

# Validity of the *International Classification of Diseases 10th revision* code for hyperkalaemia in elderly patients at presentation to an emergency department and at hospital admission

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## ABSTRACT

**Objectives:** Evaluate the validity of the *International Classification of Diseases, 10th revision* (ICD-10) code for hyperkalaemia (E87.5) in two settings: at presentation to an emergency department and at hospital admission.

**Design:** Population-based validation study.

**Setting:** 12 hospitals in Southwestern Ontario, Canada, from 2003 to 2010.

**Participants:** Elderly patients with serum potassium values at presentation to an emergency department (n=64 579) and at hospital admission (n=64 497).

**Primary outcome:** Sensitivity, specificity, positive-predictive value and negative-predictive value. Serum potassium values in patients with and without a hyperkalaemia code (code positive and code negative, respectively).

**Results:** The sensitivity of the best-performing ICD-10 coding algorithm for hyperkalaemia (defined by serum potassium >5.5 mmol/l) was 14.1% (95% CI 12.5% to 15.9%) at presentation to an emergency department and 14.6% (95% CI 13.3% to 16.1%) at hospital admission. Both specificities were greater than 99%. In the two settings, the positive-predictive values were 83.2% (95% CI 78.4% to 87.1%) and 62.0% (95% CI 57.9% to 66.0%), while the negative-predictive values were 97.8% (95% CI 97.6% to 97.9%) and 96.9% (95% CI 96.8% to 97.1%). In patients who were code positive for hyperkalaemia, median (IQR) serum potassium values were 6.1 (5.7 to 6.8) mmol/l at presentation to an emergency department and 6.0 (5.1 to 6.7) mmol/l at hospital admission. For code-negative patients median (IQR) serum potassium values were 4.0 (3.7 to 4.4) mmol/l and 4.1 (3.8 to 4.5) mmol/l in each of the two settings, respectively.

**Conclusions:** Patients with hospital encounters who were ICD-10 E87.5 hyperkalaemia code positive and negative had distinct higher and lower serum potassium values, respectively. However, due to very low sensitivity, the incidence of hyperkalaemia is underestimated.

## ARTICLE SUMMARY

### Article focus

- This study described the validity of the *International Classification of Diseases, 10th revision* (ICD-10) code for hyperkalaemia (E87.5) compared with serum potassium laboratory values, where the latter served as the reference standard.
- Knowledge of the accuracy of the code at hospital encounters guides its judicious use in health services research.

### Key messages

- The ICD-10 hyperkalaemia code has very high specificity, but very low sensitivity, which underestimates the true incidence of hyperkalaemia at presentation to an emergency department and at hospital admission.
- Being positive or negative for the code does distinguish between two groups of patients with distinct serum potassium measurements.

### Strengths and limitations of this study

- This is the first study to provide diagnostic information on the validity of the ICD-10 code for hyperkalaemia.
- It was a large population-based study and included serum potassium values from 12 hospitals across Ontario.
- Code validity in younger populations should be examined in future studies.

## INTRODUCTION

Use of information in healthcare administrative databases is a relatively easy and efficient way to identify patients with prior or current disease. It is also a simple way for the medical community to assess resources and usage of healthcare services. However, administrative codes are not always accurate.<sup>1</sup> This can lead to the under-reporting or over reporting of some diseases (ie, individuals who have

the disease but where there is no evidence of the respective database code; or individuals who have evidence of the database code but where there is no evidence of the disease). Knowledge of the validity of various database codes guides their optimal use for research, quality assurance and health system planning.

Hyperkalaemia, or high serum potassium, is a fairly common adverse event. Normal levels of serum potassium range from 3.3 to 5.1 mmol/l, with hyperkalaemia often defined by a value of 5.5 mmol/l or higher.<sup>2</sup> High serum potassium levels can have serious deleterious effects including arrhythmia and death.<sup>3</sup> Some comorbidities that predispose to hyperkalaemia include chronic kidney disease and cancer. Hyperkalaemia can also occur due to the use of a variety of prescription medications, including ACE inhibitors, angiotensin receptor blockers (ARB),  $\beta$ -blockers and certain types of diuretics.<sup>4</sup> Approximately 10% of patients prescribed an ACE inhibitor develop hyperkalaemia in the year following their initial prescription.<sup>5</sup>

The 10th revision of the *International Classification of Diseases* (ICD-10) system has been used to code health-care encounters in Canada since 2002, and has also been implemented in over 100 other countries since its inception.<sup>6</sup> Yet, after careful bibliographic database searching, we could find no published validation for the ICD-10 hyperkalaemia code using serum potassium laboratory values as the reference standard. There was a single validation study that considered the ICD-9 hyperkalaemia code from the Kaiser Permanente Health Management Organization in the USA, but this study only focused on how accurately it was used in automated healthcare data.<sup>7</sup>

We conducted the current study to determine the accuracy of the ICD-10 code for hyperkalaemia (E87.5) in two acute care settings: at presentation to an emergency department and at hospital admission. We compared the ICD-10 code with actual serum potassium laboratory values.

## METHODS

### Study design

We conducted a retrospective population-based validation study using linked administrative databases housed at the Institute for Clinical Evaluative Sciences. The province of Ontario, Canada has approximately 13 million residents, 14% of whom are 65 years of age or older.<sup>8</sup> Residents have universal access to hospital care and physician services and those 65 years of age or older have universal prescription drug coverage. Within Southwestern Ontario, we considered a catchment area that included approximately 80 000 adults 65 years of age and older, according to census information from 2006.<sup>9</sup> There were 12 hospitals that served this area from which we gathered laboratory information. We compared the ICD-10 hyperkalaemia code E87.5 with serum potassium laboratory values as the reference standard in two settings: (1) at

presentation to an emergency department and (2) at hospital admission. We calculated the sensitivity, specificity, positive-predictive value and negative-predictive value of several ICD-10 coding algorithms. Also, because serum potassium is a continuous measure, we compared patients who were positive for the code with those with hospital encounters who were negative for the code. The reporting of this study follows guidelines set out for studies of diagnostic accuracy (see online supplementary appendix A).<sup>10</sup> We conducted our study according to a prespecified protocol that was approved by the institutional review board at Sunnybrook Health Sciences Centre (Toronto, Ontario).

### Data sources

We ascertained outcome data as well as the presence of relevant comorbidities for exclusions and baseline characteristics using records from seven linked databases. The Ontario Drug Benefit Plan database contains records of prescriptions from outpatient pharmacies. The dispensing of medications for patients aged 65 and older is accurately recorded in this database with an error rate of less than 1%.<sup>11</sup> The Canadian Institute for Health Information (CIHI) National Ambulatory Care Reporting System (NACRS) contains ambulatory care information on emergency room visits, outpatient procedures and day surgeries. The CIHI Discharge Abstract Database (CIHI-DAD) reports inpatient procedures, diagnoses and discharge summaries for patients hospitalised in Ontario. The Ontario Health Insurance Plan (OHIP) database contains all physician and other specific healthcare provider claims for medical services covered under the provincial health insurance plan. Lastly, the Registered Persons Database contains demographic information, such as birth date and sex, for all Ontario residents who have ever been covered by OHIP.

In addition to the five administrative databases described above, we used two laboratory datasets to determine serum potassium values. An electronic medical record Cerner (Kansas City, Missouri, USA) contains inpatient, outpatient and emergency department laboratory values for 12 hospitals in Southwestern Ontario.<sup>12</sup> Gamma-Dynacare performs outpatient laboratory tests in Southwestern Ontario and was used to obtain baseline laboratory values for a subpopulation. We have successfully used these datasets in previous studies.<sup>13–16</sup>

### Participants

Individuals included in our study had at least one hospital-based serum potassium laboratory value between 1 June 2003 and 30 September 2010. We considered patients 66 years of age or older, to allow for a minimum of 1 year of baseline prescription information. Older patients often have important risk factors for hyperkalaemia and have full medication coverage through the provincial drug plan.<sup>17</sup> We excluded laboratory tests with missing demographic information (approximately 0.75% of the tests). We also excluded hospital stays that were

longer than 90 days to ensure that we had data for the entire hospitalisation, particularly when these occurred towards the end of our accrual period. For hyperkalaemia at presentation to an emergency department, the relevant potassium laboratory test must have occurred on an emergency department registration date or the day after. We allowed values for the date after registration to account for patients who may have come to an emergency department but did not receive their test until after midnight (ie, the day after). For hyperkalaemia at hospital admission, the relevant potassium laboratory test must have been done either in an emergency department up to 2 days prior to hospital admission, or up to 1 day after the date of hospital admission. We assigned this timeframe to account for any delays between an emergency department presentation and hospital admission, and any treatment that resulted in subsequent lower potassium values from the initial measurement. In both the emergency room and hospital settings, if multiple tests occurred, we took the highest available value. When multiple eligible hospital presentations were identified for a given patient over the study period, we randomly selected one.

#### Administrative database codes (diagnostic test)

In Canada, trained coders record appropriate diagnostic codes and their associated attributes based on information from a patient's chart. Coders in Canada follow specific rules and guidelines set out by CIHI when assigning diagnostic codes based on a patient's file. They are not allowed to interpret any diagnostic tests, such as x-rays or lab values, unless a diagnosis is specifically written by the physician in the medical chart.<sup>18</sup> Within the NACRS database, coders are allowed to include up to 10 diagnoses per visit. The first diagnosis listed is the main problem for the patient's visit that required evaluation and/or treatment or management as determined by the physician at the end of the visit. The CIHI-DAD provides the ability to record up to 25 diagnoses during a hospital admission, each of which can have additional diagnosis types. For example, coders must assign one of the diagnoses the diagnosis type 'M', which represents the condition that was most responsible for the greatest portion of the length of stay or used the greatest amount of resources. They may also assign a diagnosis type '1' to any of the listed diagnoses that existed prior to the admission and were treated during the hospital stay.

In this study, based on possible diagnosis types we developed two unique algorithms to assess hyperkalaemia at presentation to an emergency department and three unique algorithms to assess hyperkalaemia at hospital admission. We used the ICD-10 code E87.5, which is defined as 'hyperkalaemia'. There is a Canadian Modification of the ICD-10 code system which provides additional information on other comorbidities but does not alter the hyperkalaemia coding. The two emergency department algorithms identified records with code E87.5 recorded: (1) as the main problem (referred to as

'main diagnosis') or (2) in any of the 10 potential diagnostic fields (referred to as 'all diagnosis'). The three hospital admission algorithms identified records with code E87.5 recorded: (1) with the diagnosis type of 'M' (most responsible; referred to as 'most responsible diagnosis'), (2) with the diagnosis type of '1' (preadmit comorbidity; referred to as 'preadmit diagnosis') or (3) in any one of 25 potential diagnosis fields and any diagnosis type (referred to as 'all diagnosis').

#### Potassium laboratory values (reference standard)

Serum potassium laboratory tests were done either in an emergency department or in hospital and were used as the reference standard. The laboratory tests were performed with the Roche Modular Ion Selective Electrode system (Basel, Switzerland). The primary threshold to define hyperkalaemia was a serum potassium value  $>5.5$  mmol/l. Other thresholds were also considered:  $>5.0$ ,  $>6.0$  and  $>6.5$  mmol/l.

#### Data analysis

We assessed severity of hyperkalaemia based on several thresholds of serum potassium values indicated above. In the emergency department and hospital admission settings, we calculated the sensitivity, specificity, positive-predictive value and negative-predictive value of each coding algorithm for each serum potassium level (see online supplementary appendix B for two-by-two contingency table describing the relevant formulae). For the different algorithms we also contrasted the mean, median and IQRs of serum potassium values for those who were positive for the code compared with patients with hospital encounters who had no evidence of the code (ie, code negative). We calculated 95% CI for single proportions using the Wilson Score method.<sup>19</sup> We expressed continuous variables as medians with IQR and compared means using independent samples t tests. We performed all analyses with SAS V.9.2 (SAS Institute Incorporated, Cary, North Carolina, USA, 2008).

## RESULTS

The cohort creation and specific exclusions for both settings are shown in online supplementary appendix C. Patient baseline characteristics are shown in table 1.

Of the 64 579 patients who presented to an emergency department, 1679 (2.6%) had a potassium value of  $>5.5$  mmol/l. Of 64 497 patients who were admitted to hospital, 2289 (3.5%) patients had a serum potassium level  $> 5.5$  mmol/l. The diagnostic performance characteristics of the coding algorithms for hyperkalaemia (defined by serum potassium  $>5.5$  mmol/l) in the two settings are presented in table 2. The algorithm that considered the E87.5 code as 'all diagnoses' demonstrated the best sensitivity, recognising the value still remained low. For example, the sensitivity of the 'all diagnoses' algorithm to detect a serum potassium  $>5.5$  mmol/l in an emergency department was 14.1%

**Table 1** Baseline characteristics for patients with serum potassium values obtained at presentation to the emergency department and at hospital admission

	At emergency department N=64 579	At hospital admission N=64 497
<b>Demographics</b>		
Age (years) median (IQR)	77 (71–83)	77 (71–83)
Women (n (%))	35630 (55.2)	32965 (51.1)
<b>Income quintile (n (%))</b>		
One (lowest)	14231 (22.0)	13900 (21.6)
Two	12921 (20.0)	12928 (20.0)
Three (middle)	12542 (19.4)	12792 (19.8)
Four	11496 (17.8)	11601 (18.0)
Five (highest)	12407 (19.2)	12446 (19.3)
Rural Location (n (%))	11438 (17.7)	13248 (20.5)
<b>Year of cohort entry (n (%))</b>		
2003–2004	6586 (10.2)	11601 (18.0)
2005–2006	15188 (23.5)	15640 (24.3)
2007–2008	20569 (31.9)	18474 (28.6)
2009–2010	22236 (34.4)	18782 (29.1)
Long-term care facility utilisation (n (%))	4137 (6.4)	3681 (5.7)
<b>comorbidities, (n (%))</b>		
Chronic kidney disease†	5335 (8.3)	6427 (10.0)
Diabetes mellitus‡	13142 (20.4)	13632 (21.1)
Peripheral vascular disease	1690 (2.6)	2937 (4.6)
Coronary artery disease§	26979 (41.8)	30528 (47.3)
Heart failure	13691 (21.2)	15173 (23.5)
Stroke/Transient ischemic attack	2455 (3.8)	2655 (4.1)
Chronic liver disease	1238 (1.9)	1645 (2.6)
<b>Medication use in prior 6 months, n (%)</b>		
ACE inhibitors	22690 (35.1)	23770 (36.9)
Angiotensin-receptor blockers	10442 (16.2)	10012 (15.5)
Potassium sparing diuretics	5657 (8.8)	6147 (9.5)
Loop diuretics	13553 (21.0)	14618 (22.7)
Thiazide diuretics	12334 (19.1)	12458 (19.3)
Calcium channel blockers	19126 (29.6)	19951 (30.9)
β-adrenergic antagonists	21989 (34.1)	23382 (36.3)
Statins	24892 (38.6)	25273 (39.2)
NSAIDs (excluding aspirin)	11621 (18.0)	12573 (19.5)
Anticonvulsants	3847 (6.0)	3740 (5.8)
Antidepressants	15662 (24.3)	15075 (23.4)
Antipsychotics	4001 (6.2)	3532 (5.5)
Benzodiazepine	15295 (23.7)	15515 (24.1)
Antineoplastic drugs	3285 (5.1)	3624 (5.6)
<b>Baseline laboratory measurements¶</b>		
<b>Serum creatinine levels</b>		
Most recent serum creatinine (μmol/l) median (IQR)	90 (74–114)	90 (74–114)
<b>GFR<sup>††</sup> levels</b>		
Most recent eGFR (ml/min/1.73 m <sup>2</sup> ), median (IQR)	63 (47–79)	63 (47–79)
<b>eGFR category (n (%))(ml/min/1.73 m<sup>2</sup>)</b>		
≥60	20807 (54.7)	23842 (55.3)
45–59	8527 (22.4)	9566 (22.2)
30–44	5466 (14.4)	5989 (13.9)
15–29	2362 (6.2)	2694 (6.2)
<15	850 (2.2)	1021 (2.4)
<b>Serum sodium levels</b>		
Most recent serum sodium (mmol/l) median (IQR)	139 (137–141)	139 (137–141)

Continued



Table 1 Continued

	At emergency department N=64 579	At hospital admission N=64 497
Serum potassium levels		
Most recent serum potassium (mmol/l) median (IQR)	4.2 (3.8–4.5)	4.1(3.8–4.5)

\*We defined index date as the time of cohort entry.

†Assessed by administrative database codes: CIHI ICD-9 codes—4030, 3031, 4039, 4040, 4041, 4049, 582, 583, 580, 581, 584, 585, 586, 587, 5880, 5888, 5889, 5937; CIHI ICD-10 codes—I12, I13, N01, N03, N05, N07, N14, N15, N00, N04, N08, N18, N19, N26, N25, N137, N280, N2888, N06, N391; OHIP diagnostic codes—403, 580, 581, 585.

‡Assessed by diabetic medication use in previous 6 months.

§Coronary artery disease includes receipt of coronary artery bypass graft surgery, percutaneous coronary intervention and diagnoses of angina.

¶Available from emergency department, inpatient or outpatient settings for a subpopulation. A total of 33 104 (51.3%), 32 844 (50.9%) and 38 012 (58.9%) patients at presentation to emergency department had a baseline serum potassium, sodium and creatine measurement available in the 7–365 days prior to the index date, respectively. Among these patients, the baseline measurements were taken at a median (IQR) of 75 (25–174), 75(25–174) and 76 (26–173) days, respectively. A total of 39 552 (61.3%), 39 422 (61.1%) and 43 112 (66.9%) patients at hospital admission had a baseline serum potassium, sodium and creatine measurement available in the 7–365 days prior to the index date, respectively. Among these patients, the baseline measurements were taken at a median (IQR) of 29 (14–97), 29 (14–97) and 32(14–101) days, respectively.

‡eGFR was calculated using the CKD-Epi equation.

CKD-Epi equation:  $141 \times \min((\text{serum creatine in } \mu\text{mol/l}/88.4)/\kappa, 1)^\alpha \times \max((\text{serum creatine in } \mu\text{mol/l}/88.4)/\kappa, 1)^{-1.209} \times 0.993^{\text{Age}} \times 1.018$  (if female)  $\times 1.159$  (if African American)  $\kappa=0.7$  for females and  $0.9$  for males,  $\alpha=-0.329$  for females and  $-0.411$  for males,  $\min$ =the minimum of  $\text{Scr}/\kappa$  or  $1$ ,  $\max$ =the maximum of  $\text{Scr}/\kappa$  or  $1$ . Racial information was not available in our data sources and all patients were assumed not to be of non African-Canadian race. This was a reasonable assumption; as of 2006, African-Canadians represented less than 7% of the Ontario population. Source: <http://www12.statcan.ca/census-recensement/2006/dp-pd/hlt/97-562/index.cfm?Lang=E>  
eGFR, estimated glomerular filtration rate.

and the specificity was 99.9%. Similar results were obtained for individuals with hyperkalaemia at hospital admission.

The performance characteristics of the coding algorithms for the additional thresholds of serum potassium (> 5, >6 and >6.5 mmol/l) are presented in table 3. Of all the coding algorithms, those that considered the E87.5 code as ‘all diagnoses’ continued to demonstrate the best sensitivity across all the serum potassium

thresholds. As well the sensitivity of the coding algorithm increased as hyperkalaemia became more severe (ie, a higher serum potassium level). For example, in an emergency department, for the ‘all diagnoses’ algorithm, the sensitivity was 6.6% for a potassium >5 mmol/l, and 21.8% for a potassium >6.5 mmol/l. Similarly, at hospital admission, for the ‘all diagnoses’ algorithm the sensitivity was 7.5% for a potassium >5 mmol/l and 29.5% for a potassium >6.5 mmol/l. The specificities were >99% and

Table 2 Diagnostic performance characteristics for ICD-10 E87.5 coding algorithms for hyperkalaemia defined by a serum potassium value >5.5 mmol/l at presentation to an emergency department and at hospital admission

ICD-10 E87.5 coding algorithm	Emergency department		Hospital admission					
	+	-	Per cent (95% CI)		+	-	Per cent (95% CI)	
All diagnoses	+	237	Sn	14.12 (12.53 to 15.86)	+	335	Sn	14.64 (13.25 to 16.14)
	-	1442	Sp	99.92 (99.90 to 99.94)	-	1954	Sp	99.67 (99.62 to 99.71)
			PPV	83.16 (78.38 to 87.06)			PPV	62.04 (57.87 to 66.03)
			NPV	97.76 (97.64 to 97.87)			NPV	96.94 (96.81 to 97.08)
Main/most responsible diagnosis	+	98	Sn	5.84 (4.81 to 7.06)	+	59	Sn	2.58 (2.00 to 3.31%)
	-	1581	Sp	99.97 (99.95 to 99.98)	-	2230	Sp	99.99 (99.97 to 99.99)
			PPV	83.76 (76.03 to 89.35)			PPV	88.06 (78.17 to 93.82)
			NPV	97.55 (97.43 to 97.66)			NPV	96.54 (96.39 to 96.68)
Preadmit diagnosis					+			
	+		Sn	12.06 (10.79 to 13.46)	+	276	Sn	12.06 (10.79 to 13.46)
	-		Sp	99.85 (99.82 to 99.88)	-	2013	Sp	99.85 (99.82 to 99.88)
			PPV	74.59 (69.92 to 78.76)			PPV	74.59 (69.92 to 78.76)
		NPV	96.86 (96.72 to 96.99)			NPV	96.86 (96.72 to 96.99)	

+, Hyperkalaemia yes; -, hyperkalaemia no; ICD-10, International Classification of Diseases, 10th revision; NPV, negative-predictive value; PPV, positive-predictive value; Sn, sensitivity; Sp, specificity.



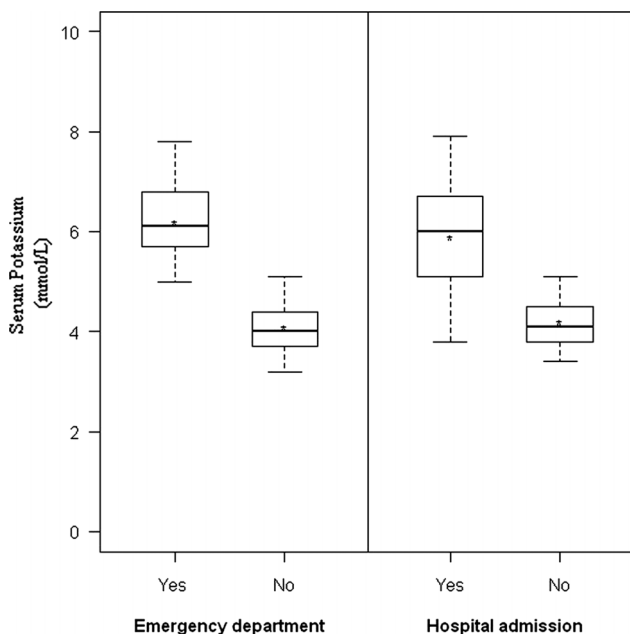
**Table 4** Serum potassium values (mmol/l) in patients who were code positive and code negative for ICD-10 code E87.5 at presentation to the emergency department and at hospital admission according to different algorithms

	Emergency department			Hospital admission				
		N	Median	IQR	N	Median	IQR	
All diagnosis	No	64294	4.0	3.7–4.4	No	63957	4.1	3.8–4.5
	Yes	285	6.1	5.7–6.8	Yes	540	6.0	5.1–6.7
Main/most responsible diagnosis	No	64462	4.0	3.7–4.4	No	64430	4.1	3.8–4.5
	Yes	117	6.2	5.7–6.9	Yes	67	6.9	6.1–7.5
Preadmit diagnosis					No	64127	4.1	3.8–4.5
					Yes	370	6.3	5.5–6.9

ICD-10, International Classification of Diseases, 10th revision; N, number of patients.

of 5.5 mmol/l or more did not receive a code for hyperkalaemia using the all diagnoses category. Even when considering severe hyperkalaemia (serum potassium >6.5 mmol/l), the sensitivity only reached a maximum of about 29%.

The most responsible diagnosis is defined as the illness responsible for the longest length of stay or the greatest use of hospital resources. This algorithm demonstrated the lowest sensitivity among all the algorithms in our study, likely because the most responsible illness was attributed to the underlying problem that caused the hyperkalaemia rather than the hyperkalaemia itself.



**Figure 1** Serum potassium measurements among patients who are code positive and code negative for hyperkalaemia (when the code was considered in the format 'all diagnoses'). For both presentation to an emergency department and at hospital admission, patients who for positive for the hyperkalaemia code had a significantly higher serum potassium measurement than patients who were code negative. The boxes represent the IQR (50% of the values). The line across the box indicates the median. The star indicates the mean. The whiskers extend to the 95th and 5th percentile.

We found that sensitivity increased as the severity of hyperkalaemia increased. Milder forms of hyperkalaemia tend to be asymptomatic and can be managed without aggressive treatment. Consequently, the physician may be less inclined in such cases to record a diagnosis of hyperkalaemia in the medical chart. In addition, hyperkalaemia often co-occurs with other more serious disorders that the physician may find to be paramount to hyperkalaemia when recording conditions in the medical chart. Furthermore, if the physician writes serum potassium 5.7 mmol/l for example, but does not write 'hyperkalaemia' or 'high potassium' the coders are unable to assume any diagnosis and some events are not recorded for this reason.<sup>18</sup>

Of the patients who had hyperkalaemia at presentation to an emergency department and at hospital admission (defined by a value >5.5 mmol/l), only 14.1% and 14.6%, respectively, were correctly coded as hyperkalaemic. The low sensitivity at this threshold may be due to less enthusiasm to act on values that are only modestly elevated. Despite this, the code was successful in differentiating between two groups of patients with distinct serum potassium values. Code-negative patients had serum potassium values in the normal range (3.5 to 5.1 mmol/l) and when the code was present, values were much higher ( $\geq 6$  mmol/l).

Our study has several strengths. It is the first study to validate the ICD-10 code for hyperkalaemia and first to validate hyperkalaemia using laboratory values as the reference standard. We validated the ICD-10 code in both an emergency department and at hospital admission examining different types of diagnoses. Previous electrolyte validation studies have not looked at these settings nor did they examine all the possible diagnosis types as done in our study. Although there have been no similar hyperkalaemia validation studies, other electrolyte studies have demonstrated similarly low sensitivities of the ICD codes.<sup>20 21</sup>

All citizens in Ontario receive universal healthcare and patients over 65 have their medications paid for by the provincial government. These two factors facilitated the collection of health administrative data and gave us the ability to have a large sample size. We based our validation on laboratory data from 12 hospitals in the most populous

province in Canada. Another study validating the ability of a computerised programme to correctly identify hyperkalaemia using the ICD-9 code restricted the analysis to a single centre and to the specific population of patient with diabetes.<sup>7</sup> In addition, another study describing the frequency of hyperkalaemic events also focused on a specific population of veterans.<sup>22</sup> Because we used a more varied and larger population, we were able to obtain good precision for estimates that are quite generalisable.

The validity measures that we used in this study have also been used in several other studies comparing ICD codes with clinical outcomes, including two validations of another electrolyte disorder, hyponatraemia.<sup>23–28</sup> Many validation studies compare diagnostic codes with information written in medical charts. However, the most accurate way to determine whether hyperkalaemia is truly present is to use laboratory values as we did in the current study.

Our study does have some limitations. We validated the ICD-10 hyperkalaemia code in a population of patients over age 65. This patient population is particularly vulnerable to developing hyperkalaemia.<sup>29</sup> In addition, these results inform future analyses of the Ontario healthcare databases since most pharmacoepidemiological research using these data sources are conducted in patients over age 65 (where receipt of prescription medications is a universal benefit). Moreover, a greater proportion of elderly patients receive a laboratory test compared with younger patients, reducing the potential for selection bias.<sup>30</sup> Nonetheless, code validity in younger populations should be examined in future studies.

We were unable to determine if the patients who presented to an emergency department or at hospital admission showed arrhythmias or other sequelae of the high serum potassium value. However, we do know the code did identify acute changes, as demonstrated by a mean increase in serum potassium of 1.5 mmol/l above the baseline prehospital value. Patients with acute changes in serum potassium are most likely to be symptomatic from the condition.

Finally, we recognise that we did not capture those patients who may have had severe hyperkalaemia but did not go to an emergency department or hospital, or those who presented but failed to have serum potassium measured. However, the latter is less of a concern as serum potassium is a common test for most patients who present for acute medical care. We were unable to detect outpatient claims for hyperkalaemia in this study as there is no administrative code set available for this in our jurisdiction. Nevertheless, emergency department and hospital records do detect more severe forms of hyperkalaemia making this of particular interest to clinicians and policy decision makers.

## CONCLUSION

Analyses of administrative codes are a cost-efficient way to assess patient comorbidity and disease in large

population-based studies. However, as observed by the low sensitivity in the current study, many individuals with an ICD-10 database code for hyperkalaemia are missed leading to an underestimate of the true incidence of the condition at hospital encounters. It is important that members of the health community responsible for making decisions about healthcare be aware of the conditions and limitations of these codes to make fully informed evaluations. Nonetheless, the group of patients who were positive for this code were distinguishable from the group of patients who were negative for the code with distinct serum potassium values in both settings. The findings of this validation study guide proper use of the ICD-10 hyperkalaemia code in future research using health administrative data.

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**Contributors** JLF participated in the coordination of the study, study design, provided interpretation of study results and drafted the manuscript. SZS participated in the study design, performed the analysis and provided interpretation of study results. SG contributed to the study design and interpretation of study results. MAW and AKJ contributed to the study design and provided feedback on the manuscript. AXG conceived of the study, participated in its design and interpretation, helped draft the manuscript and provided feedback on the manuscript. All authors read and approved the final manuscript.

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**Competing interests** None.

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**Data sharing statement** There are no additional data available.

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## Appendix A

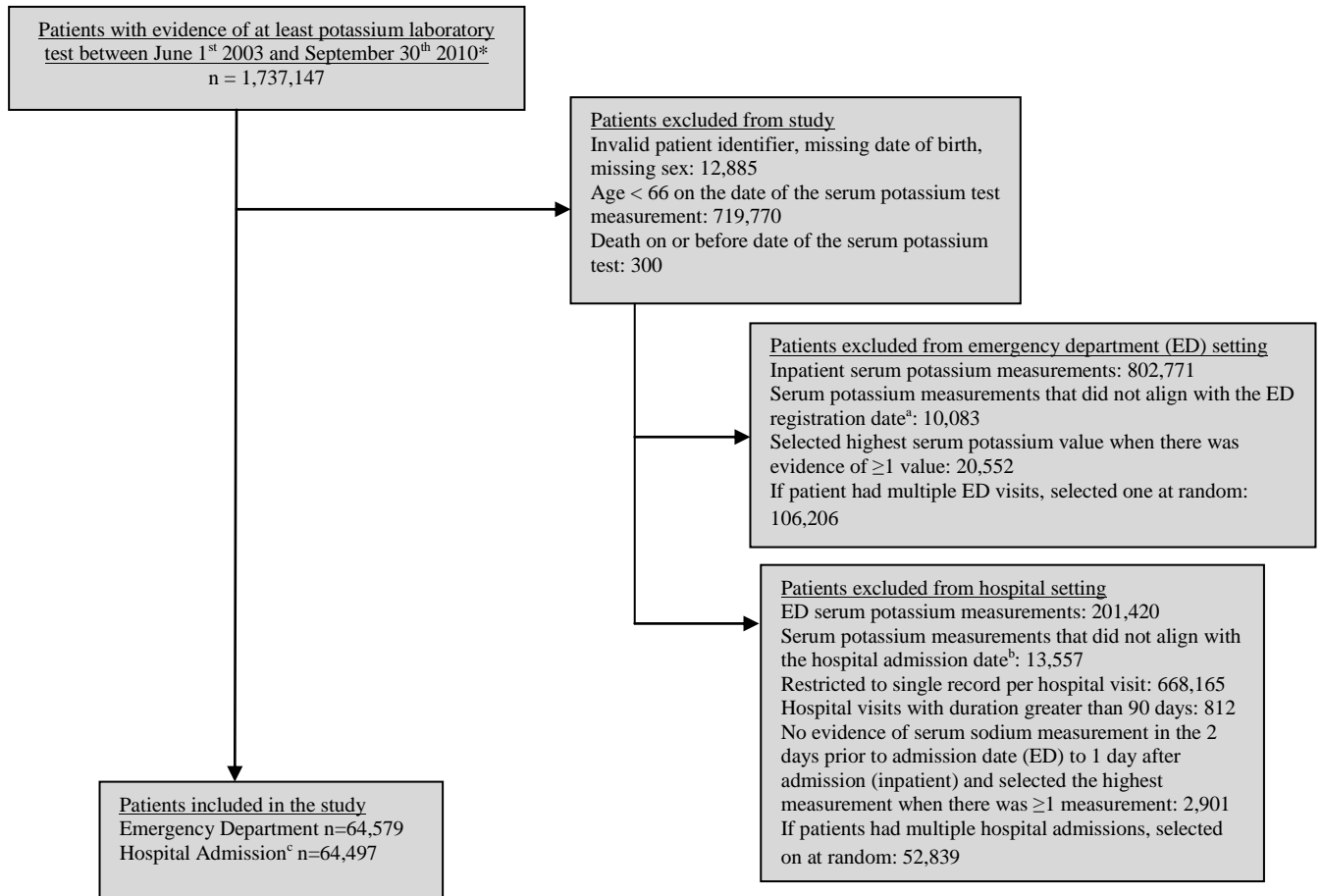
### STARD checklist for reporting of studies of diagnostic accuracy (version January 2003)

Section and Topic	Item #		On page #
TITLE/ABSTRACT/ KEYWORDS	1	Identify the article as a study of diagnostic accuracy (recommend MeSH heading 'sensitivity and specificity').	Abstract
INTRODUCTION	2	State the research questions or study aims, such as estimating diagnostic accuracy or comparing accuracy between tests or across participant groups.	Introduction
<b>METHODS</b>			
<i>Participants</i>	3	The study population: The inclusion and exclusion criteria, setting and locations where data were collected.	Methods – Participants; Appendix C
	4	Participant recruitment: Was recruitment based on presenting symptoms, results from previous tests, or the fact that the participants had received the index tests or the reference standard?	Methods – Participants
	5	Participant sampling: Was the study population a consecutive series of participants defined by the selection criteria in item 3 and 4? If not, specify how participants were further selected.	Methods – Participants; Appendix C
	6	Data collection: Was data collection planned before the index test and reference standard were performed (prospective study) or after (retrospective study)?	Methods – Study design
<i>Test methods</i>	7	The reference standard and its rationale.	Methods
	8	Technical specifications of material and methods involved including how and when measurements were taken, and/or cite references for index tests and reference standard.	Methods – Potassium laboratory value
	9	Definition of and rationale for the units, cut-offs and/or categories of the results of the index tests and the reference standard.	Methods – Potassium laboratory value
	10	The number, training and expertise of the persons executing and reading the index tests and the reference standard.	Methods – Administrative database codes
	11	Whether or not the readers of the index tests and reference standard were blind (masked) to the results of the other test and describe any other clinical information available to the readers.	n/a
<i>Statistical methods</i>	12	Methods for calculating or comparing measures of diagnostic accuracy, and the statistical methods used to quantify uncertainty (e.g. 95% confidence intervals).	Methods – Data analysis; Appendix A
	13	Methods for calculating test reproducibility, if done.	n/a
<b>RESULTS</b>			
<i>Participants</i>	14	When study was performed, including beginning and end dates of recruitment.	Methods
	15	Clinical and demographic characteristics of the study population (at least information on age, gender, spectrum of presenting symptoms).	Results; Table 1
	16	The number of participants satisfying the criteria for inclusion who did or did not undergo the index tests and/or the reference standard; describe why participants failed to undergo either test (a flow diagram is strongly recommended).	Results; Table 1; Appendix C
<i>Test results</i>	17	Time-interval between the index tests and the reference standard, and any treatment administered in between.	Table 1 Footnote; Appendix C
	18	Distribution of severity of disease (define criteria) in those with the target condition; other diagnoses in participants without the target condition.	Results; Tables 2,3,4
	19	A cross tabulation of the results of the index tests (including indeterminate and missing results) by the results of the reference standard; for continuous results, the distribution of the test results by the results of the reference standard.	Tables 2,3,4
	20	Any adverse events from performing the index tests or the reference standard.	n/a
<i>Estimates</i>	21	Estimates of diagnostic accuracy and measures of statistical uncertainty (e.g. 95% confidence intervals).	Results; Tables 2,3,4
	22	How indeterminate results, missing data and outliers of the index tests were handled.	n/a
	23	Estimates of variability of diagnostic accuracy between subgroups of participants, readers or centers, if done.	n/a
	24	Estimates of test reproducibility, if done.	n/a
DISCUSSION	25	Discuss the clinical applicability of the study findings.	Discussion

## Appendix B

		Reference Standard: <b>Hyperkalemia</b> defined by a <b>potassium laboratory value &gt;5.5mmol/L</b>	
		> 5.5 mmol/L	≤ 5.5 mmol/L
<b>Hyperkalemia</b> defined by <b>ICD-10 Code E87.5</b>	Code Positive	A	B
	Code Negative	C	D
Sensitivity= $a/(a+c)$ : the proportion of patients with serum potassium >5.5 mmol/L who are code E87.5 positive Specificity= $d/(b+d)$ : the proportion of patients with serum potassium ≤5.5 mmol/L who are code E87.5 negative Positive predictive value= $a/(a+b)$ : proportion of patients who are code E87.5 positive with serum potassium >5.5 mmol/L Negative predictive value= $d/(c+d)$ : proportion of patients who are code E87.5 negative with serum potassium ≤5.5 mmol/L			

## Appendix C



\*serum potassium measurements that were  $<0.5$  mmol/L and  $>14$  mmol/L were not considered as these were deemed data entry errors (occurred  $< 1.0\%$  of the time).

<sup>a</sup> date of serum potassium measurement must be on the day of or 1 day after an emergency department registration date.

<sup>b</sup> date of serum potassium measurement must be between a hospital admission date and discharge date, including date of admission and discharge.

<sup>c</sup> patients were included in this cohort irrespective of hospital disposition (i.e. patients may have presented to an emergency department prior to their hospital admission or may have been directly admitted to hospital)



## **Appendix D – Figure Caption**

Change in serum potassium values among patients who had baseline pre-hospital encounter serum potassium result. Patients who were code positive had evidence of the code in the ‘all diagnoses’ format. Patients who were code negative had no such code. For both presentation to an emergency department, and at hospital admission, patients who were code positive for hyperkalemia had a significantly larger change in their serum potassium value (from baseline) than patients who were code negative. The boxes represent the interquartile range (50% of the values). The line across the box indicates the median. The star indicates the mean. The whiskers extend to the 95<sup>th</sup> and 5<sup>th</sup> percentile.