada. The search strategy contained terms relative to location (Canada), surveillance, data source and HAI. In addition, we performed a second search with the same terms (except for the location) and only including systematic reviews.

A pilot selection process was carried out to identify databases with relevant studies and three electronic databases were searched: MEDLINE, EMBASE and Cumulative Index to Nursing and Allied Health Literature (CINAHL), in English and French with no date restriction. The search strategies were created on MEDLINE then adapted for the other databases

(**Supplemental Data S1**). After deduplication, two reviewers independently screened citations by title and abstract. Selected articles were evaluated for eligibility at the full-text level. The first reviewer also performed a hand search of the grey literature and reviewed the references list of all eligible and published studies to identify any articles that were not initially captured through electronic search. Conflicts were resolved through discussion until consensus was reached.

Data extraction and quality assessment

An electronic data form was developed on Distiller SR (Evidence Partners, Ottawa, Canada) for this scoping review. The following data were extracted from each article: general information; study details; types of HAI and surveillance; source of data; outcomes and results.

Both reviewers assessed each study's quality/risk of bias of each study using ROBINS-I for non-randomized studies (12) and AMSTAR-2 tool for systematic review (13). Overall, studies were ranked at low, moderate or high risk of bias. Any disagreement or inconsistency between the reviewers were resolved through discussion. The complete data collection and quality assessment items are shown in **Supplemental Data S2**.

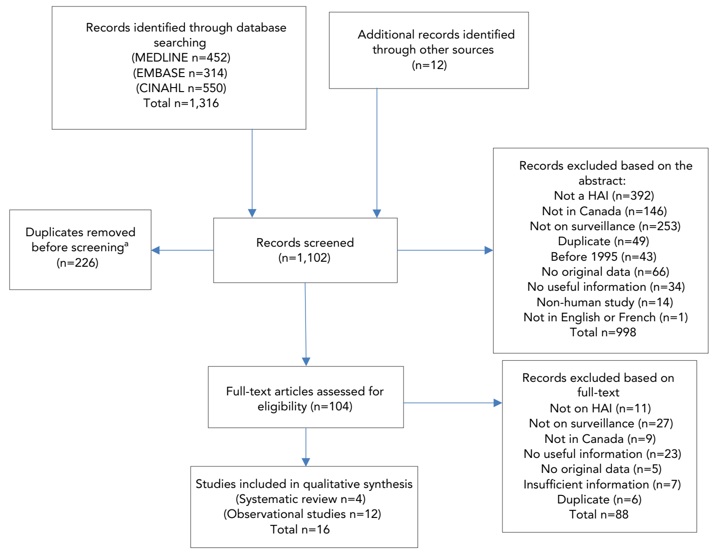
Data analysis

A qualitative descriptive approach was used to synthesize the data collected. Principal studies characteristics, summary of performance statistics and quality assessment scores were summarized into tables. We presented a summary of findings for each study grouping into categories depending on the type of administrative data used and the scope of the study. We focused on how the administrative data were used for HAI surveillance, the divergence in results with traditional surveillance and if author recommended administrative data to enhance surveillance. A synthesis of systematic reviews was also presented with studies categorized as review assessing validity of administrative data or review assessing validity of electronic surveillance system.

Results

Overall, 1,316 studies were identified through the electronic search and 12 from hand searches. After deduplication, 1,102 studies remained, of which 104 were selected for a full-text review. Finally, 16 studies were included in the scoping review from electronic search. Twelve studies were observational studies (14–25), and four were systematic reviews (26–29) (**Figure 1**).

Figure 1: Study identification flow chart



Abbreviation: HAI, healthcare-associated infection
[a] Using EndNote X9.1.1 software

Study characteristics

Of the 12 observational studies included, six focused on SSI, three on CDI, two on MRSA and one on BSI. Studies were performed from 2009 to 2020 and eight were from Alberta. Seven studies compared administrative data with hospital surveillance data and seven studies used data linkage. All studies used DAD as the source of administrative data (alone or combined with other sources). The main characteristics of all included studies are summarized in **Table 1**.

Table 1: Observational studies—Study characteristics

First author, year	Study design	Study population and sample size (n=)	Administrative data source	Condition(s)	Province(s)	Risk of bias
Crocker, 2020	Cohort study	All index laminectomy and spinal fusion procedure cases in Alberta from 2008 to 2015 (n=21,222)	DAD + NACRS[a]	Surgical site infection	Alberta	Low
Ramirez-Mendoza, 2016	Cohort study	All acute-care patients in Alberta and Ontario from April 2012 to March 2013 (n=217)[b]	DAD[a]	Methicillin resistant *Staphylococcus aureus*	Alberta and Ontario	Low
Pfister, 2020	Cohort study	All acute-care patients in Alberta from April 2015 to March 2019 (IPC n=9,557, DAD n=8,617)	DAD[a]	*Clostridioides difficile*	Alberta	Low

Table 1: Observational studies—Study characteristics (*continued*)

First author, year	Study design	Study population and sample size (n=)	Administrative data source	Condition(s)	Province(s)	Risk of bias
Rennert-May, 2018	Cohort study	All primary hip or knee arthroplasty cases in Alberta from April 2012 to March 2015 (n=24,512)	DAD[a]	Surgical site infection	Alberta	Low
Almond, 2019	Cohort study	All acute-care patients in Alberta from April 2015 to March 2017 (n=4,737)	DAD + laboratory data[a]	*Clostridioides difficile*	Alberta	Low
Rusk, 2016	Cohort study	All primary hip or knee arthroplasty cases in Alberta from April 2013 to June 2014 (n=11,774)	DAD + NACRS[a]	Surgical site infection	Alberta	Low
Daneman, 2011	Cohort study	All cesarean delivery cases at Sunnybrook Health Science Centre from January 2008 to December 2009 (n=2,532)	DAD + NACRS + physician claims[a]	Surgical site infection	Ontario	Low
Lethbridge 2019	Cohort study	All hip or knee replacement surgery cases in Nova Scotia from 2001 to 2015 (n=36,140)	DAD + NACRS + physician claims	Surgical site infection	Nova Scotia	Low
Leal, 2010	Cohort study	All adult patient in Calgary Health Region in 2005 (sample of n=2,281)	Cerner's PathNet laboratory + Oracle[c]	Bloodstream infection	Alberta	Low
Lee, 2019	Cohort study	All adult patients in four adult acute-care facilities in Calgary region from April 2011 to March 2017 (n=2,430)	DAD	Methicillin resistant *Staphylococcus aureus*	Alberta	Low
Daneman, 2009	Cohort study	All elderly patients hospitalized for elective surgery in Ontario from April 1992 to March 2006 (n=469,349)	DAD + Ontario Health Insurance Plan + Ontario Drug Benefits database	Surgical site infection	Ontario	Low
Daneman, 2012	Cohort study	All patients (older than one year old) admitted to an acute-care hospital in Ontario from April 2002 to March 2010 (n=180)[b]	DAD[a]	*Clostridioides difficile*	Ontario	Low

Abbreviations: DAD, discharge abstract database; IPC, Infection Prevention and Control; NACRS, National Ambulatory Care Reporting System
[a] Compared with active surveillance data
[b] Number of hospitals
[c] Regional warehouse's Oracle database system

Four systematic reviews were also included, three on the use of electronic surveillance system (ESS) and one on the use of administrative data for HAI surveillance. All reviews included at least one article from Canada. The study characteristics are summarized in **Table 2**.

Within-study risk of bias

Observational studies were assessed for risk of bias using the ROBIN-1 tool (Table 1). Most of these studies used similar methodology but lacked information on missing data (**Supplemental Table S3**). However, they were all assessed as low risk of bias.

Systematic reviews were assessed using the AMSTAR-2 tool (Table 2, **Supplemental Table S4**). One article was considered at moderate risk of bias as it did not report its protocol or describe included studies in adequate details. Three articles were considered at high risk of bias as some did not report their protocol or assess the risk of bias, quality or heterogeneity of included studies.

Summary of findings

Studies using one administrative database compared with active surveillance

Validation studies showed that DAD used alone for capturing HAI cases is not valid in comparison with IPC traditional active hospital surveillance. For example, Rennert-May *et al.* (17) assessed the validity of using the ICD-10 code administrative database (DAD) to identify complex SSIs within three months of hip or knee arthroplasty. The study found that the ICD codes in DAD were highly specific (99.5%) but had a sensitivity of 85.3% and a predictive positive value of only 63.6%. They concluded that DAD was not able to accurately determine if someone had an SSI according to surveillance definition (**Table 3**). Pfister *et al.* (15) came to the same conclusion with a validation study on DAD capturing CDI cases. The CDI rate was 28% higher in the DAD compared to IPC surveillance, showing that DAD seems inadequate to capture true infection incidence. Findings show that the DAD includes recurrent CDI and cannot distinguish

Table 2: Systematic Review—Study characteristics

First author, year	Number of included studies, year	Objective	Databases	Conclusion	Other information	Risk of bias
Van Mourik, 2015	57 studies from 1995 to 2013	Accuracy of administrative data used for HAI surveillance	Medline, Embase, CINAHL, Cochrane	Administrative data had limited and highly variable accuracy	n=1/3 studies included had important methodological limitation	Moderate
Leal, 2008	24 studies from 1980 to 2007	Identify and appraise published literature assessing validity of ESS compared with conventional surveillance	Medline	Electronic surveillance has good utility compared to conventional surveillance	No assessment of quality of studies included	High
Freeman, 2013	24 studies from 2000 to 2011	Assess utility of ESS for monitoring and detecting HAI	Medline, Cochrane, Ovid, Embase, Web of science, Scopus, JSTOR, Wiley Online Library, BIOSIS Preview	Hospital should develop and employ ESS for HAI	Majority of studies have emphasis on linkage of electronic database	High
Streefkerk, 2020	78 studies up to January 2018	Give insight in the current status of ESS, evaluating performance and quality	Embase, Medline, Cochrane, Web of Science, Scopus, CINAHL, Google Scholar	With a sensitivity generally high but variable specificity, ESS as yet to reach a mature stage, need further work	Authors selected 10 best studies that may constitute a reference for ESS development	High

Abbreviations: CINAHL, Cumulative Index to Nursing and Allied Health Literature; ESS, electronic surveillance system; HAI, hospital-associated infections

Table 3: Observational studies—Summary of performance statistics

First author, year	Comparator	Results						Conclusion
		Infection rate	TP, FP, FN, TN, Total	Sensitivity	Specificity	Positive predictive value	Negative predictive value	
Crocker, 2020	DAD + NACRS compared with published traditional surveillance data	2.7 per 100 procedures of laminectomy 3.2 per 100 procedures of spinal fusion	N/A	N/A	N/A	N/A	N/A	Rate reported by administrative data was similar to published rate from traditional surveillance Need validation study to verified results
Ramirez-Mendoza, 2016	DAD compared with IPC data	Alberta (cases per 10,000 patient-days) DAD: 0.43 IPC: 0.91 Ontario (cases per 10,000 patient-days) DAD: 0.25 IPC: 0.21	N/A	N/A	N/A	N/A	N/A	Using Pearson correlation there was good evidence of the comparability of administrative and IPC surveillance data
Pfister, 2020	DAD compared with IPC data	DAD: 6.49 per 1,000 admissions IPC: 5.06 per 1,000 admissions	5,477 TP 1,400 FP 968 FN 344 TN Total: 8,169	85%	N/A	80%	N/A	DAD was moderately sensitive, but likely inadequate to capture true incidence

Table 3: Observational studies—Summary of performance statistics (*continued*)

First author, year	Comparator	Results						Conclusion
		Infection rate	TP, FP, FN, TN, Total	Sensitivity	Specificity	Positive predictive value	Negative predictive value	
Rennert-May, 2018	DAD compared with IPC data	N/A	220 TP 126 FP 38 FN 24,128 TN Total: 24,512	85.3%	99.5%	63.6%	99.8%	Administrative data had reasonable testing characteristics, but IPC surveillance was superior
Almond, 2019	DAD + laboratory data compared with IPC data	DAD/lab (per 10,000 patient-days) 4.96 for HAI IPC (per 10,000 patient-days) 3.46 for HAI	1,998 TP 690 FP 71 FN 1,320 TN Total: 4,079	96.6%	65.7%	74.3%	94.9%	Laboratory surveillance method was highly sensitive, but not overly specific
Rusk, 2016	DAD + NACRS + IPC compared with IPC data alone	DAD/NACRS/ IPC: 1.7 per 100 procedures IPC: 1.3 per 100 procedures	N/A	89.9%	99%	N/A	N/A	Medical chart review for cases identified through administrative data was an efficient strategy to enhance IPC surveillance
Daneman, 2011	DAD + NACRS + physician claims compared with IPC data	N/A	N/A	77.3%	87%	17.4%	99.1%	Administrative data had poor sensitivity and positive predictive value and were inadequate as a quality indicator
Lethbridge, 2019	DAD or NACRS compared with DAD + NACRS + physician claim	Difference of 0.44 between DAD or NACRS alone and all data together	N/A	N/A	N/A	N/A	N/A	Rates were underestimated using single-source administrative data

Abbreviations: DAD, discharge abstract database; FN, false negative, FP, false positive, HAI, hospital-associated infections, IPC, Infection Prevention and Control; NACRS, National Ambulatory Care Reporting System; N/A, not applicable; TN, true negative, TP, true positive

symptomatic from asymptomatic cases. In fact, DAD had only a moderate sensitivity of 85% and a positive predictive value of 80% (Table 3).

On the other hand, Daneman *et al*. evaluated if mandatory public reporting by hospital was associated with reduction in hospitals CDI rates in Ontario (23). Aside from the main analysis, they performed a cross-validation of CDI rates from administrative data against rates reported by single institutions via the mandatory public reporting system. They used Pearson correlation coefficients weighted for hospital bed-days and found an excellent concordance across the institutions (23).

The same coefficient was used in the study by Ramirez Mendoza *et al*. (18) that compared DAD with surveillance data for hospital-acquired MRSA in Alberta and Ontario. The results showed strong correlation between DAD and IPC surveillance data. The study concluded that there was good evidence of comparability between these datasets; however, rate or denominator diverged widely between administrative data and active surveillance data (Table 3). Some authors did not agree with the study conclusion or methodology, notably with the choice of Pearson correlation using hospital-level data and the difference of rates or denominators between administrative and surveillance data (30).

Studies combining multiple administrative databases

Results show that combining databases increases the accuracy, yet still not as accurate as traditional active surveillance. Lethbridge *et al*. (24) combined multiple types of administrative data and compared them with a single source administrative data to identify SSIs following hip and knee replacement in Nova Scotia. Used alone, DAD and National Ambulatory Care Reporting System (NACRS) had higher rates than physician billing but underestimated the infection rate with a percentage difference of 44% compared with the combination of the three databases. This implies that approximately 17% of infected cases would have been missed with DAD or NACRS alone. The authors concluded that combining databases enhanced SSI surveillance.

Daneman *et al*. (20) validated the accuracy of DAD, NACRS and physician claim database against traditional surveillance for the detection of cesarean delivery SSI within 30 days of surgery in Ontario. They found a sensitivity of only 16.7% for DAD used alone, 37.9% for DAD combined with NACRS and 77.3% for DAD combined with NACRS and physician claims database. All had a high specificity (87%–98.3%) but a very low predictive positive value (17.4%–27.4%) (Table 3). The authors recommended that the administrative data not be used as a quality indicator for interhospital comparison.

In contrast, Crocker *et al*. (14) compared infection rates calculated using a combination of DAD and NACRS to identify spinal procedure and SSIs. They showed that these rates were comparable with postoperative SSI rate published using traditional surveillance (Table 3). However, the validity of the results was not verified in this study.

Studies combining administrative database with laboratory database

Studies showed that laboratory records could be used to enhance administrative data. For example, Almond *et al.* (25) assessed the validity of a laboratory-based surveillance method to identify hospital-acquired CDI (HA-CDI). Laboratory data alone can result in overestimation of CDI rates, with positive laboratory result not meeting the case definitions for HA-CDI (e.g. asymptomatic colonization, recurrent CDI). However, this study assessed the alternative of linking positive CDI laboratory records to DAD. The study demonstrated a very high sensitivity but a specificity of 65.7% and a positive predictive value of 74.3% (Table 3). These results indicated that 26% of cases classified as HAI were not true HAI cases, resulting in a higher rate observed with this method. In addition, authors completed a receiver operator characteristic (ROC) analysis to see if using a time from admission (collection date−admission date) of ≥4 days was the appropriate algorithm to use for classifying hospital-acquired cases in the laboratory dataset. The ROC analysis indicated that more cases were classified correctly five days after admission. Thus, a simple change in the laboratory detection using longer time from admission to classify cases as healthcare-associated may increase the specificity with a small cost to sensitivity.

Another study from Leal *et al*. pushed one step further by developing an electronic surveillance system (ESS) for monitoring BSI by linking laboratory and administrative databases (21). The ESS included definitions for classifying BSI and their location; nosocomial, healthcare-associated-community onset or community-acquired infection. The system was compared with chart review done by a research assistant and an infectious diseases physician. Chart review and ESS identified 329 and 327 BSI episodes respectively. The authors found high concordance regarding acquisition location of infection (Kappa=0.78) and they were able to improve definitions after *post hoc* revision. Surveillance data obtained through ESS identified and classified BSI with a high degree of agreement with manual chart review.

Studies using administrative data to enhance active surveillance

Studies showed that administrative data can be used to enhance IPC surveillance. Lee *et al.* (16) assessed the benefits of linking population-based IPC surveillance with DAD for hospital-acquired (HA) and community-acquired (CA) MRSA cases in Alberta. This enabled IPC surveillance to have more relevant information available in a timely manner. The authors were able to successfully link 94.6% of the total surveillance records and identify key differences between patients with HA and CA-MRSA, showing that administrative data could be used to enhance hospital surveillance.

Through a retrospective cohort study, Rusk *et al*. (19) evaluated a new strategy to improve traditional IPC surveillance by using administrative data to trigger medical chart review. Eligible patients followed by the IPC team were linked to DAD and NACRS and these administrative databases provided diagnosis and procedure codes for each visit and/or readmission. The strategy using administrative data captured 87% of cases identified by IPC surveillance, with a sensitivity of 90% and specificity of 99%. This confirmed that the administrative data-triggered medical chart review is an efficient strategy to improve SSI surveillance.

Study to improve hospital comparison using administrative data

Daneman *et al.* (22) demonstrated that administrative data (DAD + physician claims) can be used to create a modified Nosocomial Infections Surveillance surgical risk stratification index comparable with the one used for clinical surveillance. This index allowed for the adjustment of infection rate when comparing with other facilities. The study concluded that both administrative and clinical sources can contribute to infection surveillance, with administrative data used to identify patients with possible infections or improving detection of post-discharge diagnoses.

Systematic review and administrative data

Only one study (26) assessed the accuracy of administrative data for surveillance of HAI. Others reviewed articles on ESS using electronic medical records for HAI surveillance compared to traditional surveillance, but included many articles that used a combination of administrative data and ESS (27–29). Administrative data was found to have very heterogeneous sensitivity and positive predictive value, generally low to modest with a particularly poor accuracy for the identification of device-associated HAI (e.g. CLABSI, CAUTI) (**Table 4**) (26,28).

Table 4: Systematic review—Summary of performance statistics by type of hospital-associated infection

First author, year	Number of articles included	Sensitivity (SE), Specificity (SP), Positive Predictive Value (PPV), Negative Predictive value (NPV)					Other information
		SSI	BSI/CLABSI	CDI	Pneumonia/VAP	UTI/CAUTI	
Freeman, 2013	n=44 (SSI=6 BSI=11 UTI=4 Pneumonia=4 Other=8 Multiple HAI=12)	SE=60%–98% SP=91%–99%	SE=72%–100% SP=37%–100%	SE=80%–83% SP=99.9%	SE=71%–99% SP=61%–100%	SE=86%–100% SP=59%–100%	Three studies used single-source data, 37 used multi-source data including laboratory, four used multi-source data excluding laboratory
Van Mourik, 2015	n=57 (SSI=34 BSI=24 Pneumonia=14 UTI=15 Other=7)	SE=10%–100% PPV=11%–95%	**CLABSI** - Sensitivity below 40% for all but one study - SE higher for BSI/sepsis	-	**Pneumonia** SE and PPV around 40% **VAP** SE=37%–72% PPV=12%–57%	SE below 60% PPV below 25% SE higher in UTI than CLAUTI	Gain in sensitivity of almost 10% when combining database Studies with higher risk of bias were more optimistic
Streefkerk, 2020	n=78 (SSI=29 BSI=33 Pneumonia=16 UTI=18)	SE=0.02–1.0 SP=0.59–1.0	SE=0.32–1.0 SP=0.37–1.0	-	SE=0.33–1.0 SP=0.58–1.0	SE=0.02–1.0 SP=0.59–1.0	Sensitivity was generally high, but specificity very variable

Abbreviations: BSI, bloodstream infection; CAUTI, catheter-associated urinary tract infection; CDI, *C. difficile* infection; CLASBI, catheter-associated bloodstream infection; SSI, surgical site infection; UTI, urinary tract infection; VAP, ventilator-associated pneumonia; -, no result presented in this study

In general, the highly variable accuracy for administrative data was mainly due to the amount of different diagnostic codes used between studies (26). Van Mourik *et al*. assessed the accuracy of administrative data. One-third of included study had important methodological limitations and ones with higher risk of bias were associated with a more optimistic picture than those employing robust methodologies (26). On the other hand, Leal *et al.* found a good sensitivity and excellent specificity for administrative data (**Table 5**) (29). However, populations and methodologies were very heterogeneous, and the quality of the studies included in the review was not assessed. All four reviews found that combining administrative data sources with other sources for surveillance, in particular with microbiology data, improved the accuracy. Studies also found that microbiology data had a good sensitivity (28,29); however, Freeman *et al*. concluded that ESS using microbiology data alone tended to overestimate HAI (27). Streefkerk *et al*. (28) also found that microbiology data combined with antibiotic prescription and laboratory (biochemistry, hematology, etc.) data were more accurate than microbiology alone (Table 5). Finally, most studies concluded that administrative data were advantageous to track HAI requiring post-discharge surveillance (e.g. SSI).

Systematic review and electronic surveillance system

Results showed that electronic surveillance using algorithms for HAI detection from electronic medical records had not yet reached a mature stage but presented good opportunities and potential. Most concluded that ESS should be developed and used in hospitals, recognizing that these methods can reduce burden associated with traditional manual surveillance (27–29). In fact, sensitivity was generally high and specificity variable for most ESS compared with traditional active surveillance (Tables 4 and 5). Freeman *et al*. found that a lot of computer algorithms for electronic surveillance outperformed manual chart review method (27). A majority of studies in this review emphasized the linkage of electronic databases with "in-house" surveillance system rather than commercial software (27). Streefkerk *et al.* demonstrated that the best ESS used a two-step procedure with cases selection using ESS was followed by confirmatory assessment of selected cases by the IPC team (28). In the same review, seven studies tried to develop an ESS that could find all HAIs, with a sensitivity ranging from 0.78 to 0.99. Leal *et al.* demonstrated that ESS were potentially inexpensive, efficient and could reach a sensitivity of 100% when the infection of interest is defined by the presence of a positive culture (29).

Table 5: Systematic review—Summary of performance statistics by type of surveillance

First author, year	Number of articles included	Sensitivity (SE), Specificity (SP) (range or average)						Other information
		Administrative data	Laboratory data			Administrative data + laboratory data	Other	
			Microbiology	Microbiology + antibiotic prescription	Microbiology + antibiotic prescription + chemistry			
Streefkerk, 2020	n=78 (AD=7, L=61, O=10)	SE=30%[a] SP=94.5%[a]	SE=77% SP=92%	SE=92% SP=86%	SE=93% SP=94%	-	SE=86% SP=90%	In general, good sensitivity for studies using microbiology data
Leal, 2008	n=24 (AD=7, L=6, AD + L=6, O=5)	SE=59%–96%[b] SP=95%–99%[b]	SE=63%–91% SP=87%–99%			SE=71%–95% SP=47%–99%	-	AD + L combined had higher SE but lower SP than for either alone

Abbreviations: AD, administrative data study; L, laboratory data study; O, other; -, no result presented in this study
[a] International Classification of Diseases (ICD) coding only
[b] International Classification of Diseases (ICD) coding + pharmacy + claims databases

However, ESS were less efficient when the infection is diagnosed based on clinical evaluation of symptoms or tests other than a positive microbiology culture. Moreover, the quality of data and linkage may influence the quality of the ESS (29). Freeman *et al.* also concluded that in some studies, the lack of clinical data in an electronic format reduced the ability of ESS to detect HAI (27).

Discussion

Canada has a great wealth of administrative health data collected at the provincial/territorial level from diverse parts of the healthcare system. However, these data are not used to their full potential and their increased use could enhance HAI surveillance efforts and decrease the workload associated with traditional active surveillance. This scoping review explored the use and validity of administrative data used alone or combined with other data sources for HAI surveillance in Canada. Overall, studies showed that using one source of administrative data alone for surveillance of HAI is not sufficiently accurate in comparison with traditional active surveillance. However, combining different sources of data improved accuracy. Moreover, combining administrative data with active surveillance was shown to be an effective strategy to enhance active surveillance and decrease work burden for IPC teams.

Advantage and inconvenience of administrative data

Administrative data are not collected for surveillance purposes. However, they have a lot of attractive characteristics that make them interesting for the enhancement of HAI surveillance. They are inexpensive, available from nearly all healthcare facilities, collected in a consistent manner, subjected to quality check and do not add an administrative burden to clinicians or patients (31). Deterministic linkages can also be performed between databases that collect healthcare number, as each Canadian has a unique identifying health number.

Furthermore, many studies demonstrated that administrative data are advantageous for tracking HAIs requiring post-discharge surveillance (19,20,22,26). This is very important for infections like SSIs, where the majority are developed after discharge (19,32–34). For example, in the study by Rusk *et al.*, 96% of SSI cases were identified after discharge and 43% of confirmed SSI cases were identified at a facility other than where the procedure was performed (19). These results show that conducting active SSI surveillance only at the operative hospital limits SSI detection. The best practices for surveillance of healthcare-associated infection published by Public Health Ontario state that "to date there is no generally accepted method for conducting post-discharge surveillance for SSIs outside the hospital setting… Infection Prevention and Control Professional are encouraged to develop innovative approaches for the detection of post-discharge SSIs that do not interfere with the time spent on other components of their surveillance system" (35). Examples of solutions proposed included the use of administrative databases and electronic screening of patients' records post-discharge for symptoms and signs of infection (35).

Barriers in accurate administrative data for hospital-acquired infection surveillance in Canada

In Canada, CIHI collects clinical data through the Clinical Administrative Databases that consists of two separate databases: The Discharge Abstract Database–Hospital Morbidity Database; and NACRS (36). At this time, CIHI publicly reports on some HAIs such as in-hospital sepsis, UTIs and ARO, most at the national level only, using data collected from DAD. The

CIHI has a comprehensive data quality program and any known quality issues are addressed by the data provider or documented in data limitations documentation available to all users (36). However, there are still many barriers to be overcome before accurate administrative data for HAI surveillance could be produced. Studies show that the lack of accuracy is an important limitation in using administrative data as a quality indicator for hospital comparison. For instance, the variability of medical practice, the documentation and discharge coding amongst facilities, the interpretation of medical coders, the fact that data collection relies on primary care provider and that information is based on their capacity to detect and report a HAI (possible misclassification errors, human errors) (15,19,37,38). Essentially, information is limited by what is reported in the medical chart and depends mainly on adequate clinician documentation.

For example, reporting to the DAD database requires the physician to adequately fill the discharge summary, including HAIs if known. HAIs are usually not detected in real time and may likely be assessed differently by a clinician and the infection prevention and control team, the latter following standardized definitions. The health records department's professional coding specialist then translates charts and discharge summaries into standard codes. A study conducted in 2015–2016 in Alberta interviewed coders on physician-related barriers to producing high-quality administrative data (39). These barriers included incomplete and nonspecific documentation by physicians, physicians and coders using different terminology (e.g. physician diagnostic not in ICD-10 list), lack of communication between coders and physicians (mainly in urban settings) and the fact that coders are limited in their ability to add, modify or interpret physician documentation. Finally, coders are not allowed to use supporting documentation that could increase specificity of diagnostic codes (e.g. laboratory reports) (39). In fact, an important limitation for CIHI is that in general, the physician documentation takes priority over all other documentation, even if laboratory reports or other documentation indicate a different diagnosis. Yet there are multiple studies demonstrating that laboratory data could be used to enhance administrative data (13,21,29,37). Hence, allowing coders to use laboratory data could be a feasible solution to improve coding accuracy.

Integration of administrative data in infection prevention and control surveillance

Studies also demonstrated that the use of administrative data by IPC team can enhance HAI surveillance and reduce the workload for IPC professionals. Lee *et al*. demonstrated that linking surveillance data with administrative data allows to have detailed information in a timely manner and they urged jurisdictions and healthcare systems to consider adopting this type of data linkage for surveillance practices (16). Rusk *et al*. demonstrated an efficient strategy to identify potential SSI cases for further IPC review using administrative data codes, improving case-finding consistency and reducing time and resources needed (19). All these studies showed that administrative data can be used to enhance traditional surveillance by IPC team. The reverse could also be true. As noted previously, coders can only use physician documentations to report diagnoses. On the other hand, traditional surveillance by IPC professional is considered the gold-standard of surveillance and results in accurate data. If coders could access IPC surveillance outcome, this may enhance the validity of physician documentation and interpretation by coders.

Integration of administrative data in electronic surveillance systems

Another potential approach to make surveillance less labor-intensive is to use electronic surveillance systems. In the current review, seven observational studies used data linkage of electronic databases and three systematic reviews assessed electronic surveillance systems. Leal *et al*. developed a complete ESS to identify and classify BSI with a high degree of agreement with manual chart review (21). Results from the systematic review by Freeman *et al*. suggested that ESS implementation is feasible in many settings and should be developed by hospitals (27). The ESS can also be developed to detect more than one HAI. Moreover, the systematic review by Steefkerk *et al*. on ESS presented the 10 best studies selected based on the overall quality and performance score, and the majority used a two-step procedure using administrative, electronic medical records or microbiology data followed by a confirmatory assessment by the IPC professional (28). In this case, ESS could be designed to favor sensitivity over specificity, knowing that manual review will exclude false positives (31). Streefkerk *et al*. presented seven studies with ESS that could detect all HAIs (28). Their review even included one study describing an excellent performing algorithm to detect HAI in real time with a sensitivity of 0.99 and a specificity of 0.93; HAIs included UTI, BSI, respiratory tract infection, gastrointestinal tract infection, skin and soft tissue infection and other infections (parotitis, chickenpox, neurological infections, etc.) (40). However, these seven studies were not performed in Canada. In fact, other countries already have electronic data in place in their facilities and implementation of ESS for HAI surveillance is thus feasible. In Canada, not all hospitals have access to a good electronic health record system.

Some provinces are good models for surveillance using electronic data. For example, most studies included in this scoping review were from provinces that have electronic systems (e.g. Alberta, Ontario). Alberta is a good example for HAI surveillance as all acute-care sites conduct traditional surveillance using a single surveillance protocol and a centralized online data entry system (41). This system allows administrative information to be shared between all its facilities. Québec also has a centralized electronic system created for the *Surveillance Provinciale des Infections Nosocomiales* program using uniform definitions to detect HAI (42); however, no study from Québec met our inclusion criteria. One study by Gilca *et al*. is worth considering:

this study included 83 acute-care hospitals participating in CDI surveillance in the province of Québec (43). Authors compared administrative and surveillance data and found an excellent agreement between rates obtained from MED-ÉCHO (hospital discharge database) and CDI incidence according to provincial surveillance. However, the origin of acquisition for CDI cases was not indicated in the administrative database. Thus, it was not possible to separate nosocomial from community-acquired cases with only the use of administrative data.

A study conducted in three states in the United States and in the province of Ontario, Canada assessed the information technology challenges and strategies of developing and implementing a multihospital electronic system to prevent MRSA (44). They included 11 hospitals, all with an understaffed information technology group, and with seven different systems having unique information technology structure and unique data system. They found innovative strategies to enable automated collection, sharing, analysis and reporting of data in a compatible format for all hospitals. The study was published in 2013, and authors are currently applying the same strategies to develop ESS for other HAIs. This study is a good example of the feasibility of implementing ESS using different hospital systems.

Strengths and limitations

We used standardized and robust methods to identify, review and assess quality of the published literature with all steps performed by two independent reviewers. Two different search strategies were used to ensure that all Canadian studies were included as well as systematic reviews that included at least one study in Canada. Our review included a small number of studies; however, we are confident that our search strategies combined with hand-search captured all relevant available articles. This is the first review to report on divergences between administrative data and surveillance data for HAI surveillance in Canada.

This review has several limitations. We included only studies that were published in French or English; however, as French and English are the two official languages in Canada, we do not expect to have missed important studies. Observational studies identified represent only three Canadian provinces, with two-thirds of the studies from Alberta. Alberta has a province-wide integrated healthcare system that is easily queried, which is not the case with the systems in the remaining provinces. While our review included both articles published in English or French, our search was conducted using only English terms. We searched only three databases and we may have missed relevant articles included in other databases. This study was conducted on Canadian data only and may not be generalizable to other countries.

Conclusion

This scoping review identified numerous divergences between administrative data and active surveillance data for HAI surveillance in Canadian hospitals. However, it also identified possible solutions, depending on the HAI under surveillance, and demonstrated that administrative data can be used to enhance HAI surveillance. Electronic surveillance systems have the potential to save time and human resources and combining multiple administrative datasets may also improve data accuracy. The IPC team who used administrative data or electronic surveillance systems were able to reduce their workload in active surveillance. Although active surveillance of HAIs produced the more accurate results and remains the gold-standard, further studies on HAI surveillance in Canada should focus on the feasibility of data sharing between provinces through electronic systems, the feasibility for medical coders to have access to documentation other than physician documentation, and the feasibility of using administrative data to help reduce the burden of active surveillance.

Authors' statement

VB — Conceptualization, methodology, investigation, validation, formal analysis, writing–original draft
EP — Investigation, validation, writing–review
AM — Conceptualization, resources, writing–review and editing, funding acquisition
CQ — Conceptualization, writing–review & editing, supervision, funding acquisition

The content and view expressed in this article are those of the authors and do not necessarily reflect those of the Government of Canada.

Competing interests

None of the authors had any conflicts of interest to disclose.

Acknowledgements

V Boulanger and E Poirier are supported through a MITACS Accelerate/ Healthcare Excellence Canada internship. We thank M Clar for her assistance in the literature search strategy. L Prelude and A Chapman for their support and D Diallo for her assistance with English translation. C Quach is the Tier-1 Canada Research Chair in Infection Prevention: from hospital to the community.

Funding

This work was funding by Healthcare Excellence Canada and MITACS Accelerate and Healthcare Excellence Canada.

Supplemental material

These documents can be accessed on the Supplemental data file.

Supplemental Data S1
Supplemental Data S2
Supplemental Table S3
Supplemental Table S4

References

1. Canadian Nosocomial Infection Surveillance Program. Healthcare-associated infections and antimicrobial resistance in Canadian acute care hospitals, 2014-2018. Can Commun Dis Rep 2020;46(5):99–112. DOI PubMed

2. MacLaurin A, Amaratunga K, Couris C, Frenette C, Galioto R, Hansen G, Happe J, Neudorf K, Pelude L, Quach C, Rose SR. Measuring and Monitoring Healthcare-Associated Infections: A Canadian Collaboration to Better Understand the Magnitude of the Problem. Healthc Q. 2020;22(SP):116-28. DOI PubMed

3. Mitchell R, Taylor G, Rudnick W, Alexandre S, Bush K, Forrester L, Frenette C, Granfield B, Gravel-Tropper D, Happe J, John M, Lavallee C, McGeer A, Mertz D, Pelude L, Science M, Simor A, Smith S, Suh KN, Vayalumkal J, Wong A, Amaratunga K; Canadian Nosocomial Infection Surveillance Program. Trends in health care-associated infections in acute care hospitals in Canada: an analysis of repeated point-prevalence surveys. CMAJ 2019;191(36):E981–8. DOI PubMed

4. Aiello R. PM Trudeau questioned on COVID-19 projections, implores people to stay home. Ottawa News Bureau Online Producer, CTV News, April 2, 2020. https://www.ctvnews.ca/health/coronavirus/pm-trudeau-questioned-on-covid-19-projections-implores-people-to-stay-home-1.4879062?cache=sgjigezwskldpu%3FcontactForm%3Dtrue

5. Public Health Agency of Canada. Canadian Nosocomial Infection Surveillance Program (CNISP): Summary Report of Healthcare Associated Infection (HAI), Antimicrobial Resistance (AMR) and Antimicrobial Use (AMU) Surveillance Data from January 1, 2013 to December 31, 2017. Ottawa (ON): PHAC (updated 2021-07). https://www.canada.ca/en/public-health/services/publications/science-research-data/summary-report-healthcare-associated-infection-antimicrobial-resistance-antimicrobial-use-surveillance-data-2013-2017.html

6. Ruthledge-Taylor K, Mitchell R, Prelude L, AbdelMalik P, Roth V. Evaluation of the representativeness of the Canadian Nosocomial Infection Surveillance Program. Can J Infect Control 2015;30(1):13–7. https://ipac-canada.org/photos/custom/OldSite/cjic/vol30no1.pdf

7. Xia Y, Tunis MC, Frenette C, Katz K, Amaratunga K, Rose SR, House A, Quach C. Epidemiology of Clostridioides difficile Infection in Canada: A Six-Year Review of Provincial Surveillance Data. Can Commun Dis Rep 2019;45(7-8):191–211. DOI PubMed

8. Quan H, Smith M, Bartlett-Esquilant G, Johansen H, Tu K, Lix L; Hypertension Outcome and Surveillance Team. Mining administrative health databases to advance medical science: geographical considerations and untapped potential in Canada. Can J Cardiol 2012;28(2):152–4. DOI PubMed

9. Canadian Institute for Health Information. CIHI Data Quality Study of the 2009–2010 Discharge Abstract Database. Ottawa (ON): CIHI; 2012. https://secure.cihi.ca/free_products/Reab%202009-2010%20Main%20Report%20FINAL.pdf

10. Willemse C. Using the Canadian Institute for Health Information's Information Quality Framework to Support Integration and Utilization of Complex, Multi-Jurisdictional Data. Internat J Pop Data Sci. 2020;5(5). https://ijpds.org/article/view/1556

11. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, Moher D, Peters MD, Horsley T, Weeks L, Hempel S, Akl EA, Chang C, McGowan J, Stewart L, Hartling L, Aldcroft A, Wilson MG, Garritty C, Lewin S, Godfrey CM, Macdonald MT, Langlois EV, Soares-Weiser K, Moriarty J, Clifford T, Tunçalp Ö, Straus SE. PRISMA Extension for Scoping Reviews (PRISMA-ScR): checklist and Explanation. Ann Intern Med 2018;169(7):467–73. DOI PubMed

12. Sterne JA, Hernán MA, Reeves BC, Savović J, Berkman ND, Viswanathan M, Henry D, Altman DG, Ansari MT, Boutron I, Carpenter JR, Chan AW, Churchill R, Deeks JJ, Hróbjartsson A, Kirkham J, Jüni P, Loke YK, Pigott TD, Ramsay CR, Regidor D, Rothstein HR, Sandhu L, Santaguida PL, Schünemann HJ, Shea B, Shrier I, Tugwell P, Turner L, Valentine JC, Waddington H, Waters E, Wells GA, Whiting PF, Higgins JP. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. BMJ 2016;355:i4919. DOI PubMed

13. Shea BJ, Reeves BC, Wells G, Thuku M, Hamel C, Moran J, Moher D, Tugwell P, Welch V, Kristjansson E, Henry DA. AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both. BMJ 2017;358:j4008. DOI PubMed

14. Crocker A, Kornilo A, Conly J, Henderson E, Rennert-May E, Leal J. Using administrative data to determine rates of surgical site infections following spinal fusion and laminectomy procedures. Am J Infect Control 2021;49(6):759–63. DOI PubMed

15. Pfister T, Rennert-May E, Ellison J, Bush K, Leal J. Clostridioides difficile infections in Alberta: the validity of administrative data using ICD-10 diagnostic codes for CDI surveillance versus clinical infection surveillance. Am J Infect Control 2020;48(12):1431–6. DOI PubMed

16. Lee S, Ronksley P, Conly J, Garies S, Quan H, Faris P, Li B, Henderson E. Using data linkage methodologies to augment healthcare-associated infection surveillance data. Infect Control Hosp Epidemiol 2019;40(10):1144–50. DOI PubMed

17. Rennert-May E, Manns B, Smith S, Puloski S, Henderson E, Au F, Bush K, Conly J. Validity of administrative data in identifying complex surgical site infections from a population-based cohort after primary hip and knee arthroplasty in Alberta, Canada. Am J Infect Control 2018;46(10):1123–6. DOI PubMed

18. Ramirez Mendoza JY, Daneman N, Elias MN, Amuah JE, Bush K, Couris CM, Leeb K. A Comparison of Administrative Data Versus Surveillance Data for Hospital-Associated Methicillin-Resistant Staphylococcus aureus Infections in Canadian Hospitals. Infect Control Hosp Epidemiol 2017;38(4):436–43. DOI PubMed

19. Rusk A, Bush K, Brandt M, Smith C, Howatt A, Chow B, Henderson E. Improving Surveillance for Surgical Site Infections Following Total Hip and Knee Arthroplasty Using Diagnosis and Procedure Codes in a Provincial Surveillance Network. Infect Control Hosp Epidemiol 2016;37(6):699–703. DOI PubMed

20. Daneman N, Ma X, Eng-Chong M, Callery S, Guttmann A. Validation of administrative population-based data sets for the detection of cesarean delivery surgical site infection. Infect Control Hosp Epidemiol 2011;32(12):1213–5. DOI PubMed

21. Leal J, Gregson DB, Ross T, Flemons WW, Church DL, Laupland KB. Development of a novel electronic surveillance system for monitoring of bloodstream infections. Infect Control Hosp Epidemiol 2010 31(7):740–7. DOI PubMed

22. Daneman N, Simor AE, Redelmeier DA. Validation of a modified version of the national nosocomial infections surveillance system risk index for health services research. Infect Control Hosp Epidemiol 2009;30(6):563–9. DOI PubMed

23. Daneman N, Stukel TA, Ma X, Vermeulen M, Guttmann A. Reduction in Clostridium difficile infection rates after mandatory hospital public reporting: findings from a longitudinal cohort study in Canada. PLoS Med 2012;9(7):e1001268. DOI PubMed

24. Lethbridge LN, Richardson CG, Dunbar MJ. Measuring Surgical Site Infection From Linked Administrative Data Following Hip and Knee Replacement. J Arthroplasty 2020;35(2):528–33. DOI PubMed

25. Almond J, Leal J, Bush K, Rogers E, Henderson EA, Ellison J. Hospital-acquired Clostridioides difficile infections in Alberta: the validity of laboratory-identified event surveillance versus clinical infection surveillance. Am J Infect Control 2020;48(6):633–7. DOI PubMed

26. van Mourik MS, van Duijn PJ, Moons KG, Bonten MJ, Lee GM. Accuracy of administrative data for surveillance of healthcare-associated infections: a systematic review. BMJ Open 2015;5(8):e008424. DOI PubMed

27. Freeman R, Moore LS, García Álvarez L, Charlett A, Holmes A. Advances in electronic surveillance for healthcare-associated infections in the 21st Century: a systematic review. J Hosp Infect 2013;84(2):106–19. DOI PubMed

28. Streefkerk HR, Verkooijen RP, Bramer WM, Verbrugh HA. Electronically assisted surveillance systems of healthcare-associated infections: a systematic review. Euro Surveill 2020;25(2):1900321. DOI PubMed

29. Leal J, Laupland KB. Validity of electronic surveillance systems: a systematic review. J Hosp Infect 2008;69(3):220–9. DOI PubMed

30. Donovan TL, Forrester L, Chen Collet J, Wong L, Mori J, Lloyd-Smith E, Ranns B, Han G. Challenging the assertion of comparability of surveillance and administrative data. Infect Control Hosp Epidemiol 2018;39(11):1391–2. DOI PubMed

31. Woeltje KF. Moving into the future: electronic surveillance for healthcare-associated infections. J Hosp Infect 2013;84(2):103–5. DOI PubMed

32. Wilson J, Wloch C, Saei A, McDougall C, Harrington P, Charlett A, Lamagni T, Elgohari S, Sheridan E. Inter-hospital comparison of rates of surgical site infection following caesarean section delivery: evaluation of a multicentre surveillance study. J Hosp Infect 2013;84(1):44–51. DOI PubMed

33. Løwer HL, Eriksen HM, Aavitsland P, Skjeldestad FE. Methodology of the Norwegian Surveillance System for Healthcare-Associated Infections: the value of a mandatory system, automated data collection, and active postdischarge surveillance. Am J Infect Control 2013;41(7):591–6. DOI PubMed

34. Sands K, Vineyard G, Platt R. Surgical site infections occurring after hospital discharge. J Infect Dis 1996;173(4):963–70. DOI PubMed

35. Public Health Ontario. Ontario Agency for Health Protection and Promotion. Provincial Infectious Diseases Advisory Committee. Best practices for surveillance of health care-associated infections In patient and resident populations, 3rd edition. Toronto (ON): Queen's Printer for Ontario; 2014. https://www.publichealthontario.ca/-/media/documents/B/2014/bp-hai-surveillance.pdf

36. Canadian Institute for Health Information. Clinical Administrative Databases. Privacy Impact Assessment, Aug 2019. https://www.cihi.ca/sites/default/files/document/cad-pia-2019-en-web.pdf

37. Jhung MA, Banerjee SN. Administrative coding data and health care-associated infections. Clin Infect Dis 2009;49(6):949–55. DOI PubMed

38. Drees M, Gerber JS, Morgan DJ, Lee GM. Research Methods in Healthcare Epidemiology and Antimicrobial Stewardship: Use of Administrative and Surveillance Databases. Infect Control Hosp Epidemiol 2016;37(11):1278–87. DOI PubMed

39. Tang KL, Lucyk K, Quan H. Coder perspectives on physician-related barriers to producing high-quality administrative data: A qualitative study. CMAJ Open 5, E617. https://www.cmajopen.ca/content/5/3/E617

40. Du M, Xing Y, Suo J, Liu B, Jia N, Huo R, Chen C, Liu Y. Real-time automatic hospital-wide surveillance of nosocomial infections and outbreaks in a large Chinese tertiary hospital. BMC Med Inform Decis Mak 2014;14(1):9. DOI PubMed

41. Alberta Health Services. Surveillance & Reporting. Infection Prevention & Control. https://www.albertahealthservices.ca/info/Page15736.aspx

42. Institut National de Santé Publique du Québec (INSPQ). Nosocomial infections. QC: INSPQ; 2021. https://www.inspq.qc.ca/infections-nosocomiales

43. Gilca R, Hubert B, Fortin E, Gaulin C, Dionne M. Epidemiological patterns and hospital characteristics associated with increased incidence of Clostridium difficile infection in Quebec, Canada, 1998-2006. Infect Control Hosp Epidemiol 2010;31(9):939-47. DOI PubMed

44. Doebbeling BN, Flanagan ME, Nall G, Hoke S, Rosenman M, Kho A. Multihospital infection prevention collaborative: informatics challenges and strategies to prevent MRSA. AMIA Annu Symp Proc 2013;2013:317–25. PubMed