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Inpatient hospitalisation and mortality rate trends from 2004 to 2014 in the USA: a propensity score-matched case–control study of hyperkalaemia

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ABSTRACT

Objective To study the trends of hyperkalaemia in USA inpatient hospitalisation records with heart failure (HF), chronic kidney disease (CKD), acute kidney injury (AKI) and/or type II diabetes mellitus (T2DM) from 2004 to 2014 with respect to prevalence and inpatient mortality.

Design Observational cross-sectional and propensity score-matched case–control study.

Setting The National Inpatient Sample (representing up to 97% of inpatient hospital discharge records in the USA) from 2004 to 2014

Participants 120 513 483 (±2 312 391) adult inpatient hospitalisation records with HF, CKD/end-stage renal disease (ESRD), AKI and/or T2DM.

Exposure Hyperkalaemia, defined as the presence of an International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) code of '276.7' in any of the first 15 diagnostic codes.

Primary and secondary outcome measures The outcomes of interest are the annual rates of hyperkalaemia prevalence and inpatient mortality.

Results Among 120 513 483 (±2 312 391) adult inpatient hospitalisations with HF, CKD/ESRD, AKI and/or T2DM, we found a 28.9% relative increase of hyperkalaemia prevalence from 4.94% in 2004 to 6.37% in 2014 (p<0.001). Hyperkalaemia was associated with an average of 4 percentage points higher rate of inpatient mortality (1.71 post-matching, p<0.0001). Inpatient mortality rates decreased from 11.49%±0.17% to 6.43%±0.08% and 9.67%±0.13% to 5.05%±0.07% for matched cases with and without hyperkalaemia, respectively (p<0.001).

Conclusions Hyperkalaemia prevalence increased over time and was associated with greater inpatient mortality, even after accounting for presentation characteristics. We detected a decreasing trend in inpatient mortality risk, regardless of hyperkalaemia presence.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This is a large study, representing 120 513 483 (±2 312 391) inpatient discharges in the USA across 11 years.
⇒ Neither medication nor laboratory information is available in the National Inpatient Sample.
⇒ We did not study hypokalaemia separately from normokalaemia.
⇒ We overcame the inherent imbalance of characteristics between hospitalisations with versus without hyperkalaemia by performing additional analyses on a propensity score-matched dataset, which made our conclusions more robust.

INTRODUCTION

Hyperkalaemia, potassium levels above the upper limit of normal, is rare in the general population, but may be a concern for individuals with renal insufficiency, type II diabetes mellitus (T2DM) and/or congestive heart failure (HF) as a natural consequence of disease or corresponding medication use.[1] Many of the medications used to treat these comorbidities may induce hyperkalaemia either by altering the cellular shift of potassium or by impairing the kidneys' ability to excrete it.[2] Although mild hyperkalaemia may be asymptomatic, when potassium levels are very high (>6.5 mmol/L), life-threatening cardiac arrhythmias, muscle weakness and/or paralysis may occur; even mild hyperkalaemia can cause permanent damage, if left untreated.[1 3 4] Because the comorbidity burden and subsequent requirement for chronic medications has amplified in America as the population has become increasingly older, it is imperative to study the trends of hyperkalaemia in America over time.[5–7] Hence, the purpose of this paper is to study the trends of hyperkalaemia in American hospitalisation records with HF, chronic kidney disease (CKD)/end-stage renal disease (ESRD), acute kidney injury (AKI) and/or T2DM from 2004 to 2014 with respect to prevalence and inpatient mortality.

MATERIALS AND METHODS

Patient and public involvement

No patient or public involvement.

Data

Data source

The National Inpatient Sample (NIS) is the largest database developed for the Healthcare Cost and Utilization Project, comprised of approximately 20% of hospitals in the USA, housing approximately 8 million discharge records per year, allowing inferences to be made on approximately 97% of US population.[8] The NIS has a complex sample design. From 1998 to 2011, 100% of discharges were collected from 20% of US hospitals; from 2012 onward, a 20% national patient-level sample has been utilised.[9 10] To calculate national estimates, users must account for hospital clusters, stratification and sample weights (accounting for the sample design change in 2012, if performing a trend analysis).[11] The database may be used to evaluate inpatient mortality.[12]

Key variables

This cross-sectional observational study was designed to examine any hospital discharge in the NIS from 2004 to 2014 for adults (aged ≥18 years) with HF, CKD/ESRD, AKI and/or T2DM. We used methodology described in Healthcare Cost and Utilization Project (HCUP) documentation to search for diagnoses of interest, as documented with International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes, through the 15th diagnostic position. For example, if the code '428.X' was present in any of the first 15 listed diagnoses associated with the hospitalisation, we flagged the record as having HF and included it in this analysis. We modified the Elixhauser diabetes comorbidities code sets to select cases specifically with T2DM, and to combine 'complicated and uncomplicated' classes. Similarly, we identified the primary condition of interest, hyperkalaemia, by searching through the 15th diagnostic position for the ICD-9-CM code '276.7.' We were then able to calculate prevalence using the binary indicator variable for hyperkalaemia. We also incorporated information from the severity files available from NIS which contain information on Elixhauser comorbidities. The endpoint of inpatient mortality was all available on the yearly NIS core files provided from HCUP.

Data cleaning

The data required a minimal amount of cleaning prior to matching and analyses. Due to sparse categories, we combined levels of primary payor so that 'self-pay', 'no charge' and 'other' were combined into one group. We did the same for race/ethnicity, combining Asian, Native American, other and unknown. Finally, we did the same for the All-Patient Refined Diagnosis Related Groups (APR-DRG) severity variable, such that those with no loss of function and those with minor loss of function were combined into one group. Data were missing at low rates and were imputed as follows. If weekend admission was missing, we assigned a value of 0 (this occurred nearly 0%). If gender was missing, we designated female as the default—we did so because there were slightly more women in the sample, and gender was missing at a very small rate (0.03%). Median income quartile was missing at the highest rate (2.06%) and we created an imputation rule with a multivariable model using factors that were found to be significantly associated with it (race, gender, T2DM, hospital region, hospital location/teaching status, and hospital bed size).

Propensity score matching

We conducted the matched case–control portion of the study using a greedy nearest neighbour matching algorithm such that one record with hyperkalaemia was matched without replacement to the one record without hyperkalaemia having the closest propensity score (PS). We set a calliper boundary of 0.25 to achieve reasonable matches (if the closest possible match had a difference in score >0.25, the case was unmatched and excluded from analyses). Following the work of potassium-specific analyses and NIS-specific analyses, such as those by Basnet and colleagues, Tanenbaum and colleagues and Ahmed and colleagues, we created the regression model (using hyperkalaemia as the outcome) based on the following independent predictors: age, gender, race/ethnicity, median zip code income quartile, weekend admission, primary payor, smoking status, HF, CKD/ESRD, T2DM, APR-DRG severity, hypertension (HTN), obesity, hospital region, hospital location/teaching status and hospital bed size.[13–15] Because the NIS maintains each year of data in a separate file and our goal was to study trends over time (with future study of primary diagnosis), we conducted the matching according to primary diagnosis within year-specific files prior to combining the data. Doing so ensured a PS-matched dataset with balanced case–control representation for each year and primary diagnosis. To improve model convergence for the relatively small subgroup of CKD/ESRD primary diagnosis, we did not match on HTN, obesity, smoking, gender or hospital location; these factors did not differ according to hyperkalaemia presence. We excluded records with a primary diagnosis of hyperkalaemia prior to matching.

Statistical analyses

Due to the complex design of the NIS, as well as its restructuring in 2012, the calculation of summary statistics for this trend study required additional steps compared with a cross-sectional analysis. We applied specialised discharge weights provided from HCUP ('trendwt' for years 2004–2011 and 'discwt' for years 2012–2014) to calculate the statistics. We used the 'surveymeans' and 'surveyfreq' procedures in SAS to account for clustering by hospital, stratification by 'NIS stratum' and discharge record weight assignment. Categorical results are presented as per cent and SE. To compare characteristics between groups, we followed the work of Rosenbaum and Rubin, considering an absolute value of the standardised difference >0.10 to be significantly different.[16] We utilised the 'surveylogistic' procedure to evaluate a trend in prevalence over time, as

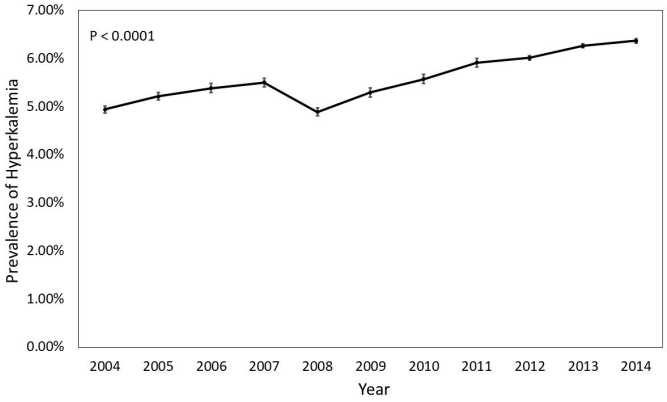

Figure 1 Prevalence of hyperkalaemia in inpatient hospitalisations including congestive heart failure, chronic kidney disease (and end-stage renal disease), acute kidney injury and/or type II diabetes mellitus.

well as to assess the significance of hyperkalaemia presence on trends in inpatient mortality rates over time.

RESULTS

Unmatched analysis

To achieve our objective regarding prevalence, we required the use of an unmatched dataset. There was a total of 24 941 608 discharge records of patients aged ≥18 years in the NIS from 2004 to 2014 with presence of CHF, CKD/ESRD, AKI or T2DM, which represent a total of 120 513 483 (±2 312 391) inpatient discharges in the USA. In this cohort, we found a total of 1 397 573 records containing hyperkalaemia, which represent a total of 6 761 577 (±149 409) discharges in the USA. This corresponds to an average annual prevalence of 5.61%, which increased over time from 4.94%±0.07% in 2004 to 6.37%±0.04% in 2014, a relative increase of 28.9% (p<0.0001, figure 1). Partly due to the large sample size, significant differences between groups were observed in every variable examined (table 1); however, the distributions of age, gender, HF and hospital characteristics were similar between those who did versus did not have hyperkalaemia. African Americans and Hispanics had a higher risk of hyperkalaemia than Caucasians. Hospitalisations including hyperkalaemia had higher rates of renal dysfunction (acute and chronic) and major/extreme loss of function (APR-DRG severity).

Inpatient mortality rates were significantly higher for cases with versus without hyperkalaemia (average absolute difference=4.0%, average relative difference=97.81%, p<0.0001), and the rate decreased non-uniformly between groups over time, decreasing at a faster rate for cases with hyperkalaemia (10.91%±0.17% to 6.23%±0.08%) than for cases without hyperkalaemia (4.81%±0.05% to 3.8%±0.03%) (p_{year}<0.0001, $p_{interaction}$<0.0001, figure 2).

Matched analysis

To achieve our objective regarding inpatient mortality rates while accounting for confounders, we performed PS matching. After matching, we had a total of 2 606 462 records, representing 12 517 269 (±174 562) hospital discharges. The unweighted records reflect the 1:1 matching (ie, 1 303 231 records in each group), but they represent an odd number of discharges due to records having unequal weights. Patient characteristics were well balanced, with standardised differences all <0.10 (table 1). Note that because we excluded cases of hyperkalaemia as the primary diagnosis for the matched analyses, the cases with hyperkalaemia and their characteristics are not identical to those in the unmatched cohort.

Inpatient mortality rates were significantly higher for cases with versus without hyperkalaemia (average absolute difference=1.71%, average relative difference=25.3%, p<0.0001), and the rate decreased uniformly between groups over time, decreasing from 11.49%±0.17% to 6.43%±0.08% for cases with hyperkalaemia and from 9.67%±0.13% to 5.05%±0.07% for cases without hyperkalaemia (p<0.0001, figure 3).

DISCUSSION

In this study, considering adult inpatient hospitalisations with HF, CKD/ESRD, AKI and/or T2DM, we found a relative increase of 28.9% in hyperkalaemia prevalence (from 4.94% in 2004 to 6.37% in 2014). We found that hospitalisations in which hyperkalaemia occurred were far more likely to be severe in nature. Accordingly, we found that the presence of hyperkalaemia was associated with a higher rate of inpatient mortality. Further, after controlling for primary diagnosis, severity of illness, comorbidities, hospital characteristics and sociodemographics, we found that the presence of hyperkalaemia continued to play a significant role in inpatient mortality risk. We also observed significant reductions in inpatient mortality over time.

Our work reiterates and extends findings from Betts and colleagues, who determined that the prevalence of hyperkalaemia among patients with CKD and/or HF increased from 4.95% to 6.35% (a relative increase of 28.2%) using insurance claims records and laboratory test results from 2010 to 2014 in the Truven MarketScan claims and encounters database.[17] The nearly 30% increase in hyperkalaemia prevalence in Betts' study, as well as in our current examination of inpatient hospitalisations may be partially explained by the ageing population, increasing comorbidity burden and need for chronic/multiple medications.[3 4] Additionally, our timeframe is large enough such that improved abilities and/or standards of documentation may have been adopted by hospitals over time.[18] For example, it is possible that the implementation of specialised tools within electronic health systems over time may have made the documentation of multiple diagnoses easier.[19] Similarly, another possible explanation is that general awareness of hyperkalaemia may have increased over time and that physicians became more likely to screen for it. For example,

Table 1 Patient characteristics of the unmatched and matched cohorts according to hyperkalaemia presence

	Unmatched cohort			Matched cohort		
	Hyperkalaemia			Hyperkalaemia		
Characteristic	Yes	No	Standardised difference	Yes	No	Standardised difference
Age group						
18–44	9.05 (0.1)	7.76 (0.07)	0.3999	8.64 (0.1)	8.14 (0.09)	0.0179
45–54	11.67 (0.09)	11.97 (0.08)	−0.0990	11.43 (0.09)	10.82 (0.09)	0.0192
55–64	18.28 (0.08)	18.4 (0.06)	−0.0426	18.09 (0.08)	16.85 (0.08)	0.0322
65–74	21.65 (0.06)	22.56 (0.05)	−0.3623	21.72 (0.06)	22.13 (0.06)	−0.0099
75+	39.35 (0.23)	39.32 (0.19)	0.0066	40.12 (0.23)	42.06 (0.22)	−0.0397
Gender (female)	49.34 (0.09)	51.79 (0.07)	−0.8118	49.43 (0.09)	49.95 (0.08)	−0.0103
Race/ethnicity						
White	53.45 (0.59)	58.94 (0.58)	−0.7165	54.23 (0.59)	55.42 (0.57)	−0.0239
Black	18.62 (0.43)	14.48 (0.33)	0.6359	18.29 (0.42)	17.79 (0.39)	0.0128
Hispanic	9.74 (0.32)	7.98 (0.26)	0.3115	9.4 (0.3)	8.99 (0.3)	0.0140
Other	18.19 (0.64)	18.6 (0.62)	−0.0517	18.08 (0.64)	17.8 (0.63)	0.0074
Heart failure	38.6 (0.16)	37.41 (0.12)	0.2958	39.26 (0.16)	39.33 (0.15)	−0.0013
CKD/ESRD	56.84 (0.18)	28.36 (0.12)	6.6531	55.42 (0.18)	54.53 (0.16)	0.0179
Acute kidney injury	49.53 (0.18)	20.12 (0.11)	6.955	51.04 (0.18)	42.31 (0.16)	0.1746
T2DM	47.28 (0.13)	60.07 (0.11)	−3.4897	46.92 (0.14)	46.69 (0.13)	0.0047
Hypertension	61.95 (0.16)	67.85 (0.12)	−1.4971	60.5 (0.16)	60.81 (0.15)	−0.0065
Obesity	11.4 (0.1)	13.92 (0.09)	−0.8082	11.93 (0.1)	11.18 (0.09)	0.0231
Smoker	7.68 (0.08)	9.69 (0.08)	−0.7077	7.58 (0.08)	6.86 (0.07)	0.0272
Primary diagnosis						
Acute kidney injury	15.01 (0.08)	2.91 (0.02)	4.1859	15.89 (0.09)	15.9 (0.1)	−0.0003
Heart failure	7.99 (0.05)	8.7 (0.04)	−0.3278	8.49 (0.05)	8.51 (0.05)	−0.0006
CKD/ESRD	0.34 (0.01)	0.1 (0)	0.2619	0.36 (0.01)	0.36 (0.01)	0.0002
Other	73.2 (0.09)	84.99 (0.05)	−3.9621	71.6 (0.09)	71.59 (0.1)	0.0003
T2DM	3.45 (0.03)	3.31 (0.02)	0.0840	3.66 (0.03)	3.65 (0.03)	0.0005
Primary payer						
Medicare	70.96 (0.22)	66.93 (0.2)	0.8573	71.07 (0.21)	72.9 (0.2)	−0.0405
Medicaid	10.44 (0.16)	9.07 (0.13)	0.3396	10.25 (0.15)	9.52 (0.14)	0.0239
Private insurance	13.48 (0.14)	17.96 (0.14)	−1.2035	13.59 (0.14)	12.89 (0.13)	0.0205
Other	5.12 (0.15)	6.03 (0.12)	−0.2395	5.09 (0.13)	4.69 (0.1)	0.0186
Zipcode income quartile						
First quartile	33.22 (0.49)	31.3 (0.44)	0.2751	32.9 (0.49)	32.95 (0.46)	−0.0011
Second quartile	27.41 (0.33)	27.78 (0.32)	−0.0646	27.32 (0.34)	27.21 (0.33)	0.0025
Third quartile	22.4 (0.29)	22.8 (0.27)	−0.0745	22.52 (0.29)	22.39 (0.28)	0.0030
Fourth quartile	16.97 (0.44)	18.11 (0.44)	−0.1720	17.26 (0.45)	17.45 (0.43)	−0.0049
Hospital region						
Northeast	17.72 (0.52)	19.39 (0.51)	−0.2331	18.12 (0.53)	18.13 (0.49)	−0.0004
Midwest	23.76 (0.58)	23.7 (0.53)	0.0088	23.17 (0.59)	23.12 (0.56)	0.0013
South	40.33 (0.74)	39.84 (0.71)	0.0574	40.54 (0.75)	41.07 (0.73)	−0.0108
West	18.18 (0.52)	17.07 (0.48)	0.1552	18.17 (0.52)	17.68 (0.5)	0.0127
Hospital setting						
Rural	11.29 (0.38)	13.1 (0.37)	−0.2952	11.16 (0.38)	11.15 (0.36)	0.0003

Continued

Table 1 Continued

Characteristic	Unmatched cohort			Matched cohort		
	Hyperkalaemia			Hyperkalaemia		
	Yes	No	Standardised difference	Yes	No	Standardised difference
Urban non-teaching	41.14 (0.7)	41.02 (0.66)	0.0146	41.56 (0.71)	41.49 (0.68)	0.0015
Urban teaching	47.57 (0.71)	45.88 (0.68)	0.2017	47.28 (0.72)	47.36 (0.7)	–0.0017
Hospital bed size						
Small	12.13 (0.31)	13.31 (0.3)	–0.2116	12.03 (0.32)	11.58 (0.28)	0.0140
Medium	25.26 (0.52)	25.23 (0.48)	0.0042	25.32 (0.53)	24.92 (0.49)	0.0093
Large	62.61 (0.61)	61.46 (0.58)	0.1475	62.64 (0.62)	63.5 (0.58)	–0.0177
Weekend admission	21.83 (0.05)	20.68 (0.04)	0.5302	21.99 (0.05)	21.15 (0.05)	0.0203
Function loss						
None/minor	0.83 (0.02)	10.25 (0.06)	–6.2509	0.76 (0.02)	0.62 (0.01)	0.0163
Moderate	16.51 (0.12)	37.44 (0.1)	–6.0681	15.39 (0.11)	14.51 (0.08)	0.0244
Major	60.75 (0.1)	39.51 (0.09)	6.7972	61.03 (0.1)	62.22 (0.08)	–0.0245
Extreme	21.91 (0.13)	12.8 (0.08)	2.4879	22.83 (0.14)	22.65 (0.12)	0.0041

Results shown as per cent (SE)
CKD, chronic kidney disease; ESRD, end-stage renal disease; T2DM, type II diabetes mellitus.

searching PubMed for the term 'hyperkalemia' yields 206 and 357 papers for 2004 and 2014, respectively.

Our findings extend those of Singer and colleagues' cross-sectional study which determined that hyperkalaemia was independently associated with greater risk of inpatient admission (80% vs 39% from patients in the emergency department with moderate hyperkalaemia vs normal potassium levels, respectively) and mortality (5.5% vs 0.8% among those with moderate hyperkalaemia vs normal potassium levels, respectively).[20] Similarly, Davis and colleagues found that having severe hyperkalaemia increased the risk of inpatient mortality by 58.5% compared with having mild hyperkalaemia (19.5% vs 12.3%).[21] Cheungpasitporn and colleagues found mild hyperkalaemia to carry an associated 22% increased risk of inpatient mortality among those with CKD, after adjusting for confounders.[22] While we do not know the severity of hyperkalaemia in our study, our results are similar in that the presence of hyperkalaemia was associated with an average 25% increase in the risk for mortality in the matched analysis and a 98% increase in the unmatched analysis. In general, hyperkalaemia's association with increased risk of mortality may simply be reflective of a more severe overall presentation, or it may contribute to death by complicating an already difficult-to-treat disease state, or even more directly by inducing life-threatening cardiac arrhythmias.[1 23] Our observation of mortality rates declining over time may be reflective of the large percentage of records with CKD in this study, as

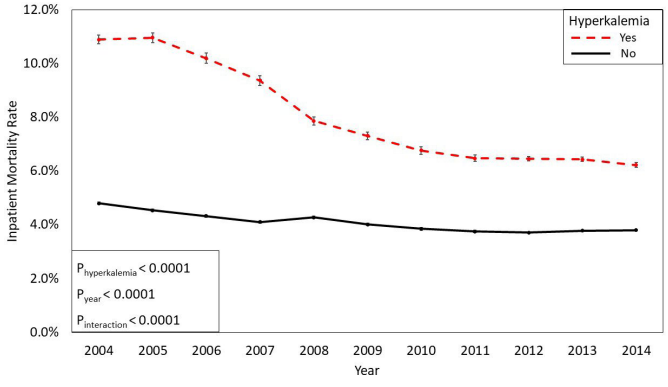

Figure 2 Annual in-hospital mortality rates (with SE bars) for the unmatched cohort according to the presence of hyperkalaemia in hospitalisations including congestive heart failure, chronic kidney disease (and end-stage renal disease), acute kidney injury and/or type II diabetes mellitus.

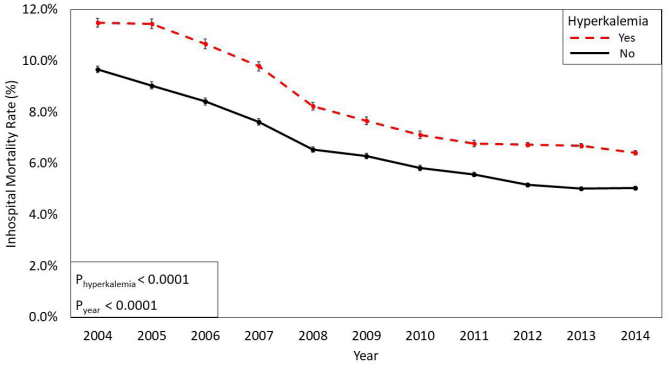

Figure 3 Annual in-hospital mortality rates (with SE bars) for the propensity score-matched cohort according to the presence of hyperkalaemia in hospitalisations including congestive heart failure, chronic kidney disease (and end-stage renal disease), acute kidney injury and/or type II diabetes mellitus.

it has been shown that CKD mortality rates in Medicare beneficiaries have declined over time but remain significantly higher than the rates observed in patients without CKD.[24] Further, the declining rates may be partially attributable to advancements in technology and medical care delivery, including medications. For example, increased use of point-of-care potassium testing could have resulted in faster delivery of care.[25]

Although we observed a significant increase in its prevalence, as well as a higher mortality rate for those who have it, preventing and treating hyperkalaemia is possible. In some cases, particularly patients with CKD at risk for chronic hyperkalaemia, a potassium-restricted diet may be beneficial.[26] For cases of drug-induced hyperkalaemia, interrupting the prescription may be a solution; however, new challenges may arise if the medication was for the management of a chronic condition, which is often true.[2] Alternatively, diuretics may be used to increase potassium excretion via urine and dialysis may be used to remove excess potassium from blood. In the setting of a hyperkalaemic emergency, an intravenous infusion of calcium and insulin may be used to both protect the heart and cause a cellular shift of potassium. Another treatment for hyperkalaemia is potassium-binding medication, which expels excess potassium through faecal matter.[27] One such drug is sodium polystyrene sulfonate (SPS), which has been used since the late 1950s, but is associated with serious gastrointestinal side effects (and even colonic necrosis in rare cases) and has a relatively low adherence rate.[28] Two additional drugs, sodium zirconium cyclosilicate and patiromer, help patients achieve and maintain normal potassium levels.[29] These have advantages over SPS in that they are associated with fewer side effects and they may be efficacious regardless of renin-angiotensin-aldosterone system inhibitors (RAASi) and/or diet.[25] These newer drugs received Food and Drug Administration approval after our study timeframe, so they do not explain our observed reduction in mortality rate; however, it is of interest to determine whether these rates have further declined since their availability. For patients taking medication for chronic diseases, incorporating a pharmacist into a team-based management approach may help protect against hyperkalaemia.[30]

The study was designed to examine any record with HF, CKD/ESRD, AKI or T2DM. Doing so provided a very large and rich dataset for studying hyperkalaemia trends in inpatient hospitalisations. Due to the broad inclusion criteria of these analyses, this work did not shed light on disease-specific inferences. It is possible that the trends observed in this overall cohort may not hold for each specific disease group. In this paper, we overcame the inherent imbalance of characteristics between hospitalisations with versus without hyperkalaemia by performing additional analyses on a PS-matched dataset, which made our conclusions more robust. Further, we conducted the PS matching within specific primary diagnoses because it is our intention to perform subgroup analyses according to primary diagnosis in future work.

Limitations of this study include that the timeframe under evaluation ended in 2014; this was due to availability of data and to maintain consistency with ICD-9-CM coding. We acknowledge that there may be additional epidemiological changes to the data since then, particularly following the introduction of newer therapies for hyperkalaemia. Hence, it may be of interest to conduct this study using more recent data. Since our interest was strictly in studying the presence or absence of elevated potassium (hyperkalaemia), our reference group was comprised of both normokalaemic and hypokalaemic patients; however, it may be of interest in the future to study them separately, as others have shown differential mortality rates.[13] Additionally, because the NIS is deidentified, it is possible that an individual may be present in the data more than once without means to identify such an occurrence; for that reason, the data are interpreted as independent hospital discharges, not as patients. Additionally, laboratory results are not available in the NIS. As such, the definition of hyperkalaemia in this study was based on its ICD code and limits our conclusions regarding potential causes of mortality, as the severity of hyperkalaemia is unknown. Hence, as with any study utilising ICD codes, our study may be subject to misclassification bias. Similarly, medications are not available in the NIS and we are unable to make inferences regarding the effects of therapies received before and/or after hyperkalaemia diagnosis. Finally, there were instances in which there was only one cluster within a stratum, so the SE could not be calculated; however, this happened in less than 1% of the data. While this work's data source represents up to 97% of US hospital discharges, more work is needed to understand whether these findings generalise to other countries.

CONCLUSION

In this large 11-year study of inpatient hospitalisations, hyperkalaemia became more prevalent and was associated with greater illness severity and inpatient mortality than hospitalisations without hyperkalaemia. Inpatient mortality rates decreased in this timeframe, regardless of hyperkalaemia presence; however, the risk of death remained higher when hyperkalaemia was present.

Contributors KMT was responsible for design, data acquisition, analyses, interpretation, drafting, critical revision, approval and accountability. RAB and LC were involved in interpretation, critical revision, approval and accountability. PAM was responsible for design, interpretation, critical revision, approval and accountability. KMT is responsible for the overall content as the guarantor.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval This research was approved by the Baylor Scott & White Research Institute's Institutional Review Board via expedited review and was found to be exempt due to being secondary research; informed consent was not required.

Provenance and peer review Not commissioned; externally peer reviewed.

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