Use of an electronic information system to identify adverse events resulting in an emergency department visit

Stacy Ackroyd-Stolarz,[1] Neil J MacKinnon,[2] Peter J Zed,[2] Nancy Murphy[2]

[1]Department of Emergency Medicine, Dalhousie University, Queen Elizabeth II Health Sciences Centre, Halifax, Nova Scotia, Canada
[2]College of Pharmacy, Dalhousie University, Halifax, Nova Scotia, Canada

Correspondence to
Dr Stacy Ackroyd-Stolarz, Canadian Patient Safety Institute/Canadian Institutes of Health Research Dr David Rippey Patient Safety, Department of Emergency Medicine, Dalhousie University, Queen Elizabeth II Health Sciences Centre, Halifax Infirmary, Suite 355, 1796 Summer Street, Halifax, Nova Scotia, Canada; stacy.ackroyd@dal.ca

ABSTRACT
Objective There is limited information about the nature of adverse events (AEs) that necessitate an emergency department (ED) visit. The objective of the current study was to demonstrate the feasibility of using routinely collected electronic data to identify AEs in patients presenting to EDs in one Canadian health authority.
Methods This retrospective cross-sectional study occurred in EDs in two community hospitals, an outpatient community health centre and a tertiary care facility in the Capital District Health Authority in Nova Scotia, Canada between 1 November 2007 and 31 October 2008. The primary outcome was identification of an AE as the main reason for the ED visit. AEs were identified from electronic diagnostic data using previously validated screening criteria.
Results There were 142 433 patient visits to the four EDs during the study period. A total of 1870 (1.3%) AEs were identified using the screening criteria. This included 1133 (0.8%) procedure-related, 673 (0.5%) drug-related, 63 (0.04%) device-related and one radiation-related AE. The AEs identified using this method were most likely the manifestation of treatment decisions made prior to the ED visit and/or related to care in other settings (eg, primary or long-term care, acute hospital care) including previous ED visits.
Interpretation Although the use of electronic data significantly underestimates AEs treated in the ED, for relatively low cost, it provides new information on AEs arising from a variety of care settings that may otherwise not be captured. Significant and clinically important differences in healthcare utilisation underscore the value in identifying these AEs.

INTRODUCTION
The epidemiology of adverse events (AEs) or unintended injuries caused by medical management[1] in acute care has been well described in countries around the world. Many studies used a resource-intensive methodology involving two stages of health record review—screening and confirmation of an AE.[1–6] Most of the landmark patient safety studies concluded that a proportion of AEs identified during an acute hospital admission occurred prior to hospitalisation, with estimates ranging from 13% in the US to 49% in Australia.[2–5] Important gaps remain in our understanding of AEs along the continuum of care and in novel, less costly methods to measure healthcare-related harm to patients.

The current study sought to determine the nature and frequency of AEs that necessitated a visit to an Emergency Department (ED) for assessment and treatment. A secondary objective was to demonstrate the feasibility of using routinely collected electronic data to identify AEs in patients presenting to EDs in one Canadian health authority.

METHODS
Design and setting
This retrospective cross-sectional study occurred in four EDs from the Capital District Health Authority (CDHA) in Nova Scotia, Canada between 1 November 2007 and 31 October 2008. These include EDs in a tertiary care hospital (annual ED census of 60 000), two community hospitals (annual ED census of 40 000 and 17 000 respectively) and a community health centre (annual ED census of 26 000). The CDHA Research Ethics Board approved the study. All patients presenting to one of four study EDs were eligible for inclusion. Patients may have had multiple visits to the ED during the study period. All visits were included.

Data source
Data were obtained from the Emergency Department Information System (EDIS), which is a real-time system for electronically collecting administrative (eg, age, gender, date and time of ED visit) and clinical data (eg, presenting complaint, diagnosis, consult services and disposition). The same system is used in all four of the study facilities. Patients could be transferred from one facility to another, as in the example of a patient from the community health centre being transferred to hospital for an inpatient admission; however, EDIS treats encounters at each facility as separate events.

Outcome measure
The primary outcome was an AE as the main reason for the ED visit. AEs were identified from electronic diagnostic data using previously validated screening criteria developed by the Wisconsin Medical Injury Prevention Program (WMIPP).[7] The screening criteria use a combination of ICD-9-Clinical Modification (CM) diagnosis and external cause of injury codes applied to administrative data. The diagnosis code describes the nature of the problem (eg, rash) and the external cause of injury codes identify the mechanism (eg, complication due to antibiotics). In comparison with retrospective health record review by a clinician, a validation study determined the screening criteria to be 59.9% sensitive (95% CI 42.8 to 75.0) and 97.4% specific (95% CI 94.1 to 98.8).[7] The EDIS diagnosis data are

coded using ICD-9-CM; however, there were no external cause-of-injury codes available. The criteria are categorised into four groups: (1) drug-related; (2) procedure-related; (3) related to devices, implants or grafts; and (4) radiation-related. EDIS also has text descriptions of presenting complaint and ED diagnosis. The text descriptions were compared with ICD codes for all positive records, and only those that matched were considered to be positive for an AE. Information from text was included to minimise misclassification and to exclude AEs that were intentional in nature. In addition to the text descriptions, the patient's age, sex, postal code and date of ED visit(s) were compared to identify patients transferred from one facility to another for the same AE. The screening criteria exclude illegal drugs. The AEs identified using this method were most likely the manifestation of treatment decisions made prior to the ED visit and/or related to care in other settings (eg, primary or long-term care, acute hospital care) including previous ED visits. It did not capture AEs that occurred during the ED visit under study.

Data analysis

Descriptive statistics were generated using STATA statistical software (Version 9; STATA Corp., College Station, Texas). Differences between those with and without an AE were compared using the χ^2 test for categorical data, an unpaired t test for normally distributed continuous data and the Mann−Whitney U test for data that were not normally distributed.

RESULTS

There were 142 433 patient visits between 1 November 2007 and 31 October 2008 to four EDs in CDHA. Figure 1 is a flow chart of the study population, and table 1 describes their characteristics. A total of 1870 (1.3% of 142 433) AEs were identified using the screening criteria, including 1133 (0.8%) procedure-related, 673 (0.5%) medication-related, 63 (0.04%) device-related and one radiation-related AE.

There were 15 patients with an AE who were seen in two different EDs. Of these, 11 (73.3% of 15) were patients seen in the community health centre and transferred to the ED at the tertiary care hospital.

Patients with procedure-related AEs most often presented with postoperative complications (436 of 1133 (38.5%)), request for a wound check (106 (9.4%)), abdominal pain (91 (8.0%)), localised swelling/redness (70 (6.2%)) and lower-extremity pain (49 (4.3%)). The most common types of procedure-related AEs were infection and/or inflammation (282 (24.9%)), a haematoma, haemorrhage or seroma (203 (17.9%)) or a non-healing wound (94 (8.3%)). Although those presenting with a procedure-related AE had a shorter length of stay in the ED (2.8 vs 3.1 h, p=0.001) compared with other patients, they were more likely to be admitted to hospital (17.6% vs 9.5%, p<0.0001).

The most common presenting complaints for patients with drug-related AEs were 'overdose/ingestion' (317 of 673 (47.1%)), allergic reaction (79 (11.7%)) and rash (50 (7.4%)). The medications most frequently implicated in AEs were analgesics and antipyretics (142 of 673 (21.1%)), psychotropic medications (121 (18.0%)) and other sedatives and hypnotics (95 (14.1%)). Compared with all other ED patients, those patients who presented with a drug-related AE were more likely to have been transported to the ED by ambulance (37.6% vs 13.1%, p<0.0001), to have had a longer length of stay in the ED (4.5 vs 3.1 h, p<0.0001), to have been admitted to hospital (15.2% vs 9.5%, p<0.0001) and to an intensive care unit (5.1% vs 0.4%, p<0.0001).

The presenting complaint for patients with a device-related AE was often recorded as a 'medical device problem' (13 of 63 (20.6%)). The most common types of events were those related to cardiac devices (21 (33.3%)) and dialysis (17 (27.0%)). Patients with device-related AEs were most likely admitted to neurosurgery (10 of 20 recorded (50.0%)) or cardiology (5 (25.0%)). All of the 10 patients admitted to neurosurgery were experiencing shunt-related problems. Compared with all other ED patients, those patients who presented with a device-related AE were more likely to be older (median age 60.0 vs 43.0, p<0.0001), to have been transported to the ED by ambulance (25.4% vs 13.1%, p= 0.004), to have had a longer length of stay in the ED (5.0 vs 3.1 h, p=0.0002) and to have been admitted to hospital (36.5% vs 9.5%, p<0.0001). Table 2 displays the differences between those with and without AEs.
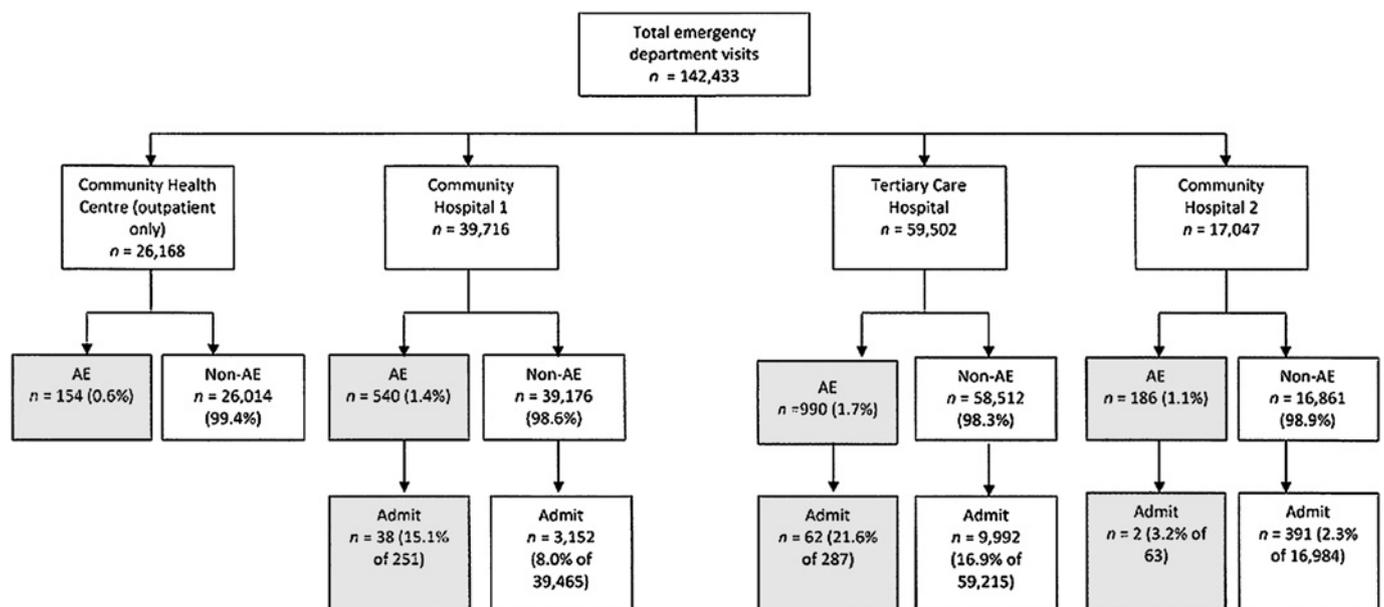

Figure 1 Study flow chart. AE, adverse event.

Table 1 Characteristics of patients presenting to four Capital District Health Authority emergency department (EDs) November 2007 to October 2008

Characteristic	No (%) of patients* n=142433
Sex	
Male	68131 (47.8)
Female	74302 (52.2)
Age in years, median (IQR†)	43.0 (26.0 to 60.0)
Transported by emergency medical services‡	18805 (13.2)
Site	
Tertiary care hospital	59502 (41.8)
Community hospital 1	39716 (27.9)
Community health centre	26168 (18.4)
Community hospital 2	17047 (11.9)
CTAS§ triage level	
Emergent or urgent	77187 (54.2% of 142355¶)
Less or non-urgent	65168 (45.8)
ED presentation	
Emergency presentation	124375 (95.9% of 129642¶)
Direct to consultation	3,482 (2.7)
Return visit—planned	1357 (1.1)
Return visit—unplanned	428 (0.3)
ED disposition	
Return to usual place of residence	113426 (79.7% of 142395¶)
Admitted to hospital	13637 (9.6)
Left without full assessment or treatment	9472 (6.7)
Discharge to other hospital	4316 (3.0)
Left against medical advice	549 (0.4)
Deceased	199 (0.1)
Other	796 (0.5)
ICU admission	612 (0.4)

*Unless otherwise specified.
†Interquartile range.
‡Includes LifeFlight & Ground Ambulance.
§Canadian Triage and Acuity Scale (emergent or urgent=CTAS Level I–III; Less or non-urgent=CTAS Level IV–V).
¶Number with information recorded.

DISCUSSION

The results of the current study demonstrate the feasibility of using routinely collected electronic data to screen for AEs. A total of 1870 (1.3%) AEs were identified using the screening criteria. Although the event rate is low, the types of AEs that were identified are consistent with those reported in other settings and using different methodologies. The most common types of AEs were procedure and drug-related. Significant and clinically important differences in healthcare utilisation were identified for those patients with an AE. They were more likely to be transported to hospital by ambulance, to have a longer length of stay in the ED and to be admitted to hospital and to an intensive care unit.

Although there are several studies that have described AEs occurring as a result of care in the ED,[8–10] there is limited literature describing AEs identified in the ED setting, but related to events that took place prior to an ED visit. In a retrospective chart review, Hendrie et al screened records from patients presenting to the ED in a tertiary care hospital in Australia. They determined an event rate of 5.1%, with more than half of the events occurring prior to the ED visit. The rest of the events occurred during the ED visit. Drug reactions and diagnostic issues were the most common types of events.[11 12]

Using data from the 2006 National Hospital Ambulatory Medical Care Surveys and National Hospital Discharge Surveys in the USA, Burt et al concluded that 2.3 million ED visits (2.0% of the total) were made by patients who had recently been hospitalised. Moreover, they suggested that approximately 10% of those visits were for medical or surgical complications that may have been related to the hospitalisation.[13] Forster et al determined that 19% of patients discharged from hospital experience an AE soon after discharge. Adverse drug events and complications from procedures were the most common types of AE.[14] In a prospective study of patients discharged from a medical service in a Canadian hospital, 23% experienced an AE within 30 days of their discharge, of whom 12% required an ED visit.[15] In the current study, most of the procedure-related AEs appear to be secondary to surgical complications and are thus likely to have had their genesis during a hospital admission.

There is limited literature on AEs resulting from treatment in primary or long-term care that are identified in the ED. In the Harvard Medical Practice Study, it was concluded that the majority of AEs that occurred prior to the index hospital admission took place in physicians' offices (7.7% of all AEs), at home (2.7%) or in an ambulatory care unit (1.4%).[3] There were similar findings in New Zealand with 6.4% occurring in doctor's offices, 5.3% at home and 3.8% in a nursing home.[5] In these hospital-based studies of AEs, those that may have occurred prior to hospitalisation, but not identified until the patient was admitted, represent the more severe end of the spectrum. That is, the AE was serious enough to warrant hospitalisation. The current study provides more information on the full spectrum, with the majority of patients with AEs (82.7%) being discharged from the ED. Those with device-related AEs were more likely to be admitted to hospital (36.5%), and those with drug-related AEs were more likely to be admitted to an intensive care unit (5.1%).

Drug-related AEs identified and treated in the ED have received greater attention in the literature.[16–20] In a prospective study conducted in the ED of a tertiary care hospital in a large Canadian city, Zed et al concluded that one in 10 visits to the ED was for a drug-related AE.[16] Capuano et al[17] found that 1.2% of visits to 10 EDs in Italy were due to adverse drug events. In the US, Budnitz et al estimated that 2.5% of all unintentional injury presentations to EDs were due to adverse drug events.[18] In the current study, less than 1% of the visits were drug-related. The variation may be due to a number of factors including differences in study design and methods, definition of a drug-related adverse event and regional incidence. It is likely that the methodology employed in the current study underestimates the total burden of ED visits related to harm from earlier healthcare interventions. In part, this is related to the nature of assigning a diagnosis using EDIS. For example, if a patient presents to the ED because of an intracerebral haemorrhage secondary to over-coagulation from warfarin, the ED diagnosis will likely be coded by the condition (haemorrhage), not the underlying or contributing factors. In a validation study of the screening criteria, it was determined that identification of drug-related events was significantly reduced if external cause of injury codes were not used, as was the case with the current study. For this reason, it is likely that the actual number of drug-related AEs during the study period was higher than identified.[7] It is possible that some of the drug-related AEs included episodes of intentional self-harm; however, the potential for misclassification was minimised by reviewing all relevant text descriptions in EDIS with respect to intent.

Despite the likely underestimation, this method has several advantages over other methods of event detection. The information is routinely collected, readily available and accessible for low cost. Most importantly, data can be obtained without any impact on clinical staff. These attributes increase the utility for ongoing system-level monitoring. Although the current study

Table 2 Comparison of patients with and without any adverse event (AE) presenting to four Capital District Health Authority emergency departments (EDs) November 2007 to October 2008

Characteristics	Type of ED visit				
	Procedure-related AEs n=1133 No (%)†	Drug-related AEs n=673 No (%)†	Device-Related AEs n=63 No (%)†	Any AE n=1870 No (%)†	Non-AE n=140563 No (%)†
Demographics					
Male*	523 (46.2)	285 (42.3)	36 (57.1)	844 (45.1)	67,287 (47.9)
Female	610 (53.8)	388 (57.7)	27 (42.9)	1026 (54.9)	73276 (52.1)
Age in years, median (IQR‡)**	49 (35 to 63)	37 (22 to 51)	60 (33 to 74)	45 (29 to 60)	43 (26 to 60)
Transported by emergency medical services§***	122 (10.8)	253 (37.6)	16 (25.4)	391 (20.9)	18414 (13.1)
Site					
Tertiary care hospital	660 (58.3)	287 (42.6)	43 (68.3)	990 (52.9)	58512 (41.6)
Community hospital 1	279 (24.6)	251 (37.3)	9 (14.3)	540 (28.9)	39176 (27.9)
Community health centre	78 (6.9)	72 (10.7)	4 (6.3)	154 (8.2)	26014 (18.5)
Community hospital 2	116 (10.2)	63 (9.4)	7 (11.1)	186 (10.0)	16,861 (12.0)
CTAS¶ triage level***					
Emergent or urgent	608 (53.7)	571 (84.8)	53 (84.1)	1232 (65.9)	75955 (54.1% of 140485)††
Less or non-urgent	525 (46.3)	102 (15.2)	10 (15.9)	638 (34.1)	64530 (45.9)
ED length of stay in hours, median (IQR)***	2.8 (1.5 to 4.7)	4.5 (2.6 to 8.6)	5.0 (2.7 to 7.4)	3.4 (1.9 to 5.9)	3.1 (1.8 to 5.0)
Admitted to hospital***	199 (17.6)	102 (15.2)	23 (36.5)	324 (17.3)	13313 (9.5)
ICU admission***	7 (0.6)	34 (5.1)	0	41 (2.2)	571 (0.4)

Significant at: *$p<0.05$; **$p<0.005$; ***$p<0.0001$.
†Unless otherwise specified.
‡Interquartile range.
§Includes Air & Ground Ambulance.
¶Canadian Triage and Acuity Scale (emergent or urgent=CTAS Level I–III; Less or non-urgent=CTAS Level IV–V); differences between the groups (any AE and no AE) were compared using the χ^2 test for categorical data, an unpaired t test for normally distributed continuous data and a Mann–Whitney U test for data that were not normally distributed.
††Number with information recorded.

examined EDIS data retrospectively, because of its real-time data collection capabilities, data queries can be developed to create an ongoing surveillance system. This novel approach expands the potential sources for relevant information on the overall burden of AEs to the healthcare system and can be used on a regular basis to inform development and enhance evaluation of targeted interventions. Many EDs in countries around the world use some form of electronic data capture such as EDIS, thus facilitating adoption of the methods.

LIMITATIONS
This is the first study to apply the screening criteria to ED diagnostic data. It has demonstrated the feasibility of using routinely collected data to screen for AEs. Although it was beyond the scope of the study to validate the criteria in a new setting, this is a necessary next step prior to widespread adoption of the criteria. The results are likely an underestimate of the problem. The approach does not permit identification of diagnostic-related AEs; nor did it include the external cause of injury codes found in the original screening criteria. Although the sensitivity of the screening criteria is less than optimal, more sensitive measures of detection are prohibitively resource-intensive. The findings from one health authority in a Canadian province can only be generalised to a similar study population and setting; however, the study included different types of EDs with variable patient populations and volumes, thus improving the generalisability of the results.

CONCLUSION
Although the use of electronic data significantly underestimates AEs treated in the ED, it nevertheless provides new information on AEs arising from a variety of care settings (eg, primary or long-term care) that would otherwise not be captured. Significant and clinically important differences in healthcare utilisation underscore the value in identifying these AEs. Further work applying these methods to other healthcare settings will contribute to our understanding of the nature and breadth of the problem across the continuum of care.

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