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Deriving ICD-10 Codes for Patient Safety Indicators for Large-scale Surveillance Using Administrative Hospital Data

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Background: Existing administrative data patient safety indicators (PSIs) have been limited by uncertainty around the timing of onset of included diagnoses.

Objective: We undertook de novo PSI development through a data-driven approach that drew upon "diagnosis timing" information available in some countries' administrative hospital data.

Research Design: Administrative database analysis and modified Delphi rating process.

Subjects: All hospitalized adults in Canada in 2009.

Measures: We queried all hospitalizations for ICD-10-CA diagnosis codes arising during hospital stay. We then undertook a modified Delphi panel process to rate the extent to which each of the identified diagnoses has a potential link to suboptimal quality of care. We grouped the identified quality/safety-related diagnoses into relevant clinical categories. Lastly, we queried Alberta hospital discharge data to assess the frequency of the newly defined PSI events.

Results: Among 2,416,413 national hospitalizations, we found 2590 unique ICD-10-CA codes flagged as having arisen after admission. Seven panelists evaluated these in a 2-round review process, and identified a listing of 640 ICD-10-CA diagnosis codes judged to be linked to suboptimal quality of care and thus appropriate for inclusion in PSIs. These were then grouped by patient safety experts into 18 clinically relevant PSI categories. We then analyzed data on 2,381,652 Alberta hospital discharges from 2005 through 2012, and found that 134,299 (5.2%) hospitalizations had at least 1 PSI diagnosis.

Conclusion: The resulting work creates a foundation for a new set of PSIs for routine large-scale surveillance of hospital and health system performance.

Key Words: patient safety indicators, ICD-10, administrative data, diagnosis timing

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Health systems nationally and internationally are faced with the challenges of suboptimal safety and quality of care. Several studies conducted in multiple countries have derived estimates of the high risk of adverse events arising

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during hospitalization.[1–8] The establishment of adverse event measurement systems (or "monitoring/surveillance systems") has been a recognized focus of national and international efforts in patient safety. Several data collection approaches have been proposed for patient safety surveillance in the US, including voluntary hospital reports of nosocomial infections, a nationally representative survey of drug-drug interactions, and regional and national voluntary reporting of adverse events and medical errors.[9] These methods, all potentially valuable, have the limitations of either focusing on a specific type of event, collecting data from nonrandom and biased populations, relying on voluntary reporting, covering limited geographic areas, or being too labor-intensive for widespread use.

In the face of these limitations, researchers and health system decision-makers have turned their attention to routinely collected administrative hospital data as a potential resource for population-based studies of adverse events. A large amount of research and investment has gone into the development of patient safety indicators (PSIs) that involve using *International Classification of Diseases, 9th or 10th revision* (ICD-9-CM or ICD-10) codes to identify the occurrence of adverse events (eg, accidental falls in hospital, pressure ulceration, and venous thromboembolism) that may be linked to suboptimal safety and quality of care. The most compelling attribute of administrative hospital discharge data, relevant to their widespread use as a surveillance tool for the monitoring of in-hospital adverse events, is that these data are routinely generated for all hospital stays in many developed countries.

PSIs based on administrative hospital data such as those developed by Iezzoni et al[10] and extended by the US Agency for Healthcare Research and Quality (AHRQ[11]), are now widely used despite a widespread awareness among health system stakeholders of some of their shortcomings.[12–15] First, the widely used AHRQ PSIs were developed using ICD-9-CM diagnosis codes, but the ICD-10 code set currently in use in most developed countries offers greater specificity in many clinical domains.[16] Second, previous PSIs were developed before the implementation of "diagnosis timing" data flags in the US to distinguish diagnoses arising during hospital stay from those present at admission, so some relevant concepts may have been discarded at the time of PSI development due to concerns about uncertain diagnosis timing that may no longer be relevant. Third, previous PSIs were selected by expert panels through iterative processes that limited the comprehensiveness or coverage properties of the resulting indicator set. Recent work by the Inspector General of the US Department of Health and Human Services and other research teams has demonstrated that the resulting indicators capture a small minority of all adverse events resulting from hospital care.[17] Also, fourth, the existing PSIs may not comprehensively cover the field, because they were selected through an evidence-based process focusing on review of prior literature (most notably, the seminal work of Iezzoni and colleagues, who developed the Complications Screening Program). Events that had not previously been considered as complications of hospital care were unlikely to be selected as PSIs. In addition, clinical experts on the AHRQ expert panels may have made arbitrary or incorrect judgments about the preventability of specific adverse events, leading them to be excluded unnecessarily from the PSI set.

The PSI shortcomings just discussed inspired our methodological research. In this study, we undertook a de novo process of PSI development through a data-driven approach that drew upon the established "diagnosis timing" information available in Canadian administrative hospital data that now also currently exist as a resource in other countries such as the United States and Australia. Our research involved 4 discrete steps to produce a comprehensive list of diagnosis codes for PSIs.

First, we queried all acute care hospitalizations for a 1-year period in the Canadian Discharge Abstract Database (DAD) for ICD-10-CA diagnosis codes that were coded as arising after admission to hospital, and thus potentially relevant to patient safety events. Second, we undertook a modified Delphi panel process involving clinicians with expertise in safety and quality of care to rate the extent to which each of the identified diagnoses has a potential link to suboptimal safety and quality of care. Third, we grouped the identified quality/safety-related diagnoses into relevant clinical categories. And fourth, we queried a separate administrative hospital dataset (from the province of Alberta, Canada) to assess the frequencies of the newly developed potential PSI events, by code and clinical grouping, as a pilot demonstration of the feasibility of the proposed approach. The resulting work creates a foundation for a new set of PSIs for routine monitoring and surveillance of hospital and health system performance using hospital administrative data.

METHODS

Step 1: Interrogation of the Canadian DAD for Diagnoses Arising after Admission

The DAD from the Canadian Institute for Health Information for fiscal year 2009 (April 1, 2009 through March 31, 2010) was queried to define a sample of hospital discharges flagged with diagnoses arising after admission. The DAD captures all hospital separations for all Canadian provinces and territories, with the exception of the province of Quebec. The value of this data source is that it provides a nationally representative picture of hospital separations. Each hospital discharge record includes up to 25 diagnosis codes, recorded using the ICD-10-CA coding system, along with other clinical and demographic information. In addition, each diagnosis field in the database has an accompanying single digit field for the diagnosis type that is recorded whenever a diagnosis is recorded. The diagnosis type codes are as follows[18]: type M: most responsible diagnosis; type 1: preexisting conditions (comorbidities) that influence care or the hospital stay; type 2: conditions that arose after admission and that may thus represent complications of care; and type 3: preexisting conditions (comorbidities) that do not influence care or the hospital stay.

A listing of all diagnoses coded as type 2 was produced. For each diagnosis, the alphanumeric ICD-10-CA code was recorded, along with the nominal diagnosis description (eg, "postoperative delirium"), the absolute number

of times that it appeared in the national dataset (ie, the numerator for the event rate), and the number of patient discharges queried (ie, the denominator for the national event rate).

Step 2: Expert Panel Review of Candidate Diagnoses to Rate their Potential Relationship to Quality and Safety

In this second step, we used a modified Delphi panel process to review the type 2 diagnoses identified in step 1.[19] Panelists were asked to rate the extent to which each listed diagnosis related to quality of care and safety (and thus the extent to which it is potentially suitable as a component of a PSI). Seven panelists were chosen from expert members of the WHO Family of International Classifications Network (http://www.who.int/classifications/icd/TAGs) attending a Quality and Safety Topic Advisory Group meeting in New York in 2011. These panelists are international experts in both ICD and patient safety.

The modified Delphi panel review process involved initial review of clinical information (including the step 1 output described above), followed by 2 full-day face-to-face meetings. We used a modification of the RAND appropriateness rating methodology, recognizing that the 2-step rating process[19] (ie, initial ratings done in isolation followed by face-to-face discussion) is highly appropriate for this type of clinical judgment scenario. The RAND appropriateness method involves rating clinical scenarios on a 9-point scale.[19] We adapted this ordinal scale to our ratings of the quality/safety link to the candidate diagnoses. Specifically, we asked participating panelists the following question: "Please rate the extent to which this candidate diagnosis relates to quality of care/patient safety, and thus the extent to which it would be appropriate as a patient safety indicator." Their response options included: 1, 2, 3—not linked to quality of care and thus not appropriate as a PSI; 4, 5, 6—uncertain link to quality of care, and thus uncertain merit as a PSI; 7, 8, 9—linked to quality of care and thus appropriate as a PSI.

An additional set of considerations was presented to panelists as they considered the appropriateness of specific diagnosis codes to potentially include in a PSI. Specifically, they were asked to consider the likelihood that a diagnosis arose after admission; and the likelihood that action or inaction by providers or the health care system contributed to occurrence of the event.

Drawing upon RAND definitions of agreement of appropriateness ratings,[20] we considered there to be panel agreement when all of the 7 panelist ratings fell within the same 3-point zone of appropriateness (ie, 1–3, 4–6, or 7–9) after exclusion of both the highest and lowest assigned scores. Diagnoses without such agreement were discussed at the face-to-face meeting and rerated after discussion, whereas those with agreement prior to the meeting were not discussed unless a panelist expressed desire to discuss a particular diagnosis.

The RAND methodology recommends the use of median ratings to determine appropriateness.[19] Diagnoses that had median ratings indicating a link to quality of care (ie, median ratings of 7–9) were carried forward to the third study step—grouping of diagnoses into clinically meaningful categories. All combinations of results (ie, median ≥ 7 vs. <7, and agreement vs. nonagreement) are presented in the results.

Step 3: Grouping of Identified Diagnoses

Upon completion of appropriateness ratings, a second working group (D.A.S., H.Q., W.F., and W.A.G.) identified potential thematic groupings of diagnoses into adverse event diagnosis categories that could potentially be combined in later work to define a single diagnosis concept (eg, overlapping diagnosis codes for postoperative delirium could be grouped in later work). PSI candidate codes were then grouped according to a list determined through consensus by the project investigators. Codes were flagged according to perceived severity (events threatening life or major vital organ) and 17 categories based on disease/type of event. The categories were not mutually exclusive and so codes could be assigned to >1 grouping. In step 2, the 7 panelists had also articulated the potential at-risk patient population for each adverse event cluster, similar to the approach of Iezzoni et al[10] (eg, "adult surgical patients" for some indicators vs. "hospitalized pediatric patients" for others). This latter step is relevant to identifying the denominator for future PSI implementation and rate calculations.

Step 4: Assessing the Frequencies of the Potential PSI Events in Hospital Discharge Data from Alberta, Canada

Discharge abstract records for all acute care hospitalizations in Alberta between April 1, 2005 and March 31, 2012 were queried for the PSI codes and created groupings. Age and sex were queried to define relevant denominators for each clinical category of PSI as defined in step 3. Numerators were determined from implementation of the PSI diagnosis listings, and rates of events (overall and by subcategory) were reported in a demonstrative pilot analysis, and rates were compared across years (2005 through 2011). ICD-10 was introduced in 2002 in Canada and therefore there were no notable coding changes between 2005 and 2009. Statistical methods for this step were simply descriptive, with reporting of proportions of PSI indicator events in the denominator of at-risk hospitalizations.

The study was performed in accordance with the Declaration of Helsinki, and the Conjoint Health Research Ethics Board of the University of Calgary approved the study protocol. Written SAS code (SAS, version 9.4, Cary, NC) for derivation of these PSIs from administrative data is available for download at http://themethodshub.com/toolbox/downloads/.

RESULTS

Step 1: Listing of Diagnoses Arising After Admission

Overall, we queried 2,416,413 records in Canadian Institute for Health Information DAD containing all acute care hospitalizations in Canada (except Quebec) between April 1, 2009 and March 31, 2010. All listed diagnosis codes were compiled, and 2613 unique codes were found to have a

diagnosis type 2 (ie, postadmit comorbidity). Twenty-three diagnosis codes were excluded as coding errors or inappropriate use of diagnosis type 2. We excluded the CMS' "official and final" list of ICD-10-CM codes that will be exempt from present on admission (POA) reporting. These codes are exempt—labeled E in American databases—because their POA status (yes) is intrinsic in the meaning of the code. One such example is I25.2: old myocardial infarction. Similarly, we excluded *Z*-codes. This chapter typically describes circumstances as opposed to diagnoses, and while a circumstance could change or arise after admission, the situation is not the same as a condition that develops after admission (Z012: dental examination; Z290: isolation). We considered these codes to be ineligible since they should not be used in POA reporting.

Step 2: Modified Delphi Review of Candidate Diagnoses

Seven panelists were then asked to review all of the remaining 2590 codes before meeting face-to-face and to return their ratings. Highest and lowest ratings were dropped and ratings were then analyzed to determine the number of codes that had agreement as potential PSIs (all remaining panelists rated as 7 or higher) or were rejected with agreement (all remaining panelists rated as 1–6 on the 9-point scale; Fig. 1).

Of the 2590 codes, 219 were agreed upon as potential PSIs in round 1 based on unanimous ratings ≥ 7. Another 1493 diagnosis codes were rejected with agreement based on unanimous ratings ≤ 3. The remaining 878 diagnosis codes had disagreements in panelist ratings from the first round of discussion, so these were brought forward to the face-to-face meeting for discussion (round 2). The detailed review and discussion of these codes required 2 full days of panel discussion. Using the same agreement definition, the second round of reviews (with associated discussion) rated another 438 diagnosis codes for which there was agreement that they were appropriate as potential PSIs. Another 153 of the 878 codes discussed in round 2 had some disagreement among panelists, but their median appropriateness score was ≥ 7), and so they were also included in the listing of codes judged appropriate for inclusion in PSIs. In total, this 2-step process of reviewing and rating postadmit diagnosis codes produced a list of 657 codes that were determined to be appropriate for consideration as novel PSIs. Several closely related obstetrical codes with a common stem were collapsed to the higher level stem code, thus reducing the total number of included diagnosis codes to 640. Table 1 and the Appendix (Supplemental Digital Content 1, http://links.lww.com/MLR/B282) present the full listing of the selected diagnosis codes. Codes in the appendix marked with an asterisk are conditions where the median score was ≥ 7, but for which there was some disagreement (so that users can decide on their inclusion versus exclusion in applied uses of this code list).

Step 3: Grouping of Identified Diagnoses

The identified diagnoses were grouped into relevant diagnosis categories by an interdisciplinary group of coding and safety/quality experts (WF, HQ, D.A.S., and W.A.G.). Clinical categories in this process were not mutually exclusive, and as a result, individual diagnosis codes could

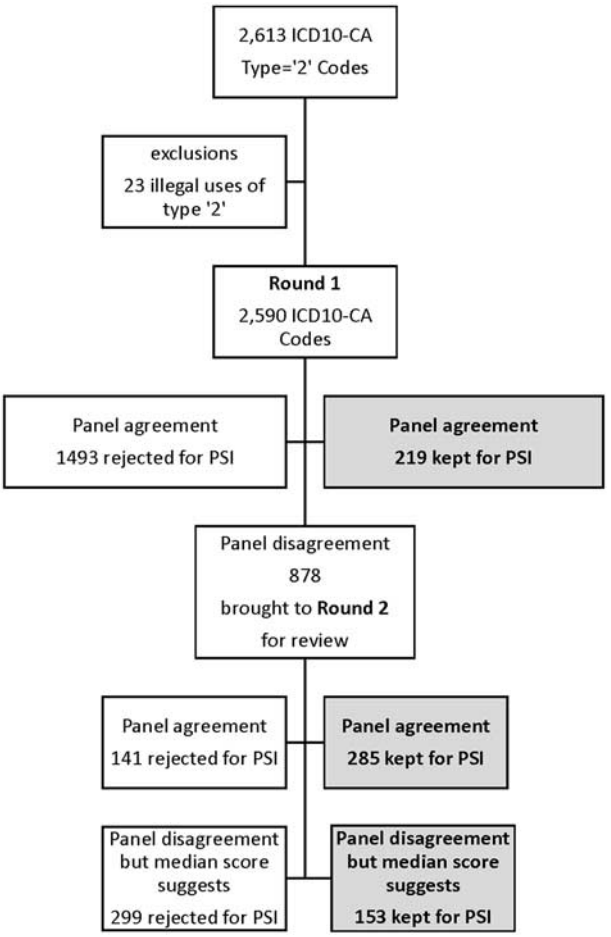

FIGURE 1. Determination of possible patient safety indicators (PSIs).

appear in >1 diagnosis category (eg, infectious diarrheal illnesses appearing in both the "hospital-acquired infection" and "gastrointestinal complication" categories). The resulting groupings are shown in full detail in Table 1 and the Appendix (Supplemental Digital Content 1, http://links.lww.com/MLR/B282) and include: (1) hospital-acquired infections, (2) decubitus ulcers, (3) endocrine and metabolic complications, (4) venous thromboembolic events, (5) cardiac complications, (6) respiratory complications, (7) hemorrhagic events, (8) drug-related adverse events, (9) adverse events related to fluid management, (10) obstetrical complications affecting mother, (11) obstetrical complications affecting fetus, (12) complications directly related to surgery, (13) traumatic injury suffered in hospital, (14) anesthesia-related complications, (15) delirium, (16) central nervous system complications, (17) gastrointestinal complications, and (18) a special category for "severe complications" proximally threatening to life or to major vital organs.

Step 4: Assessing the Frequencies of the Potential PSI Events

There were 2,381,652 hospital discharges in Alberta between April 1, 2005 and March 31, 2012. Among these

TABLE 1. Categories of PSIs

Category/Type	ICD-10 Codes
Global PSI for any adverse event	Any of the codes listed in Appendix 1 (Supplemental Digital Content 1, http://links.lww.com/MLR/B282)
Hospital-acquired infections	A02.0, A02.1, A04.4, A04.5, A04.7, A04.8, A04.9, A08.0, A08.1, A41.0, A41.1, A41.2, A41.4, A41.50, A41.51, A41.52, A41.58, A41.80, A41.88, A41.9, A49.0, B30.9, B37.3, B37.4, B37.7, B37.80, B37.81, B95.6, B95.7, B95.8, B96.1, B96.2, B96.4, B96.5, B96.81, B96.88, B97.4, G00.3, J15.0, J15.1, J15.2, J15.5, J15.6, J15.9, J18.1, J21.0, J85.3, J86.0, J86.9, J95.01, K65.0, N39.0, N99.51, O75.30, O85.00, O86.00, O86.10, O86.20, O86.30, O86.80, P36.0, P36.1, P36.2, P36.3, P36.4, P36.8, P36.9, P38, R57.2, T81.4, T82.6, T82.7, T83.5, T83.6, T84.53, T84.54, T84.60, T84.61, T84.63, T84.64, T84.65, T84.68, T84.7, T85.7, T87.42, T87.46, T87.47, T87.48
Decubitus ulcer	L89.0, L89.1, L89.2, L89.3, L89.8, L89.9
Endocrine and metabolic complications (electrolyte abnormalities, diabetes, etc.)	E10.10, E10.63, E10.64, E11.0, E11.10, E11.11, E11.63, E11.64, E13.63, E14.63, E15, E16.0, E27.2, E89.1, E89.2, E89.3, G37.2, T50.3
Venous thromboembolic events	I26.0, I26.9, I80.1, I80.2, I82.2, O87.102
Cardiac complications	I20.0, I20.1, I20.88, I20.9, I21.0, I21.1, I21.2, I21.3, I21.4, I21.9, I22.0, I22.1, I22.8, I22.9, I46.1, I46.9, I47.2, I48.1, I49.00, I49.01, I50.0, I50.1, I50.9, J81, O74.20, S26.811, T82.0, T82.1, T82.2, T82.5, T82.6, T82.7, T82.8, T82.9
Respiratory complications	J15.0, J15.1, J15.2, J15.5, J15.6, J15.9, J18.1, J21.0, J38.01, J38.02, J38.09, J69.0, J69.8, J85.3, J86.0, J86.9, J94.2, J95.00, J95.01, J95.02, J95.03, J95.08, J95.1, J95.2, J95.5, J95.80, J95.81, J95.88, J95.9, J96.0, S20.2, S22.200, S22.300, S22.400, S22.410, S22.490, S27.000, S27.001, S27.100, S27.200, S27.300, S27.310, T17.3, T17.4, T17.5, T17.8, T17.9, T71, T79.7, T81.81
Hemorrhagic events	D62, D68.3, J94.2, J95.00, O71.701, O71.704, O71.801, O72.00, O72.10, O72.20, O90.20, P12.0, S06.4, S06.5, S06.6, S27.100, S27.200, S27.300, S36.090, S36.091, S36.150, S36.151, S36.800, S36.810, S37.000, S37.300, T79.2, T81.0
Drug-related adverse events	D68.3, E16.0, E88.3, H91.0, I95.2, O74.50, T36.0, T36.1, T36.5, T36.8, T36.9, T37.8, T38.0, T38.3, T39.0, T39.1, T39.3, T39.8, T40.2, T40.3, T40.4, T40.6, T41.2, T41.3, T42.0, T42.1, T42.4, T42.6, T427, T43.0, T43.2, T43.4, T43.5, T43.8, T44.5, T44.7, T45.0, T45.1, T455, T457, T45.8, T46.0, T46.1, T46.2, T46.4, T46.5, T47.4, T48.0, T48.6, T49.0, T50.1, T50.2, T50.9, T80.8, T80.9, T81.80, T88.2, T88.3, T88.6
Adverse events related to fluid management	E86.0, E86.8, E87.7, G37.2, T50.3, T80.8, T80.9
Obstetrical complications affecting mother (for females only)	O08.6, O29.50, O70.20,O70.30, O70.90, O71.10, O71.11, O71.18, O71.30, O71.40, O71.50, O71.60, O71.70, O71.80, O72.00, O72.10, O72.20, O74.20, O74.30, O74.50, O74.60, O74.80, O75.10, O75.30, O75.40, O75.40, O75.60, O85.00, O86.00, O86.10, O86.20, O86.30, O86.80, O87.10, O89.40, O89.50, O89.80, O90.00, O90.10, O90.20
Obstetrical complications affecting fetus (for age < 1 y only)	P03.3, P12.0, P12.3, P12.8, P13.4, P14.3, P15.4, P15.8, P36.0, P36.1, P36.2, P36.3, P36.4, P36.8, P36.9, P38
Complications directly related to surgery	H59.80, M96.6, O75.401, O75.40, O86.00, O90.00, S26.811, S27.001, S36.091, S36.151, S36.411, S36.461, S37.111, S37.211, S37.311, T81.0, T81.1, T81.2, T81.3, T81.52, T81.58, T81.59, T81.6, T81.81, T81.88, T81.9
Traumatic injuries (nonprocedural) arising in hospital	S01.00, S01.01, S01.10, S01.20, S01.30, S01.40, S01.50, S01.70, S01.80, S01.90, S02.000, S02.100, S02.200, S02.300, S02.480, S02.490, S02.5, S02.890, S03.0, S05.0, S05.1, S05.8, S05.9, S06.0, S06.1, S06.25, S06.35, S06.4, S06.5, S06.6, S06.85, S06.9, S09.0, S09.8, S09.9, S10.1, S10.9, S13.48, S14.38, S20.2, S20.4, S20.8, S22.200, S22.300, S22.400, S22.410, S22.490, S27.000, S27.100, S27.200, S27.300, S27.310, S27.810, S27.860, S30.0, S30.1, S30.80, S30.81, S30.88, S30.9, S31.200, S31.400, S32.100, S32.400, S32.500, S32.700, S32.800, S33.5, S35.1, S35.2, S35.5, S36.090, S36.150, S36.460, S36.610, S36.810, S37.000, S37.090, S37.110, S37.190, S37.210, S37.290, S37.300, S37.310, S37.390, S37.610, S39.08, S39.8, S39.9, S40.0, S40.8, S40.9, S41.10, S41.11, S42.010, S42.020, S42.090, S42.190, S42.200, S42.210, S42.220, S42.280, S42.290, S42.300, S42.390, S42.400, S42.480, S43.000, S43.090, S43.100, S46.00, S46.08, S49.7, S49.8, S49.9, S50.0, S50.1, S50.7, S50.8, S50.9, S51.00, S51.01, S51.70, S51.80, S51.90, S52.000, S52.100, S52.300, S52.500, S52.580, S52.590, S52.600, S52.800, S59.8, S59.9, S60.0, S60.2, S60.7, S60.8, S60.9, S61.00, S61.70, S61.80, S61.90, S62.000, S62.500, S62.690, S62.800, S63.100, S63.59, S69.8, S69.9, S70.0, S70.1, S70.8, S70.9, S71.10, S71.11, S72.000, S72.010, S72.080, S72.090, S72.100, S72.190, S72.200, S72.300, S72.410, S72.420, S72.490, S72.800, S72.900, S73.000, S73.090, S74.18, S75.0, S79.9, S80.0, S80.1, S80.7, S80.8, S80.9, S81.00, S81.01, S81.80, S81.81, S81.90, S81.91, S82.000, S82.100, S82.200, S82.300, S82.400, S82.500, S82.600, S82.800, S82.890, S83.6, S89.8, S89.9, S90.0, S90.1, S90.3, S90.7, S90.8, S90.9, S91.00, S91.10, S91.20, S91.30, S92.000, S92.300, S92.400, S92.500, S93.49, S99.8, S99.9, T00.1, T00.8, T00.9, T09.0, T11.0, T11.1, T13.0, T13.1, T14.0, T14.9, T20.0, T20.2, T21.0, T21.1, T21.2, T21.3, T22.0, T22.4, T23.0, T23.2, T24.0, T24.2, T25.0, T25.2, T71, T79.2, T79.6, T79.7
Anesthesia-related complications	O29.50, O74.20, O74.30, O74.50, O74.60, O74.80, O89.40, O89.50, O89.80, T41.2, T41.3, T88.2, T88.3, T88.4, T88.5
Delirium	F05.0, F05.1, F05.8, F05.9
Central nervous system complications	E11.0, E15, F05.0, F05.1, F05.8, F05.9, G00.3, G37.2, G97.2, O74.30, O89.40, S06.0, S06.1, S06.25, S06.35, S06.4, S06.5, S06.6, S06.85, S06.9

(*Continued*)

TABLE 1. Categories of PSIs (*continued*)

Category/Type	ICD-10 Codes
Gastrointestinal	A02.0, A04.4, A04.5, A04.7, A04.8, A04.9, A08.0, A08.1, B37.80, B37.81, K22.3, K65.0, K91.0, K91.3, S27.810, S27.860, S36.150, S36.151, S36.411, S36.460, S36.461, S36.610, T18.1, T18.2, T18.3, T18.9, T28.2, T85.5
Severe events proximally threatening to life or to major vital organs	G37.2, I21.0, I21.1, I21.2, I21.3, I21.4, I21.9, I22.0, I22.1, I22.8, I22.9, I26.0, I46.1, I46.9, I47.2, I49.00, I49.01, J96.0, K22.3, K65.0, O74.20, O74.30, O75.10, O75.40, R57.1, R57.2, R57.8, T71, T80.0, T80.5, T81.1, T88.2, T88.3, T88.4, T88.6

PSI indicates patient safety indicator.

discharges, there were 206,900 (8.7%) discharges where there was at least 1 type 2 diagnosis. Of the 2,381,652 discharged patients, 2,039,610 (85.6%) were aged 18 years and older, 398,309 (16.7%) were newborns and 1,485,709 (62.4%) were female. Overall, 134,299 (5.2%) hospitalizations had at least 1 diagnosis code defined as a potential PSI (Fig. 2).

Table 2 presents the numerator and denominators for the categories. Category proportions for the individual subtypes of PSI ranged from 0.03% (obstetrical complications affecting fetus) to 1.96% (hemorrhagic events). Given that there is widespread interest in using hospital care PSIs to report aggregate rates of events associated with all adult inpatient hospital stays (ie, all patients admitted to hospital for medical and/or surgical care), we applied a global denominator that was identical for many of the PSIs. That global denominator was simply adult hospital admissions, applied for deriving rates of PSI events in our demonstration of the PSI coding algorithms applied to Alberta hospital data. Users will have the ability to apply the PSI code lists to more confined denominators, if desired (eg, rates of PSI events only on a neurosurgical hospital service).

DISCUSSION

Through analysis of nationwide hospital discharge data and an extensive modified Delphi process, this study has produced a comprehensive set of ICD-10 diagnosis codes that could be used to construct a new generation of PSIs, drawing on the established diagnosis timing information that has existed for a number of years in Canada, and that now exists in other countries such as the United States and Australia. In so doing, we have overcome one of the primary limitations of the AHRQ PSIs, which was the relatively narrow clinical scope of adverse events that could be unambiguously identified as diagnoses arising in hospital without a diagnosis timing indicator. This effort will lead to a set of PSIs with better coverage of the entire spectrum of preventable adverse events that affect hospitalized patients. Similar to AHRQ's PSI development process, our approach emphasized face validity and the detection of events with plausible links to inpatient quality of care.

The most widely known set of PSIs was developed in 2003 by the Agency for AHRQ[21] based largely on the Complications Screening Program developed by Iezzoni et al.[10] PSIs were translated for ICD-10 by colleagues in the International Methodology Consortium for Coded Health Information network and have subsequently been adapted for international use by the Health Care Quality Indicators Programme of the Organization for Economic Cooperation and Development.[22]

The appropriateness of using administrative data for these purposes has been widely debated in the literature in the absence of strong evidence on the validity of the AHRQ PSIs.[23–25] Despite widespread recognition that the sensitivity and specificity of administrative data for such events is suboptimal, the AHRQ PSIs have been broadly implemented in analyses of American and International administrative databases. It is widely recognized and acknowledged that in the absence of other more valid measures, they remain a potentially valuable tool for surveillance.[12–14,26] Validation studies show substantial variation across PSIs in sensitivity and positive predictive value, from 37% and 45%

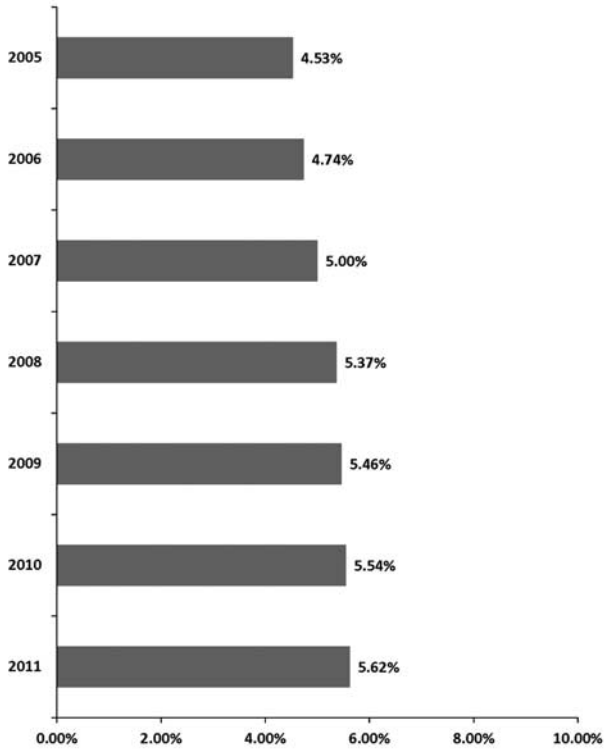

FIGURE 2. Frequency of patient safety indicator groupings by year.

TABLE 2. Numerators/Denominators for PSI Groupings

Category/Type	Limits	Numerator N (%)	Denominator (N)
Hospital-acquired infections		33,753 (1.65)	2,039,610
Decubitus ulcer		1957 (0.10)	2,039,610
Endocrine and metabolic complications		1787 (0.09)	2,039,610
Venous thromboembolic events		3290 (0.16)	2,039,610
Cardiac complications		16,572 (0.81)	2,039,610
Respiratory complications		19,353 (0.95)	2,039,610
Hemorrhagic events		39,900 (1.96)	2,039,610
Drug-related adverse events		3760 (0.18)	2,039,610
Adverse events related to fluid management		4095 (0.20)	2,039,610
Obstetrical complications affecting mother	Female only	26,420 (1.30)	1,485,709
Obstetrical complications affecting fetus	Newborn only	130 (0.03)	398,309
Complications directly related to surgery		20,736 (1.02)	2,039,610
Traumatic injuries (nonprocedural) arising in hospital		5558 (0.27)	2,039,610
Anesthesia-related complications		898 (0.04)	2,039,610
Delirium		5224 (0.26)	2,039,610
Central nervous system complications		5627 (0.28)	2,039,610
Gastrointestinal		10,174 (0.50)	2,039,610
Severe life or major vital organ threatening event		15,140 (0.75)	2,039,610

Any PSI = 134,299 (5.2%).

(respectively) for postoperative sepsis[27] to 84%–100% and 81%–99% (respectively) for postoperative deep vein thrombosis or pulmonary embolism.[28] Such a validation context for other PSIs indicates that the proposed indicators may not be ideal for hospital report cards, but that they still hold promise as tools for surveillance and for triggering more detailed case reviews.[9]

The Classification of Hospital Acquired Diagnoses (CHADx) system developed by Jackson et al[29] in Australia, and related work by Brand et al,[30] also in Australia, produced administrative data analysis tools that have some conceptual similarity to our work. Like our proposed PSIs, the CHADx tool uses a "condition onset" flag available in Australian administrative data to capture complications in inpatient data. It is also focused on the identification of diagnoses arising after admission, but unlike our list focusing on safety and quality of care, the codes in the CHADx system were not subjected to a clinical expert review to select only the subset of diagnoses that have a clinical link to safety and quality of care. The CHADx therefore includes a large number of diagnoses (eg, Giardiasis) that are coded as having arisen in hospital, but that appear unlikely to have a clinical link to patient safety and quality of care. This latter difference notwithstanding, the Australian CHADx system has considerable conceptual overlap to the methodology presented here, and indeed, our starting listing of codes from step 1 of our code selection methodology very closely resembles the CHADx code listing.

Our study thus contributes a comprehensive set of ICD-10 codes representing potential safety and quality-related adverse events. The newly derived code list has a potential advantage over the AHRQ PSIs because its derivation was based on the diagnosis timing information, whereas the AHRQ PSIs in both ICD-9-CM and ICD-10[16] were somewhat constrained by the exclusion of diagnosis codes for which there was undue ambiguity as to timing of diagnosis in the absence of diagnosis timing information. As a result, common and important clinical conditions such as certain hospital-acquired pneumonias were intentionally excluded from the AHRQ PSIs, largely because the timing of the diagnosis could not be determined with confidence. Such diagnoses would likely be adverse events of interest in a national monitoring system for patient safety and quality of care. With the diagnosis timing information (so central to our methodology) comes the opportunity to step outside of the constrained paradigm of existing PSIs to create an entirely new set of PSIs for use with administrative data. This new code list and methodology may be of great interest to health systems that have the diagnosis timing information. Our reported overall event rate of 5.2% underlines that the selected diagnoses arise with considerable frequency. And indeed, the nature of the diagnoses in the code listing we have produced is such that there will likely be considerable interest among health system stakeholders to create surveillance systems using administrative data for the capture of such events.

A first caveat to mention is that there is now a need to undertake future validation studies of the patient safety diagnosis code listings created here against chart review or prospective case reviews. Such future studies will require significant resources and effort, and the capacity and resources of multiple teams working in multiple jurisdictions. This paper describes the extensive code selection work undertaken to date, as a foundation for such future work. We anticipate that future validation studies against chart review or prospective review gold standards will reveal similar findings to some of the prior validation studies undertaken on AHRQ PSIs—namely that specificity will typically be very high, but that sensitivity will be somewhat variable and not always high. This relates to the inherent limitation of administrative hospital discharge data, and underlines that any PSIs derived from such data are probably best used to create confidential "trigger positive"

reports for hospitals to undertake quality reviews of selected cases, rather than for public reporting of adverse event rates.

A second caveat to our findings is that the diagnosis timing information, so key to the entire premise of our study, may not always be accurately coded. Indeed, there were some diagnoses coded as postadmit and thus identified in step 1 of our study that clinical experts recognized as being improperly coded. Limited published findings from both Canada[31,32] and the US[33–35] suggest that the accuracy of diagnosis timing information is not perfect, and that it may vary across jurisdictions, hospitals, and conditions. Over-reporting of conditions as being POA may cause under-detection of adverse events, whereas other conditions that are accurately coded as postadmit may have resulted from the trajectory of illness, which started before admission and was unresponsive to appropriate treatment (eg, delirium or renal failure in a patient admitted with sepsis).

A third caveat to our study, and the overall potential of our new patient safety code list, is that diagnosis timing information is not universally available in all countries. To our knowledge, such timing indicators only currently exist in Canada, the US, and Australia. Some other countries are considering ICD-10 implementation of diagnosis timing indicators, and encouragingly, the WHO is contemplating the development of a global diagnosis timing coding mechanism for ICD-11, to be released in 2018 (http://www.who.int/classifications/icd/en/).

In conclusion, there is an appropriate global spotlight on the universal challenge of suboptimal quality of care and patient safety. With that spotlight comes scrutiny and stakeholder interest in the development of quality and safety monitoring systems. Despite their inherent limitations, and the caveats just discussed, administrative data continue to be an important resource for the monitoring of adverse events associated with hospital stays. The methodological work presented here utilizes the unique potential of diagnosis timing information to produce a clinically relevant listing of diagnosis codes that have potential as PSIs that may overcome some of the notable shortcomings of existing PSI systems. The resulting work has great potential to inform future approaches to monitoring health system performance and quality/safety improvement internationally.

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