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Hyperkalaemia among hospital admissions: prevalence, risk factors, treatment and impact on length of stay

Yalin Yu[1], Venkat N. Vangaveti[2,4], Rudolf J. Schnetler[2], Benjamin J. Crowley[2] and Andrew J. Mallett[2,3,4,5*]

Abstract

Background Hyperkalaemia is one of the common electrolyte disorders among hospital patients, affected by many risk factors including medications and medical conditions. Prompt treatment is important given its impact on patient mortality and morbidity, which can lead to negative patient outcomes and healthcare resource utilisation. This study aims to describe the prevalence, characteristics, and treatment of patients admitted to hospitals with hyperkalaemia and compare findings between patients with kidney failure on maintenance haemodialysis therapy and patients without kidney failure. It also aims to identify associations between hyperkalaemia and hospital length of stay.

Methods We undertook a retrospective cohort study on adult patients admitted to Townsville University Hospital between 1st January 2018 and 31st December 2022 ($n=99,047$). Patients were included if they had a serum potassium result of 5.1 mmol/L and above during their admission/s. Statistical analysis was conducted using several methods. A Welch's t test and Chi-square test were employed to assess differences between groups of patients with kidney failure on maintenance haemodialysis therapy and those without kidney failure. For comparison among multiple groups with varying severities of hyperkalaemia, the Kruskal-Wallis test with Mann-Whitney U test and logistic regression were used.

Results 8,775 hyperkalaemic patients were included in the study, with a mean age of 64.7 years. The prevalence of hyperkalaemia was 8.9% of patients. Risk factors for hyperkalaemia were highly prevalent among those who had the condition during their admissions. Patients with kidney failure on haemodialysis who had hyperkalaemia were, on average, 6 years younger, more often Indigenous, and experienced more severe hyperkalaemia compared to other patients without kidney failure. There was a notable difference in hyperkalaemia treatment between groups with varying degrees of hyperkalaemia severity. Hyperkalaemia was not found to be associated with prolonged hospital stay.

Conclusion Hyperkalaemia is common among hospital admissions. Patients with kidney failure on haemodialysis are at higher risk of developing severe hyperkalaemia. Treatment for hyperkalaemia was variable and likely insufficient. Timely detection and treatment of hyperkalaemia is recommended.

Keywords Hyperkalaemia, Haemodialysis, Risk factors, Treatment, Hospital length of stay

*Correspondence:
Andrew J. Mallett
Andrew.mallett@health.qld.gov.au

Full list of author information is available at the end of the article

Background

As a major intracellular cation, potassium is one of the most essential electrolytes in the human body. The potassium concentration gradient between intracellular and extracellular spaces generates cell membrane potential, which is essential for the normal functioning of the neuromuscular and cardiac conduction systems [1]. Potassium homeostasis essentially entails dynamically balancing potassium intake and excretion. The kidney, and specifically its functional unit the nephron, plays a primary role in potassium excretion. Therefore, kidney disorders that cause impairment in nephron glomerular filtration and/or tubular function can result in abnormal serum potassium levels [2]. Other medical comorbidities, including heart failure, diabetes mellitus and liver disease, have also been known to cause increased risk of hyperkalaemia [3]. Hyperkalaemia has been shown to lead to prolonged hospital stays and increased patient morbidity and mortality [4]. For patients who are on maintenance haemodialysis, an increased serum potassium level correlates with increased all-cause and cardiovascular death [5]. Therefore, preventing hyperkalaemia is crucial in improving clinical and patient outcomes.

An extensive systematic literature review conducted by Humphrey et al. (2023) [3] found that the prevalence of hyperkalaemia reported in studies has been highly variable due to differences in study populations and diagnostic criteria. There are limited studies on hyperkalaemia prevalence, risk factors and treatment in Australian hospital inpatient population. Studies on hyperkalaemia in kidney failure (KF) patients undergoing haemodialysis are even more lacking. In this study, we sought to determine the prevalence, patient characteristics, risk factors and treatment of hyperkalaemia in hospitalised patients at Townsville University Hospital (TUH), a tertiary hospital in northern Queensland. We placed a specific focus on patients with KF receiving haemodialysis and compared their findings to those of patients without KF. Additionally, we examined the association between hospital length of stay (LOS) and hyperkalaemia severity.

Methods

The study was conducted at TUH, a tertiary hospital in northern Queensland with a referral catchment of almost 700,000 people. The project was approved by the hospital's Audit, Quality and Innovation Review (AQUIRE) panel (approval number THHSAQUIRE1573) which incorporates Townsville Hospital and Health Service Human Research and Ethics Committee exemption review and approval. This included approval for waiver of consent as per the Townsville Hospital and Health Service Human Research and Ethics Committee and the relevant legislation (Queensland Hospital and Health Boards Act (Sect. 150; 2011)). Patients were included if they were admitted to TUH as an inpatient between 1st January 2018 and 31st December 2022 and had at least one episode of serum potassium result of 5.1 mmol/L or above. Patients were excluded if they were less than 18 years old. Relevant data was extracted from iEMR (integrated electronic medical record) by the TUH Research Data Lab. Covariates recorded included age, sex, indigenous status, serum potassium level, eGFR (estimated glomerular filtration rate, CKD-EPI equation), selected medical conditions, Charlson Comorbidity Index (CCI) score, medication orders, haemodialysis treatments, and LOS. The CCI was calculated based on the presence of specific comorbidities, identified using the ICD-10 codes [6]. Medical conditions associated with an increased risk of hyperkalaemia were extracted using the ICD-10 codes and included diabetes mellitus, hypoaldosteronism, congestive heart failure, cirrhosis and KF. Chronic kidney disease was not included as a covariate of interest, as kidney failure was instead studied in more detail, with a comparison between patients with KF on haemodialysis and patients without KF. Medications included beta-blockers, angiotensin-converting enzyme inhibitors (ACEi), angiotensin receptor blockers (ARB), potassium-sparing diuretics, trimethoprim, nonsteroidal anti-inflammatory drugs (NSAIDs), digoxin and potassium supplements [7]. Medications recognised as a treatment for hyperkalaemia included nebulised salbutamol, calcium gluconate, sodium bicarbonate, intravenous insulin (Novorapid, Actrapid), and Resonium [8]. Patiromer and sodium zirconium cyclosilicate were not used in inpatient or outpatient settings at Townsville University Hospital and therefore were not included in the study. Orders made for these medications within 24 h after biochemical diagnosis of hyperkalaemia and haemodialysis undertaken within 72 h were reported as interventions undertaken for hyperkalaemia. For patients with multiple eligible admissions during the study period, the admission episode during which the patient had the highest recorded serum potassium level was included. Hyperkalaemia was defined to be a serum potassium level of 5.1 mmol/L and above. Mild hyperkalaemia was defined as a serum potassium level of 5.1–5.9 mmol/L, moderate hyperkalaemia as 6.0-6.4 mmol/L and severe hyperkalaemia as 6.5 mmol/L and above [7]. LOS was measured for all inpatient admissions of all the patients included in the study.

Descriptive statistics were used to compare patient characteristics, risk factors, treatment for hyperkalaemia and LOS. Continuous variables were reported as median and interquartile range. Categorical variables were reported as counts and percentages. For statistical analysis to determine associations between patients with KF on HD and patients without KF, Welch's t-test was used for continuous variables due to unequal variances (based

on Levene's test), and Chi-square test was applied for categorical variables. For hospital LOS, normality of data was evaluated, measuring skewness and kurtosis. Kruskal-Wallis test with Mann-Whitney post-hoc test were conducted as a univariate analysis to determine effect of hyperkalaemia severity on hospital LOS. Multivariate analysis was also conducted using logistic regression to ascertain the effect of multiple factors on hospital LOS. A p value of less than 0.05 was determined to be a statistically significant result. Statistical analysis was conducted using IBM Corp. Released 2023. IBM SPSS Statistics for Windows, Version 29.0.2.0 Armonk, NY: IBM Corp.

Table 1 Patient characteristics, risk factors and treatment for hyperkalaemia

Patient variables	Total patients
Overall cohort (n)	8775
Age (years), mean (SD)	64.7 (17.2)
Sex (n, %)	
Female	3442 (39.2)
Male	5333 (60.8)
Indigenous status (n, %)	
Aboriginal and/or Torres Strait Islander	1388 (15.8)
Non-Indigenous	7387 (84.2)
Serum potassium level (mmoL/L), (n, %)	
5.1–5.9 (Mild)	6877 (78.4)
6.0-6.4 (Moderate)	996 (11.4)
6.5 and above (Severe)	902 (10.3)
eGFR, mean (SD)	63.8 (24.4)
Comorbidities predisposing to hyperkalaemia (n, %)	
Diabetes mellitus	2918 (33.3)
Hypoaldosteronism	1 (0)
Congestive heart failure	489 (5.6)
Cirrhosis	167 (1.9)
Medications predisposing to hyperkalaemia (n, %)	
beta-blocker	2579 (29.4)
ACE-i/ARB	3026 (34.5)
Spironolactone	804 (9.2)
Trimethoprim	199 (2.3)
NSAIDS	2844 (3.2)
Digoxin	428 (4.9)
Potassium supplements	1525 (7.4)
Treatment for hyperkalaemia (n, %)	
IV Calcium gluconate	218 (2.5)
PO Resonium	1017 (11.6)
IV Actrapid	460 (5.2)
IV Novorapid	1227 (14.0)
Inhaled salbutamol	1474 (16.8)
IV Sodium bicarbonate	458 (5.2)
Haemodialysis	101 (1.2)

Legend: This table summarises the demographic and clinical characteristics of patients, including risk factors associated with hyperkalaemia and the corresponding treatments administered. Data include age, gender distribution, comorbidities, medications, and treatments

Results

99,047 adult patients were admitted to TUH during the study period. Of these patients, 8,775 (8.9%) had at least one episode of hyperkalaemia and were included in the study, among which 214 patients (2.4%) had KF and were on haemodialysis. Patient characteristics, risk factors and treatments are outlined in Table 1. The mean age of the study population was 64.7 years, with the majority being male (60.8%) and 15.8% identifying as Aboriginal and/or Torres Strait Islander. 78.4% of the hyperkalaemia results were in the mild range, with 11.4% in the moderate range and 10.3% in the severe range. The average eGFR of the total study group was 63.8 mL/min/1.73m^2 (CKD-EPI). 38.8% of the patients had at least one medical comorbidity that predisposed them to hyperkalaemia. 54.3% were prescribed at least one medication that increases the risk of hyperkalaemia. 3,061 patients (34.9%) were prescribed treatment for hyperkalaemia.

KF receiving haemodialysis patients compared to non-KF patients

Comparing patients with KF on haemodialysis to the rest of the patients, as detailed in Table 2, there was a statistically significant difference in a wide range of patient variables between these two groups. The median age of the patients with KF on haemodialysis was 61 years compared to 67 years in the other patient group ($p<0.001$). The majority of the patients in both patient groups were males. 53.7% of patients with KF on haemodialysis identified as Aboriginal and/or Torres Strait Islander, compared to 14.9% in the other group ($p<0.001$). Hyperkalaemia severity was also very different between the two groups ($p<0.001$). Among patients with KF on haemodialysis, severe hyperkalaemia (45.8%) was almost twice as common as mild and moderate hyperkalaemia (29.9 and 24.3%, respectively). The findings were the opposite in the other group, where most hyperkalaemia results were mild (79.6%), and severe hyperkalaemia only occurred in 9.4% of the patients. In terms of risk factors, the prevalence of diabetes mellitus was shown to be statistically different between the two groups ($p<0.001$). However, diabetes mellitus is a potential confounder given that it is a risk factor for KF. There were different percentages of patients being prescribed beta-blockers, ACEi/ARBs, Spironolactone and potassium supplements between the two patient groups ($p<0.05$).

Treatment of hyperkalaemia

As outlined in Table 3, more patients with severe hyperkalaemia were prescribed treatment to reduce potassium levels than those with mild and moderate hyperkalaemia. In patients with moderate to severe hyperkalaemia, oral Resonium was the most commonly prescribed treatment, with over 20% of patients receiving the medication. In

Table 2 Comparison of patient characteristics and risk factors for hyperkalaemia between the two study groups

Patient variables	Patients with KF on HD	Patients without KF	*P* value
Overall cohort (n)	214	8561	
Age (years), median (IQR)	61 (50–71)	67 (55–78)	< 0.001
Sex (n, %)			0.01
Female	102 (47.7)	3340 (39.0)	
Male	112 (52.3)	5221 (61.0)	
Indigenous status (n, %)			< 0.001
Aboriginal and/or Torres Strait Islander	115 (53.7)	1273 (14.9)	
Non-Indigenous	99 (46.3)	7288 (85.1)	
Serum potassium level (mmol/L), (n, %)			< 0.001
5.1–5.9 (Mild)	64 (29.9)	6813 (79.6)	
6.0-6.4 (Moderate)	52 (24.3)	944 (11.0)	
6.5 and above (Severe)	98 (45.8)	804 (9.4)	
eGFR, median (IQR)	8 (7.0–9.0)	82 (56–89)	< 0.001
Comorbidities predisposing to hyperkalaemia (n, %)			
Diabetes mellitus	141 (65.9)	2777 (32.4)	< 0.001
Hypoaldosteronism	0	1	N/A
Congestive heart failure	11 (5.1)	478 (5.6)	0.78
Cirrhosis	5 (2.3)	162 (1.9)	0.64
Medications predisposing to hyperkalaemia (n, %)			
beta-blocker	93 (43.5)	2486 (29.0)	< 0.001
ACEi/ARB	47 (22.0)	2979 (34.8)	< 0.001
Spironolactone	6 (2.8)	798 (9.3)	0.001
Trimethoprim	0	199 (2.3)	N/A
NSAIDS	80 (37.4)	2764 (32.2)	0.12
Digoxin	8 (3.7)	420 (4.9)	0.43
Potassium supplements	14 (6.5)	1511 (17.6)	< 0.001

Legend: This table compares demographic and clinical characteristics, as well as risk factors associated with hyperkalaemia, between patients with kidney failure undergoing haemodialysis and patients without kidney failure. Data include age, gender distribution, comorbidities, medications, and relevant risk factors

Table 3 Treatment of hyperkalaemia in patient groups with different hyperkalaemia severity

Treatment	Mild hyperkalaemia (5.0-5.9) (n, %)	Moderate hyperkalaemia (6.0-6.4) (n, %)	Severe hyperkalaemia (6.5 and above) (n, %)	*P* value
Resonium	569 (8.3)	246 (24.7)	202 (22.4)	< 0.001
salbutamol	1067 (15.5)	218 (21.9)	189 (21.0)	< 0.001
IV Novorapid	856 (12.4)	200 (20.1)	171 (19.0)	< 0.001
IV Actrapid	141 (2.1)	161 (16.2)	158 (17.5)	< 0.001
Calcium gluconate	59 (0.9)	72 (7.2)	87 (9.6)	< 0.001
Sodium bicarbonate	300 (4.4)	78 (7.8)	80 (8.9)	< 0.001
Haemodialysis	35 (0.5)	20 (2.0)	46 (5.1)	< 0.001

Legend: This table summarises the treatment protocols for hyperkalaemia across patient groups categorised by severity levels (mild, moderate, severe). Columns include medications used and hyperkalaemia severities

contrast, only 8.3% of patients with mild hyperkalaemia were prescribed oral Resonium. In patients with mild hyperkalaemia, nebulised salbutamol was the most frequently prescribed treatment, with 15.5% of patients receiving the medication. 5.0% of patients with severe hyperkalaemia received haemodialysis, which is significantly higher in proportion compared to those with mild or moderate hyperkalaemia.

Length of stay

For the duration of the study period, all episodes of care (EOC) that the study cohort had were extracted, totalling 108,581 episodes. When multiple potassium levels were recorded during an EOC, the EOC was categorised using the highest potassium level recorded. In univariate analysis, the median LOS was compared across groups of EOC with normokalaemia, mild, moderate, and severe hyperkalaemia, as outlined in Table 4. It was found that the median LOS was significantly shorter for EOC during which there was no hyperkalaemia compared to EOC

Table 4 Length of hospital stay in groups of EOC categorised by hyperkalaemia severity

Median LOS (days) Median (IQR)	Normokalaemia	Mild hyperkalaemia	Moderate hyperkalaemia	Severe hyperkalaemia	*P* value
All EOC for all the patients	3.67 (1.13–8.54)	6.63 (2.00-14.58)	7.54 (1.49–17.92)	6.88 (2.04–17.21)	< 0.001
All EOC for patients with KF on HD	5.96 (3.00-15.42)	6.83***^ (3.00-15.42)	9.17 (3.92–17.92)	7.67 (2.96–21.50)	< 0.001
All EOC for patients without KF	3.58 (1.83–14.63)	6.67 (1.21-18.00)	7.00 (1.21-18.00)	6.85 (1.67–16.65)	< 0.001

Legend: This table presents the median length of hospital stay (LOS) for different groups of EOC categorised by hyperkalaemia severity. Severity categories include normokalaemia, mild hyperkalaemia, moderate hyperkalaemia, and severe hyperkalaemia. Data are presented in days. ***: Significant difference in LOS between EOC with mild versus moderate hyperkalaemia ($p < 0.001$). ^: Significant difference in LOS between EOC with mild versus severe hyerpakaelmia in KF patients on HD ($p = 0.02$)

with any degree of hyperkalaemia ($p < 0.001$). However, in multivariate logistic regression analysis, adjusting for confounding factors such as comorbidities (measured through CCI) and patient demographics (age and sex), hyperkalaemia severity did not increase the risk of prolonged hospital stay (defined as more than 9 days) (odds ratio, 1.13; 95% CI, 0.98–1.30). The 9-day threshold was established based on the median LOS plus one standard deviation for EOCs without kidney failure, to provide a clinically relevant cutoff for prolonged hospital admission. The median was used as the measure of central tendency due to the non-normal distribution of LOS data, to capture the central trend more accurately.

Discussion

In this study, we comprehensively reviewed the experience of hyperkalaemia in a large tertiary hospital in northern Queensland, Australia. The prevalence of hyperkalaemia in this study was 8.9%, which is lower compared to other studies. In 40 adult studies conducted in similar hospital inpatient settings and adopting the exact definition as our study (serum potassium greater than and including 5.1 mmol/L), the prevalence of hyperkalaemia was 12.5%.[3]

Prevalence of hyperkalaemia was higher among males than females, which is consistent with other studies.[3] 15.8% of total patients with hyperkalaemia were Indigenous. Among patients with KF on haemodialysis, the figure is even higher, with more than half of the patients being Indigenous. There is no similar study for comparison. However, in a recent Australian study on potassium abnormalities in patients with chronic kidney disease [8], Indigenous people were identified as more likely to have hyperkalaemia, which is consistent with our study findings.

Hyperkalaemia is more likely to be moderate to severe in patients with KF on haemodialysis. 45.8% of hyperkalaemia results were in the severe range in this patient group, whereas only 10.3% of the other group had severe hyperkalaemia. Hyperkalaemia in patients on HD can be influenced by a variety of factors including inter-dialytic interval, non-compliance with dialysis and access malfunction [9]. Hyperkalaemia has been proven to cause increased mortality in patients on haemodialysis compared to patients with normal serum potassium levels, with risks of adverse outcomes increasing with the severity of hyperkalaemia [10, 11]. Further studies can be done to assess the adequacy of monitoring and preventing hyperkalaemia in this patient group.

The prevalence of diabetes mellitus was shown to be statistically different between the two study groups. 65.9% of the patients with KF on haemodialysis had diabetes mellitus, which is higher than the percentage of people among the rest (32.4%). Diabetes mellitus status is a potential confounder given it is one of the very common causes of kidney failure. Poor glycaemic control increases the risk of mortality in diabetic patients on haemodialysis [12]. Further studies can be done to assess these patients' glycaemic control and determine relationships between HbA1C and hyperkalaemia. The prevalence of other medical comorbidities was independent of whether the patient was on haemodialysis.

43.5% of the patients with KF on haemodialysis were taking beta-blockers, which is much higher than the percentage of patients who are not on haemodialysis (29.0%). Current study recommends beta-blocker use in patients with advanced chronic kidney disease and heart failure with reduced ejection fraction [13]. There is no existing study on the impact of beta-blocker use in patients with atrial fibrillation and chronic kidney disease. There have been inconsistent opinions on the risks and benefits of beta-blocker use in chronic dialysis patients, with most existing studies suggesting beta-blockers, which are cardio-selective and highly dialysable, can be beneficial [14]. Given that a large percentage of our patient group was on beta-blockers, the specific drug option should be carefully considered. A considerable percentage of the patients were on NSAIDs in both patient groups (37.4% of the patients who had KF on HD and 32.2% of the rest of the patients). Studies quantifying NSAID use in dialysis patients are lacking. In patients with KF, NSAID use is associated with dialysis commencement and increased mortality [15, 16]. There is a lack of studies on predictors of hyperkalaemia in the general population when

prescribed NSAIDs. However, studies have shown NSAID initiation can cause an increased risk of hyperkalaemia in multiple patient cohorts, including in the elderly population [17], in people with low body mass index and when concomitantly used with ACEi [18]. Therefore, NSAIDs should be prescribed with caution, and more frequent monitoring of electrolytes and kidney function can be considered after initiation of NSAIDS.

34.1% of patients with any degree of hyperkalaemia and 41.7% of those with moderate to severe degree of hyperkalaemia received treatment for hyperkalaemia. 42.2% of patients with severe hyperkalaemia received treatment, including haemodialysis, which suggests that patients with severe hyperkalaemia were most treated. However, compared to similar studies, our cohort appeared to be under-treated. In an Australian emergency department study [19], 66.1% of the patients presented to ED with moderate or severe hyperkalaemia received one or more medications to lower potassium levels. Hyperkalaemia treatment depends on several factors, including the severity of hyperkalaemia, coexisting medical conditions, patient symptoms and electrocardiogram changes [7]. Electrocardiogram changes were not included in the study due to the current limitation of the iEMR construct. Further study is needed to investigate barriers to standardised hyperkalaemia treatment and the treatment response to hyperkalaemia, with patients' clinical status and medical background considered at the time of the events.

Our study found that hyperkalaemia is not independently linked with a prolonged hospital stay. This finding is different compared to the two other studies that reported a significant association between hyperkalaemia and longer hospital admission. A retrospective cohort study of 75,555 patients with chronic kidney disease (CKD) [20] and an observational study on dialysis-dependent patients [21] both found that the length of stay across all hospitalisations was longer for patients with hyperkalaemia. However, the CKD study focused primarily on the severity of hyperkalaemia and did not adjust for potential confounders. In our study, the univariate analysis suggested that hyperkalaemia is associated with longer length of stay of stay. However, after adjusting for key factors, including age, gender and the Charlson Comorbidity index scores, this association was no longer statistically significant. Our findings highlight the importance of considering comorbidities and other patient factors when assessing the impact of hyperkalaemia on patient outcomes. There is a notable lack of studies on the association between hyperkalaemia severity and LOS. However, several studies have revealed a significant association between severe hyperkalaemia and higher mortality rates in patients with chronic kidney disease [10, 22, 23]. Further studies can be conducted on the outcomes of the study cohort utilising other clinical parameters including mortality rate and Intensive care unit admissions. This will not only identify associations between LOS and other parameters, but also provide a more comprehensive understanding of the topic.

The strengths of this study include the large patient sample size and its near complete capture of the healthcare use in a large geographical area, given that TUH was the only tertiary hospital in Northern Queensland and there were limited health services in the region. The electronic medical records provided clear documentation of patient details and pathology results, which significantly increased data accuracy. It is one of the largest studies in Australia on the experience of hyperkalaemia during hospital admissions. It is also the first Australian study to identify relationships between hospital length of stay and severity of hyperkalaemia.

There are several limitations in this study. The study was conducted in a single facility, so the results may not represent other patient cohorts. As a study relying on data recorded in the past, there are general limitations associated with this type of study due to falsely recorded or absent data. We included selected categories of medications associated with increased risk of hyperkalaemia, with an aim to provide a broad overview of hyperkalaemia risk factors in the population. However, it is not an exhaustive list. For instance, we did not include angiotensin receptor-neprilysin inhibitors, such as sacubitril with valsartan, or mineralocorticoid antagonists other than spironolactone, as their use is less widespread compared to traditional ACE inhibitors and ARBs. Treatment of hyperkalaemia was inadequately reported. Although medication orders made within 24 h after the biochemical diagnosis of hyperkalaemia were extracted in the hope of capturing all treatment prescribed, the actual therapeutic intent for the medications was a complex challenge to identify. The results likely included medications that were prescribed for other reasons, rather than targeted at hyperkalaemia, which could dilute specificity of the findings. In addition, due to the current limitations of iEMR, electrocardiogram findings cannot be extracted from the system electronically. Collection of these data would require a manual review of all patient charts, which was not feasible given the significant size of patient population. Therefore, these information were not included in the study. The future evolution of iEMR may allow for electronic collection of such information. Or smaller-scale studies which could facilitate manual review of patient charts can be considered.

Conclusion

Hyperkalaemia is a common condition among hospitalised patients at TUH. Risk factors for hyperkalaemia were highly prevalent among those who had the condition

during their admissions. Patients with kidney failure on haemodialysis who had hyperkalaemia were found to be younger, had a higher percentage of the Indigenous population, and experienced more severe hyperkalaemia results compared to the rest of the patients. This necessitates more frequent blood chemistry monitoring and medication reviews in these patients. The variability and likely insufficiency of treatment for hyperkalaemia are concerning. Further studies are needed to investigate the adequacy of potassium monitoring and control. Importantly, hyperkalaemia was not found to have an impact on prolonged hospital stay.

Abbreviations

ACEi	Angiotensin–converting enzyme inhibitors
ANOVA	Analysis of variance
ARB	Angiotensin receptor blockers
CCI	Charlson comorbidity index
EOC	Episodes of care
eGFR	Estimated glomerular filtration rate
iEMR	Integrated electronic medical record
KF	Kidney failure
LOS	Length of stay
NSAIDS	Non–steroidal anti–inflammatory drugs
TUH	Townsville university hospital

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Author contributions
A.M., Y.Y. and V.V. conceptualised the study and undertook ethical approvals. R.S. and B.C. undertook data extraction, Y.Y. and V.V. undertook data analysis. A.M. and Y.Y. contributed to the study design and interpretation. Y.Y. drafted the manuscript with all co-authors providing input, review and edits. Authors had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. All authors read and approved the final manuscript.

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Data availability
The datasets generated and/or analysed during the current study are not publicly available due to restrictions related to participant confidentiality and privacy concerns, but are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This project was approved by Townsville University Hospital's Audit, Quality and Innovation Review (AQUIRE) panel (approval number THHSAQUIRE1573) which incorporates Townsville Hospital and Health Service Human Research and Ethics Committee exemption review and approval. This included approval for waiver of consent as per the Townsville Hospital and Health Service Human Research and Ethics Committee and the relevant legislation (Queensland Hospital and Health Boards Act (Sect. 150; 2011)).

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Internal Medicine, Townsville University Hospital, Douglas, QLD, Australia
[2]Townsville Institute of Health Research and Innovation, Townsville University Hospital, Douglas, QLD, Australia
[3]Department of Renal Medicine, Townsville University Hospital, Douglas, QLD 4029, Australia
[4]College of Medicine and Dentistry, James Cook University, Douglas, QLD, Australia
[5]Institute for Molecular Bioscience, The University of Queensland, St Lucia, QLD, Australia

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