Preventable adverse drug events causing hospitalisation: identifying root causes and developing a surveillance and learning system at an urban community hospital, a cross-sectional observational study

Jane de Lemos,1 Peter Loewen,2 Cheryl Nagle,3 Robert McKenzie,3 Yong Dong You,4 Anna Dabu,5 Peter Zed,2 Peter Ling,4 Richard Chan6

ABSTRACT

Objectives To identify root causes of preventable adverse drug events (pADEs) contributing to hospital admission; to develop key messages which identify actions patients/families and healthcare providers can take to prevent common pADEs found; to develop a surveillance learning system for the community.

Methods Cross-sectional observational study; 120 patients and families, 61 associated healthcare providers were interviewed then root cause analysis was performed to develop key learning messages and an electronic reporting tool was designed. Most common pADE-related medical conditions and their root causes and most common pADE root causes of entire cohort are reported.

Results Most common pADE-related medical conditions: chronic obstructive pulmonary disease/asthma (13.3%), bleeding (12.5%), hypotension (12%), heart failure (10%), acute kidney injury (5%) and pneumonia (5%). Most common root causes were: providers not confirming that the patient/family understands information given (29.2%), can identify how a medication helps them/have their concerns addressed (16.7%), can identify if a medication is working (14.1%) or causing a side effect (23.3%); can enact medication changes (7.5%); absence of a sick day management plan (12.5%), and other action plans to help patients respond to changes in their clinical status (10.8%); providers not assessing medication use and monitoring competency (19.2%). Ten key learning messages were developed and a pADE surveillance learning system was implemented.

Conclusions To prevent pADEs, providers need to confirm that patients/families understand information given, how a medication helps them, how to recognize and respond to side effects, how to enact medication changes and follow action plans; providers should assess patient’s/families’ medication use and monitoring competency.

INTRODUCTION

Adverse drug events (ADEs) are responsible for 15% of hospital admissions in patients 65 years or older and up to 20% of patients admitted to acute medical units.1-9 ADE refers to harm that occurs as a result of taking or not taking a medication or treatment that is below the expected standard of care.10-11 Up to 50% of ADEs are potentially preventable, most commonly due to suboptimal prescribing or monitoring and patient self-management issues (30% of cases each).12-17 The need to reduce severe avoidable medication-related harm is recognised by the WHO which is leading a 5-year global effort to halve it by 2022.18 In the USA, the National Action Plan for Adverse Drug Event Prevention aims to develop strategies to reduce ADEs through surveillance and research.19 Despite recognition that public health could be improved by preventing preventable ADEs (pADEs), few studies have performed root cause analysis (RCA) of pADEs on a case-by-case basis with interviews of patients and providers to find out why they occurred.20 Such analysis is necessary to design effective strategies to prevent or mitigate pADEs. Therefore, in this study, we aimed to identify root causes of pADEs that caused or contributed to hospital admission, translate findings into actions that care providers and patients/families can take to prevent them. In addition, we set out to design a routine surveillance and reporting system to share root causes of pADEs with community providers. This shared learning system for the community could help prevent pADE recurrence in individual patients and their incidence in future patients. This programme is unique in its emphasis on searching for the root causes of pADEs and systematic sharing of that learning with community providers.
The study objectives were to develop and evaluate a system to report, monitor, mitigate and prevent pADEs by (1) identifying root causes of pADEs causing or contributing to hospitalisation, (2) developing learning messages to translate identified root causes into actions that providers, patients and families could take to prevent pADEs, and (3) developing a surveillance learning system to capture, report and share pADE root causes with providers to prevent their recurrence.

METHODS

Setting
The study was conducted at an urban community hospital in British Columbia with patient recruitment between November 2016 and December 2017.

Design
This was a cross-sectional observational study of pADEs that caused or contributed to a patient’s hospital admission. Results were synthesised into learning messages for community care providers, patients and families, and used to inform development of an electronic pADE surveillance system. Reporting follows the Strengthening the Reporting of Observational Studies in Epidemiology guidelines for cross-sectional studies.21

Participants
Admitted patients were eligible to participate if they were deemed to have at least a possible ADE by Neiker or Naranjo criteria that caused or contributed to hospital admission and was deemed to be at least potentially preventable using the Hallas criteria.22–27 Patients admitted due to intentional self-harm were excluded. Screening for pADEs was performed on all patients admitted to the medical or critical care unit and on patients in the emergency department (ED) who were 65 years or older and admitted to the hospitalist service, medical unit or critical care unit.

If necessary, the patient’s family member/carer and healthcare providers were interviewed if deemed relevant to understanding the root cause of the possible pADE.

An ADE was defined as harm resulting from either (1) taking or not taking a medication or (2) therapeutic failure as a result of treatment not in accordance with current evidence and (3) an intervention was required to manage the resulting harm.7 10 11

Data collection
pADE screening and assessment was performed on weekdays by specially trained pharmacists. The online supplemental appendix contains more explanation of the pharmacist training process. Emergency and hospital physicians were also encouraged to report patients with potential pADEs to a pharmacist, using a reporting form which was already in routine use.

Informed consent or assent was sought from eligible patients, and consent was sought from families and providers as applicable. We conducted interviews with patients and all potentially relevant providers (eg, family doctors, specialists, pharmacists, nurses and so on) and family members using a semistructured format designed to identify potential environmental or self-management issues involving medication or monitoring that may have contributed to the suspected pADE.

Structured chart abstracts containing all relevant information about the case were produced. Community healthcare providers were interviewed by telephone, hospital providers in person. Routinely collected data extracted included at a minimum, age, gender, presenting symptoms, treatment in ED, list of verified medications taken preadmission and changes to medications considered involved in the potential pADE, cognitive and physical deficits, and the patient’s living situation. Results of imaging and the eventual discharge summary were obtained from the patient’s electronic health record.

Patient and family interviews were conducted by a research nurse after first discussing with the research pharmacist potential avenues to explore in the context of the pADE suspected. The research nurse also received training in qualitative interview techniques and the nature of various anticipated pADEs.28 Other data collected during interviews preferred languages spoken, whether their family doctor speaks the same language, medication adherence aids used, use of action plans, understanding of purpose of medication and how to identify if is working or causing a side effect.

Interviews with family doctors, community pharmacists, specialists and nurse practitioners reflected the context of the suspected pADE and sought to identify and understand events leading up to the ADE. The online supplemental appendix contains further detail on family doctor engagement prior to the start of the study. When applicable, these providers were also asked if they could think of any actions that, if taken, could have avoided or mitigated the pADE, including system-level changes. Physicians and pharmacists were interviewed by a research physician (AD) or research pharmacist (principal investigator (PI) JdL), respectively.

Health literacy was assessed by the Rapid Evaluation of Adult Literacy in Medicine REALM-65 Revised (if English preferred) or the Chinese Health Literacy Scale Short Form and the 3 Brief Questions test.29–31 Patient’s medication adherence was assessed using the Morisky score (when relevant).32–34 Where relevant, inhaler technique was assessed using a checklist.35 At the time of the study more than 90% of admitted patients had their best possible medication history verified in the ED, supported by dedicated ED pharmacy technicians, using a jurisdictional pharmacy dispensing record.

All content of interviews was captured by audio recording and/or detailed note-taking for later verification and content analysis. Certified translators were used to interview non-English-speaking participants in person or on the telephone as needed.

All collected data and assessments were summarised in a standardised electronic case summary for review.
by the investigator committee using REDCap electronic data capture tools hosted at the University of British Columbia.36,37

Data analyses

To assess preventability and perform RCA, pairs of raters from the investigator committee (three internists, one emergency physician, two family physicians and three PharmD-trained pharmacists) independently reviewed all the case summaries. Each rater completed the following instruments as applicable: Naranjo and WHO algorithms for causality, Hallas and Thornton preventability assessments, and Pirmohahmed seriousness assessment.7 23 24 26 27 Raters then used a Hishikawa process (ie, fishbone diagram) to identify all causal factors and associated root causes using a systems perspective.38 Root causes were considered to be reasons why the causal factors existed.39 Reviews were performed independently to reduce bias.

After cases were assessed, each was adjudicated at an all-investigator meeting to, by consensus, resolve discrepancies, reclassify causality or preventability, and identify additional root causes.39 The PI (JdL) reviewed all interview transcripts with the research nurse to identify potential themes (inductively then deductively) that could represent the causal factors or root causes, and presented these at investigator meetings for discussion if not previously identified.40 Participant recruitment and case adjudication occurred in parallel.

Following adjudication of all recruited patients, the PI sorted the root causes identified for each patient into mutually exclusive categories, which were subsequently reviewed by the investigator committee (see online supplemental table 1).

For reporting, we categorised participants by pADE-related medical conditions (eg, ‘bleeding’) and expressed this as a percentage of the cohort, then described the root causes of that type of pADE. We also expressed the root causes contributing to pADEs as a percentage of all root causes found. Statistical analysis was descriptive. Agreement between case reviewers for causality and seriousness was assessed using Cohen’s weighted kappa, and seriousness with Cohen’s unweighted kappa.41

Developing and sharing key learning messages, surveillance system

Using the RCA aggregate results, the committee synthesised root causes across cases into actionable key messages for community-based care providers and for patients and families. These were developed collaboratively with local experts in the hospital and community. See online supplemental table 1 for further detail on how these messages were developed and shared.

Finally, using the study results, we constructed an electronic pADE surveillance and reporting system for use in routine care (see online supplemental table 2).

Study size

No formal sample size calculation was performed, as the research questions were not hypothesis driven. Instead, we estimated a target of 120 patients would provide a reasonable number of pADEs to provide a range of representative root causes. We anticipated a study duration of 6 months to enrol 120 participants based on an average of 25 admissions per day, an anticipated 15% ADE incidence, 30% capture of patients with ADEs in non-acute medical areas and a 30% anticipated rate of ADEs being preventable. Study recruitment was extended to 9 months to recruit 120 patients with pADEs.

Patient and public involvement

Our data gathering process involved interviewing patients and their families to understand potential causal factors of the pADE to permit subsequent root cause identification. In addition, for the learning messages for patients and families, volunteer members of the public who work with our institution’s community engagement group reviewed for clarity and provided input to message style and formatting.

RESULTS

Over 9 months (November 2016–December 2017), 136 patients with a possible pADE were identified and 134 were recruited. Ninety per cent were identified by pharmacist screening and 10% were referred by physicians. Case review resulted in no cases having the ADE downgraded to below ‘possible’, and 13 cases having the ADE’s preventability downgraded to below ‘possibly’, leaving 121 eligible pADE cases. One case was removed from the analysis due to a readmission with a diagnosis refuting the previously confirmed pADE. Thus, 120 patients with a pADE provided data for RCA. During the final 3 months of the study, the PI rather than a research nurse interviewed the 34 patients recruited and did not perform formal tests of health literacy or adherence. Study flow is depicted in figure 1.

Seventy patients were interviewed alone, 23 were interviewed with a family member and 28 family members were interviewed alone. A total of 61 healthcare provider interviews pertaining to 47 pADE cases occurred, with 4 providers declining to participate and 12 non-responsive to interview requests.

Demographics of the participants and other study measures are shown in table 1.

Of the patients assessed for health literacy, 69% failed either the REALM-65 or the 3 Brief Questions test; 61% of these patients were unilingual English speakers.

Table 2 shows the post-adjudication assessments of causality, preventability and seriousness of included pADEs.

Two participant deaths attributed to pADEs occurred. Pre-adjudication agreement between research investigators’ assessment was ‘moderate’ for causality (Cohen’s weighted kappa 0.48 (95% CI 0.36 to 0.61)), ‘substantial’
for seriousness (Cohen’s weighted kappa 0.76 (95% CI 0.62 to 0.91)) and ‘fair’ for preventability (Cohen’s unweighted kappa 0.38 (95% CI 0.20 to 0.55)).

The most common pADEs by type of presentation are shown in table 3.

Overall, 33 categories of root causes were identified (online supplemental table 2), with 281 root causes involved in all 120 patients. The most common causal factors and root causes of included pADEs are shown in table 4.

Key learning messages
Six key messages were identified and developed for community-based providers (table 4) and four for the public (table 5).

In total, in-person knowledge translation activities reached a total of 82 physicians, 24 community nurses and 62 community pharmacists (with some providers attending two sessions).

Surveillance system
This system is organised around common pADE-related adverse outcomes; populated with drop-down menus for root causes, informed from our findings, with expected actions required to prevent recurrence. Once information is entered, a PDF letter is generated for relevant community providers (see figure 2). In addition, since December 2019, as part of a national adverse drug reaction (ADR) surveillance programme, it became mandatory for hospitals to report ADRs. Therefore, in collaboration with the relevant provincial agency, we developed a process to share with them reports of pADEs that meet the criteria for an ADR (harm resulted from taking a medication).

CONCLUSIONS
Summary of findings
We are unaware of similar programmes designed to prevent or mitigate pADEs by finding and translating root causes into learning messages for providers, patients and families and by implementing a pADE surveillance system for community feedback. Providers are encouraged to ask patient/families open-ended questions to confirm their understanding of how taking a medication will help them, how to recognise and respond to side effects, how to know if a medication is working (why monitoring helps them), and understanding of medication changes and how to enact them.43 Such conversations would identify patients with reduced medication use or monitoring competency who need additional supports (eg, referral to community resources or in-home services).

### Table 1 Description of the study cohort

<table>
<thead>
<tr>
<th>Variable</th>
<th>Cohort, n=120 (unless specified)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (SD) age, years</td>
<td>77 (11)</td>
</tr>
<tr>
<td>Female, n (%)</td>
<td>65 (54)</td>
</tr>
<tr>
<td>Language spoken, n (%)</td>
<td></td>
</tr>
<tr>
<td>English, unilingual</td>
<td>65 (54)</td>
</tr>
<tr>
<td>Cantonese, unilingual</td>
<td>16 (13)</td>
</tr>
<tr>
<td>English/Cantonese/Mandarin, bilingual</td>
<td>14 (12)</td>
</tr>
<tr>
<td>Mandarin, unilingual</td>
<td>7 (6)</td>
</tr>
<tr>
<td>Punjabi, unilingual</td>
<td>7 (6)</td>
</tr>
<tr>
<td>Other (various)</td>
<td>7 (6)</td>
</tr>
<tr>
<td>Tagalog, unilingual</td>
<td>4 (3)</td>
</tr>
<tr>
<td>Health literacy</td>
<td></td>
</tr>
<tr>
<td>REALM-65 score 6 or less, failed</td>
<td>19/40 (48%)</td>
</tr>
<tr>
<td>3 Brief Questions, failed</td>
<td>36/45 (80%)</td>
</tr>
<tr>
<td>STIHLS 13/15 or less, failed</td>
<td>0/5 (0%)</td>
</tr>
<tr>
<td>Medication adherence, Morisky Medication Adherence Score (MMAS-8)*</td>
<td></td>
</tr>
<tr>
<td>Less than 6, low adherence</td>
<td>16/45 (36%)</td>
</tr>
<tr>
<td>6 to less than 8, medium adherence</td>
<td>15/45 (33%)</td>
</tr>
<tr>
<td>Lives alone and 70 years or more</td>
<td>34/101 (34%)</td>
</tr>
<tr>
<td>Picks up prescriptions themselves</td>
<td>36/61 (59%)</td>
</tr>
</tbody>
</table>

*The MMAS, Morisky Medication Adherence Scale and Morisky are trademarks of Donald E Morisky, and may be used only with permission. All rights reserved. Use of the MMAS-8 is protected by US copyright laws. Permission to use the MMAS scales is required. Reproduction and distribution of the MMAS is protected by US copyright laws, A license agreement to use the scale is available from: Donald E Morisky, ScD, ScM, MSPH, Professor, 2020 Glencoe Ave, Venice, California 90 291-4007, dmorisky@gmail.com 2007 Donald E Morisky.
In addition to the learning messages developed, system-level changes as a result of our root cause findings included an update to our multisite hospital pharmacy drug-drug interaction alert system (carvedilol–amiodarone) and a change to our provincially based private laboratory reporting system (phenytoin–albumin reminder). Further work is planned and ongoing to address root causes found related to provider culture in our hospital.

**Implications**

Our findings provide insights that could help to reduce the burden of pADEs. First, our results suggest that many ADEs involving anticoagulants, antihyperglycaemic agents, antihypertensive and cardiovascular drugs could be prevented by providers confirming that patients can follow the actions in our learning messages. Previous studies report that these drugs cause 40% of hospital admissions, but because patients/providers were not interviewed to identify root causes, the true opportunity for preventability was likely missed.15 Second, chronic obstructive pulmonary disease (COPD) and heart failure are top reasons for recurrent hospitalisations.43 Yet, we found that their root causes are also present in hospital. In the current culture, hospital providers take over the care of the patient and tend not to use the hospitalisation as an opportunity to engage the patient and family to confirm their understanding and impart skills needed to manage, monitor and respond to changes in their condition. Consequently, as this is not a current goal of care, hospital providers often miss opportunities to confirm the patient or family’s ability to perform certain tasks (eg, correct inhaler technique or daily weighing) or ensure understanding of information by the most competent family member. As a result, hospital providers fail to identify the need to arrange appropriate supports for patients/families with reduced medication use/monitoring competency.

The concept and process of identifying root causes of ADEs could also be integrated into mandatory adverse drug reporting programmes. If the root cause is not considered, the ADR may be misattributed to the drug itself, the role the patient and provider played may be ignored, and thus potentially modifiable causes may be overlooked.

Finally, these findings highlight an important opportunity to reduce healthcare burden if systems of care and healthcare provider training address identified gaps. At an individual patient level, in order to prevent pADE recurrence, first requires that care providers recognise the presence of the pADE and then identify and address the root causes. This does require a change in thinking, to spend time analysing, for example, why the patient had a COPD/asthma or heart failure exacerbation, a bleeding event or a fall, then incorporate managing the root causes within the treatment plan (rather than limiting treatment to the symptoms or consequences related to the medical condition diagnosed). It has been previously shown that the risk of ADE non-recognition is higher when the ADE

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Adjudicated assessments of ADE causality (certain, probable or possible), preventability (definitely or possibly) and seriousness (mild, moderate, severe, death)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADE causality</td>
<td>Definitely preventable</td>
</tr>
<tr>
<td>Certain (31/120, 25.8%)</td>
<td>0</td>
</tr>
<tr>
<td>Probable (51/120, 42.5%)</td>
<td>0</td>
</tr>
<tr>
<td>Possible (38/120, 31.7%)</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Severity</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
<th>Death</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Moderate</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Severe</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Death</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>0</td>
<td>4</td>
<td>5</td>
<td>1</td>
<td>11</td>
</tr>
</tbody>
</table>

**ADE**, adverse drug event.
is part of a presenting illness rather than a direct drug effect. Additionally, our findings suggest a need for healthcare providers to fundamentally alter how they may speak to patients to ensure they understand how to take medications safely and increase the likelihood that they will adhere to an agreed on regimen. At an institutional level, a rethink of the goals of care while the patient is in hospital should be broadened to include the patient/families’ ability to demonstrate competency in managing tasks that can help them stay at home longer. This will require training of all healthcare providers to have more skilful conversations with patients and robust care processes developed to incorporate patient/family demonstration of competency to perform required tasks into the goals of care (eg, daily weighing, inhaler technique).

**Related research**

Previous reports have described the development of a prospective surveillance system to detect adverse events (not specifically drug related) in a multisite hospital setting. The motivations underpinning that work mirror our intent to identify ways we can prevent pADEs. The authors developed trigger methodology, reflecting the medical context of certain patient care areas and used trained observers to screen for potential adverse events that were then peer reviewed to identify preventability and areas for quality improvement. Elements of this approach (trigger methodology, prompts to consider root causes at admission) could be explored for inclusion in our pADE surveillance programme.

Although studies have described the epidemiology of pADEs, we suggest that to view the full scope of preventability requires a lens focused on identifying root causes to purposefully learn how pADEs could be prevented. Therefore, differences in types of pADEs reported across studies, will in part, likely reflect differences in study objectives, design, ADE definition and identification process, and whether patient and provider interviews were conducted and RCA was performed.

**Generalisability and further research**

Although the type of pADEs may differ across communities, we suggest that the process of considering whether a medical illness is caused by a pADE, identifying the root causes, addressing them, then sharing with relevant community providers is a worthwhile means to try to prevent ADEs given their expected incidence and public health impact. Further research is needed to assess whether providers can identify pADE root causes on hospital presentation, can incorporate actions from our learning messages into practice and whether providing feedback to community providers can reduce pADEs.

**Limitations**

Our study population of 34% of predominantly elderly patients being non-English speaking was reflective of our local demographics but may not be of other communities,
limiting our study’s generalisability. Our reliance on pharmacist screening of pADEs may have resulted in unknown biases in the types of patients and pADEs identified compared with another type of healthcare professional screening, although pharmacist screening is common in hospital-based ADE surveillance programmes.22

Limitations of RCA as a method to improve healthcare have recently been reviewed.47 Broadly, limitations can relate to poorly conducted data gathering and analysis. RCA can fail to yield improvements if strong solutions (described as controls) are not identified or implemented. The RCA process itself can be impaired by a weak political mandate. Finally, RCA needs to be followed by some means of measurement to know whether the implemented control is working and to provide feedback to relevant actors to complete the learning process.

We believe our study aims, objectives and methods address these known weaknesses of RCA. Our data gathering process started with interviewing patients and their families. Understanding derived from these interviews is central to our study findings. A wide system view was taken to identify root causes, which were required to be actionable issues that providers or patients could change. We performed aggregated review of potential pADE cases, as each research committee meeting

<table>
<thead>
<tr>
<th>Causal factor due to associated root cause</th>
<th>Example of type of pADE</th>
<th>% of all root causes</th>
<th>% of patients impacted by root cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient had not understood information (possibly) previously provided due to provider not confirming patient understanding</td>
<td>Many different pADEs (except antibiotic related)</td>
<td>35/281 (12.4)</td>
<td>35/120 (29.2)</td>
</tr>
<tr>
<td>Unable to recognise medication side effect due to providers not confirming ability to do this</td>
<td>Bleeding, orthostatic hypotension, constipation</td>
<td>28/281 (10.0)</td>
<td>28/120 (23.3)</td>
</tr>
<tr>
<td>Prescribing (and not identified or managed at dispensing) antibiotics for CAP 25% of pADEs due to lack of referral to guideline</td>
<td>Unresolved pneumonia</td>
<td>24/281 (8.5)</td>
<td>24/120 (20)</td>
</tr>
<tr>
<td>Intentional non-adherence due to mainly not understanding purpose/benefit of medication—having concerns about taking it; provider not confirming that patient understands benefits/not identifying or addressing concern</td>
<td>Stroke, MI, aortic dissection, COPD, asthma, heart failure exacerbations</td>
<td>20/281 (7.1)</td>
<td>20/120 (16.7)</td>
</tr>
<tr>
<td>Medication monitoring provider (no actionable root cause identified: lack of system reminder, healthcare provider lapse, community pharmacy not routinely asking patient about bloodwork, except for lack of reminder on laboratory report to calculate phenytoin for low albumin n,1)</td>
<td>Acute kidney injury, hypothyroidism, phenytoin toxicity (n,1)</td>
<td>18/281 (6.4)</td>
<td>18/120 (15.0)</td>
</tr>
<tr>
<td>Could not identify if medication was working due to provider not confirming that patient can identify how medication is working and providing specific parameters (daily weighing, measuring BP)</td>
<td>Heart failure exacerbations, intracranial haemorrhage, hypertensive urgency</td>
<td>17/281 (6.0)</td>
<td>17/120 (14.1)</td>
</tr>
<tr>
<td>Patient did not have a sick day medication plan; due to lack of locally available resource in use, incorporation into routine practice; recognition of this as root cause in affected pADEs</td>
<td>Hypotension, acute kidney injury, elevated INR, bleeding, hypoglycaemia</td>
<td>15/281 (5.3)</td>
<td>15/120 (12.5)</td>
</tr>
<tr>
<td>Lack of provision of action plans for COPD, asthma or heart failure</td>
<td>COPD, asthma, heart failure</td>
<td>13/281 (4.6)</td>
<td>13/120 (10.8)</td>
</tr>
<tr>
<td>Provider not assessing medication use competency (ability to safely and reliably take medications)</td>
<td>Bleeding, drug toxicity, stroke</td>
<td>12/281 (4.3)</td>
<td>12/120 (10)</td>
</tr>
<tr>
<td>Provider had not adjusted medication based on laboratory parameters (actionable root cause not identified, presumed lapse by providers, laboratory results not available to community pharmacists)</td>
<td>Acute kidney injury, bleeding, stroke (due to hyperthyroidism)</td>
<td>11/281 (3.9)</td>
<td>11/120 (9.2)</td>
</tr>
<tr>
<td>Provider not assessing medication monitoring competency (ability to monitor for side effects or lack of effectiveness)</td>
<td>Bleeding, weakness, hypotension, heart failure, myxoedema</td>
<td>11/281 (3.9)</td>
<td>11/120 (9.2)</td>
</tr>
</tbody>
</table>

BP, blood pressure; CAP, community-acquired pneumonia; COPD, chronic obstructive pulmonary disease; INR, international normalised ratio; MI, myocardial infarction; pADE, preventable adverse drug event.
For learning to occur, the surveillance system does need to be used by providers. We therefore measure the performance of our system by tracking a key performance indicator, a target pADE reporting rate of 5% of medical admissions, (reflecting 50% of expected pADEs, assuming an incidence of 10%). Currently, we are reporting 2%–3% of medical admissions as pADEs. Further work is planned to improve reporting of pADEs by providers. We also implemented a reporting structure to share aggregated reports of pADEs with hospital leadership and the local family physician network. Such engagement is important if the burden of pADEs is to be fully understood, and increases the likelihood that we can find appropriate solutions and build support for any required organisational change to be levied to resolve them.

A study limitation is selection of relatively weak corrective solutions. Potential solutions may be viewed as a hierarchy, with changes to processes inferior to systems.47 Our solutions, mainly relate to changes in processes, as they aim to help providers do things differently, for example, asking patients questions around non-steroidal anti-inflammatory drug use, or asking a patient to demonstrate how they use their inhaler. This requirement for a conversation is unavoidable, but by taking a systems view led us to develop an organisational change to address a root cause of provider culture. Patients admitted with COPD or who visit the ED with asthma is working. Describes specific symptoms of orthostatic hypotension and what to do.

For learning to occur, the surveillance system does need to be used by providers. We therefore measure the performance of our system by tracking a key performance indicator, a target pADE reporting rate of 5% of medical admissions, (reflecting 50% of expected pADEs, assuming an incidence of 10%). Currently, we are reporting 2%–3% of medical admissions as pADEs. Further work is planned to improve reporting of pADEs by providers. We also implemented a reporting structure to share aggregated reports of pADEs with hospital leadership and the local family physician network. Such engagement is important if the burden of pADEs is to be fully understood, and increases the likelihood that we can find appropriate solutions and build support for any required organisational change to be levied to resolve them.

A study limitation is selection of relatively weak corrective solutions. Potential solutions may be viewed as a hierarchy, with changes to processes inferior to systems.47 Our solutions, mainly relate to changes in processes, as they aim to help providers do things differently, for example, asking patients questions around non-steroidal anti-inflammatory drug use, or asking a patient to demonstrate how they use their inhaler. This requirement for a conversation is unavoidable, but by taking a systems view led us to develop an organisational change to address a root cause of provider culture. Patients admitted with COPD or who visit the ED with asthma is working. Describes specific symptoms of orthostatic hypotension and what to do.
To date, our work has resulted in two system level changes (for COPD/asthma and managing medication changes, respectively). Key learning messages specify actions that providers and patients need to take to avoid a pADE. Although it is hard to systematise this process, we hope our findings will allow others to identify stronger solutions that enable and ensure providers have good quality conversations with patients.

CONCLUSION

We identified 33 root causes of pADEs resulting in hospitalisation, most commonly in cases of COPD/asthma exacerbation, bleeding, hypotension, heart failure, hyponatraemia, pneumonia and acute kidney injury. The root causes identified suggest that providers should confirm: patient’s/families’ understanding of information, how a medication helps them, how to know if it is working or causing a side effect, how they plan to enact medication changes, whether they can follow action plans for variations in their clinical status, and if needed, arrange additional supports in context of medication use and monitoring competency. The process also allowed us to identify system-level and organisational changes that could reduce the risk of future pADEs and the surveillance system provides an ongoing means to identify new learning messages as needs arise.

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Contributors

All authors contributed to study concept, design, planning, obtaining funding, analysis and review of the manuscript. JdL is mainly responsible for study concept and design. JdL and RC are mainly responsible for study conduct. JdL and PL are mainly responsible for writing of the manuscript. JdL and RC are mainly responsible for the development of the surveillance database with contributions from TL, AL, DH, AD, IA, MF, KG and JS contributed to writing and or review of learning messages. AD and JS conducted physician interviews. MM contributed to design of the pADE tool and patient resources. OK facilitated the appropriate institutional oversight for the conduct of this research. KS obtained patient consent/assent and family consent, conducted patient, family and nursing interviews, performed data collection and helped to identify themes from interviews. RD provided operational support. JW contributed to select learning messages. KG coordinated technical development of the electronic pADE reporting tool. JS and EG provided project support for pADE tool development and implementation. SB, from the provincial academic detailing service, reviewed the sick day medication plan and community-acquired pneumonia learning messages with local healthcare providers. AT facilitated linkage of pADE reports with the BC Patient Safety and Learning System (BCPSLS). IC, DG and CC managed receipt of these reports by BCPSLS and subsequent transmission to the national adverse drug reaction database.
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