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Original Article

Intensive care admissions for adults with treated kidney failure in Australia: A national retrospective cohort study

Dominic Keuskamp, PhD [a, b, *], Christopher E. Davies, PhD [a, b], Paul J. Secombe, BMBS (Hons) MClinSc FCICM [c, d, e], David V. Pilcher, MBBS MRCP(UK) FRACP FCICM [d, e, f], Shaila Chavan, MSPH [d, e], Sarah L. Jones, MBChB (Hons) MRCP(UK) DICM(UK) FCICM FRACP [g, h, i], Benjamin E. Reddi, MA PhD FRCP(UK) FCICM [b, j], Stephen P. McDonald, MBBS (Hons) PhD FRACP [a, b, k]

[a] *Australia and New Zealand Dialysis and Transplant (ANZDATA) Registry, South Australian Health and Medical Research Institute (SAHMRI), Adelaide, South Australia, Australia;* [b] *Faculty of Health and Medical Sciences, University of Adelaide, Adelaide, South Australia, Australia;* [c] *Intensive Care Unit, Alice Springs Hospital, Alice Springs, Northern Territory, Australia;* [d] *Australian and New Zealand Intensive Care Research Centre, School of Public and Preventive Medicine, Monash University, Melbourne, Victoria, Australia;* [e] *The Australian and New Zealand Intensive Care Society (ANZICS) Centre for Outcomes and Resources Evaluation, Prahran, Victoria, Australia;* [f] *Department of Intensive Care, Alfred Hospital, Melbourne, Victoria, Australia;* [g] *Intensive Care Unit, Northern Health, Epping, Victoria, Australia;* [h] *Department of Nephrology, Northern Health, Epping, Victoria, Australia;* [i] *Department of Intensive Care, Austin Health, Heidelberg, Victoria, Australia;* [j] *Intensive Care Unit, Royal Adelaide Hospital, Adelaide, South Australia, Australia;* [k] *Central and Northern Adelaide Renal and Transplantation Services (CNARTS), Royal Adelaide Hospital, Adelaide, South Australia, Australia*

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ABSTRACT

Objective: Limited data are available on intensive care unit (ICU) admissions for adults receiving kidney replacement therapy (KRT – dialysis or transplantation) in Australia. Our aim is to characterise admissions for patients receiving long-term dialysis and kidney transplant recipients relative to the general intensive care population in Australia.

Design: Retrospective registry-based data linkage cohort study.

Setting: All ICUs in Australia that reported to the Australian and New Zealand Intensive Care Society Adult Patient Database, 1 January 2018–31 December 2020.

Participants: All admissions were included. Data were deterministically linked to the Australia and New Zealand Dialysis and Transplant (ANZDATA) Registry. Subgroups analysed were defined by sex, age, admission type, APACHE III-j diagnostic category, diabetes status, body mass index (BMI), dialysis modality, dialysis vintage, and kidney transplant vintage.

Outcome measures: Admission to ICU for patients receiving KRT at the time of admission (as reported to the ANZDATA Registry).

Results: Patients receiving long-term dialysis prior to admission and those with a kidney transplant numbered 2826 (0.6% of all admissions) and 1194 (0.3%), respectively. Age-sex standardised admission rates relative to the non-KRT cohort (n = 438,271 or 99.1%) were highest for long-term dialysis patients (relative rate 10.18 [95% CI: 9.46,10.93]) and associated with diabetes and sepsis, cardiovascular and respiratory diagnoses.

Conclusions: Rates of ICU admission for people receiving long-term dialysis or kidney transplantation were many times higher than the general population, with particularly increased relative risk among younger age groups and for key medical diagnoses. Given the burden on patients and health services, exploration of strategies to reduce this risk is important.

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* Corresponding author at: Australia and New Zealand Dialysis and Transplant Registry, Australia.
E-mail address: dominic@anzdata.org.au (D. Keuskamp).

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1. Introduction

In Australia, one in three adults is at risk of chronic kidney disease (CKD) which if untreated may lead to kidney failure (KF) and consideration of kidney replacement therapy (KRT), i.e. long-term dialysis or kidney transplantation (KT).[1] People with KF live with an increased burden of comorbidities owing to general factors (e.g. diabetes mellitus, hypertension) and KF-specific factors (e.g., volume overload, shunt due to arteriovenous fistulas).[2] They present to intensive care at a higher rate than the general population, owing to the underlying causes of their CKD or its complications.[3,4] While long-term dialysis or KT sustains life, cardiovascular complications are common and both treatments increase patients' susceptibility to infection.[5,6]

The prevalence of adults with KF treated with KRT in Australia is projected to increase to approximately 37,000 by 2030, most rapidly among people over 60 years of age.[7] Greater comorbidity is also anticipated, associated with the rise of chronic disease in the general population and accelerating demand for critical care. Clinical and technological advances in critical care medicine, in conjunction with rising community expectations are also likely to lead to increasing numbers of critically ill patients with CKD and KF. Conversely, some have argued that clinical perceptions of risk associated with the admission of KRT patients, perhaps influenced by mortality associated with acute kidney injury (AKI), have restricted access to critical care for the KRT population.[8,9]

Limited data are available on admission trends for KRT cohorts in Australia[8,10] and they are not generalisable to the wider national population.[11,12] Worldwide, the examination of large cohorts is rare,[2] and the specific consideration of KT recipients even more so.[4] Contemporary estimates of the recent burden of critical illness, risk of admission, and case mix are therefore critical to inform patients, clinicians, and facilitate accurate assessment of the requirement for services and capacity planning. This study aimed to characterise ICU admissions among adults receiving KRT at the time of admission in a retrospective population-based data linkage cohort study, conducted between two clinical quality registries.

2. Methods

2.1. Ethics approval

Ethics approval was obtained from the University of Adelaide Human Research Ethics Committee (H-2020-206). Data from ANZDATA were used with approval from the Central Adelaide Local Health Network Human Research Ethics Committee (HREC Reference number HREC/17/RAH/408, CALHN Reference number, R20170927). ANZICS CORE Management Committee granted access to the ANZICS APD following standing protocols on 07/10/2020.

2.2. Study design and setting

The study population comprised adult (aged 18 years or older) first admissions to an intensive care unit in Australia between January 2018 and December 2020, as reported to the Australian and New Zealand Intensive Care Society (ANZICS) Adult Patient Database (APD), managed by the ANZICS Centre for Resource Outcome and Evaluation (CORE). The ANZICS APD was established in 1993 and 170 (94%) Australian adult ICUs contributed in the study period. As the remainder were rural and small private units only, 98% coverage of all admissions was achieved.[13]

Adults receiving KRT at the time of admission were identified from data linkage between the ANZICS APD study population and Australian resident patients from the Australia and New Zealand Dialysis and Transplant (ANZDATA) Registry. The ANZDATA Registry was established in 1977 and captures data from all people commencing and receiving dialysis (defined by the intention to treat being long-term) or with KT (together a prevalent population of approximately 35,000 in the study period).[14] Cases of acute kidney injury are excluded. Data are collected in real time and via an annual unit survey. Coverage in Australia is considered near universal, with all units fully reporting in the study period and only small numbers of patients opt out or are reported late in subsequent years. While the ANZICS APD and the ANZDATA Registry each collect data from Australia and New Zealand, only data from Australia were included in this study.

2.3. Data linkage and outcomes

Data linkage was undertaken specifically to achieve the primary outcome of this study, namely the rates of ICU admissions among adults receiving KRT for KF at the time of admission in Australia. While the ANZICS APD has predefined coding for some of these patients (defined as 'receiving chronic haemodialysis or peritoneal dialysis'), it does not record the duration of dialysis, nor does it identify patients who have received KT.

A statistical linkage key (SLK-581) was introduced to the ANZICS APD in mid-2017 and was adopted almost universally by 2020 (95% of admissions in 2018, 97% in 2019, and 99.7% in 2020); therefore, 2018 was chosen as the first year for this study.[15] Approvals were sought in 2021 for the most recent available data at the time, to the end of December 2020. An SLK-581 was generated for prevalent KRT patients in 2018–2020 sourced from the ANZDATA Registry (n = 34,503) and deterministic matching with all patients in the ANZICS APD population with an SLK-581 (n = 442,369) was undertaken by a third party, SA-NT DataLink (Fig. 1).

Data on admission date, type, diagnosis, demographics, comorbidity, and body mass index (BMI) were extracted from the ANZICS APD. Data on the modality of long-term dialysis at admission and dates of KRT commencement were extracted from the ANZDATA Registry. Both registries contain data variables that are predefined according to their respective data dictionaries.[16,17]

2.4. Analysis

Among the linked patients, cohorts for analysis were defined as either of two KRT modalities, i.e. adults receiving long-term dialysis or those with a functioning KT (or hereafter 'transplant'), with KRT commencing at least the day before ICU admission (Fig. 1). These were compared with the population not receiving KRT at the time of their admission ('Non-KRT'). All rates were calculated for the period 2018–2020, with the denominator being the sum of the annual prevalent populations for the respective cohorts. Data were sourced from the Australian Bureau of Statistics for calculation of the non-KRT denominators.[18] To understand the data linkage in retrospect more clearly, estimated glomerular filtration rate (eGFR) using the 2009 CKD-EPI creatinine equation was calculated for all patients coded with what is termed 'chronic renal failure' (defined as 'receiving chronic haemodialysis or peritoneal dialysis') in the ANZICS APD. Severity of CKD was classified using eGFR according to the KDIGO (Kidney Disease: Improving Global Outcomes) CKD staging system, in which Stage 5 is KF.[19]

Demographics, comorbidities, and other characteristics at admission were described with percentages or medians and chi-square or Kruskal-Wallis testing, as appropriate to the type and distribution of the data. A modified APACHE (Acute Physiology and

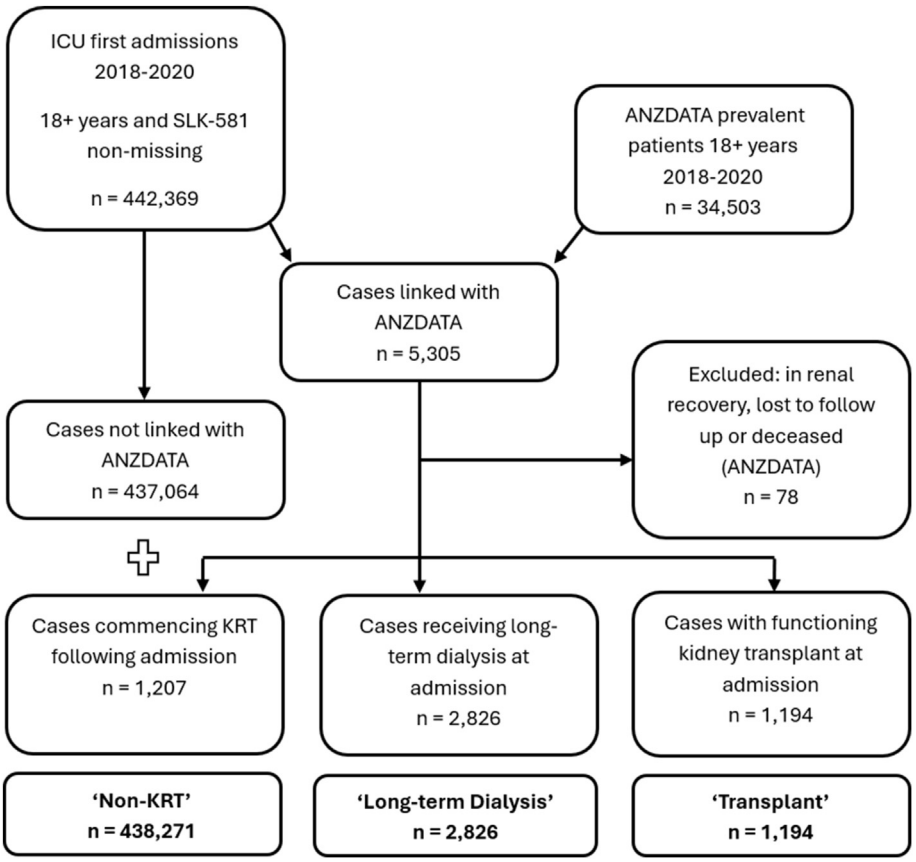

Fig. 1. Flow diagram of case inclusion.

Chronic Health Evaluation) III-j score was included, which removed those components strongly associated with the KRT cohorts—creatinine, urine output and AKI—for a less biased comparison of illness severity across the cohorts. Incidence rate ratios (IRRs, relative to the non-KRT population) were calculated within the long-term dialysis and KT populations by sex and age group (18–39, 40–49, 50–59, 60–69 and ≥70 years) with confidence intervals estimated using a binomial model.

Admission rates were age-sex-standardised to the adult Australian estimated resident population in 2001[20] and stratified by groups defined by admission type, APACHE III-j diagnostic category, diabetes status, BMI (<25 kg/m^2, 25–30 kg/m^2 kg/m^2, ≥30 kg/m^2), dialysis modality (facility haemodialysis [HD], i.e. hospital or satellite unit; home HD; peritoneal dialysis [PD]), dialysis vintage (commencement <30 days before admission, ≥30 days to 1 year, ≥1 year to 2 years, ≥2 years to 3 years, ≥3 years), and transplant vintage (<30 days before admission, ≥30 days to 1 year, ≥1 year to 5 years, ≥5 years to 10 years, ≥10 years). Relative admission rates were calculated for the long-term dialysis and KT population (or subpopulation) to the respective non-KRT population, except for (a) the dialysis modality group, where rates were calculated relative to the facility HD cohort, and (b) the dialysis vintage and transplant vintage groups, where rates were calculated relative to the 30-days-to-1-year cohort. Confidence intervals for all standardised rates were based on the gamma distribution.[21] For analyses involving BMI, extreme values generally considered unrealistic (<10 kg/m^2 or ≥60 kg/m^2) were coded as missing.[22] For analyses requiring age-sex standardisation, admissions not coded as female or male sex were omitted. Analyses were performed in STATA version 17.1 (StataCorp).

3. Results

From the 442,369 valid admissions available for data linkage, the cohorts for analysis were ultimately determined as 2826 (0.6%) long-term dialysis patients, 1194 (0.3%) transplant patients, and 438,271 (99.1%) non-KRT patients (Fig. 1). Excluded were cases coded in the ANZDATA Registry, as in renal recovery (n = 27), lost to follow-up (20), and deceased or withdrawn before admission (31), collectively 0.02%. For analyses requiring age-sex standardisation, 398 admissions (0.09% of total) not coded as female or male were further excluded.

Following the determination of the analysis cohorts, it was clear that the long-term dialysis cohort was considerably smaller than the number of patients that were coded with 'chronic renal failure' among the ANZICS APD population (n = 11,761 among the combined analysis cohorts). Of the 11,761, only 2437 (20.7%) were receiving long-term dialysis. A cross-tabulation of eGFR against modality at the time of admission for the 11,761 admissions revealed that only 5048 (42.8%) could be classified as having Stage 5 CKD or KF, i.e. eGFR <15 mL/min/1.73 m^2 (Supplementary Table 1). Of the 2437 receiving long-term dialysis according to the ANZDATA Registry, 2159 (88.6%) had an eGFR indicative of KF yet only 2871 (30.8%) did of the remaining 9324.

The APACHE III-j score in original and modified form was highest for long-term dialysis, then KT, then non-KRT cohorts, and KRT groups had a higher prevalence of diabetes mellitus and cardiovascular disease (Table 1). Adults receiving KRT tended to have unplanned, nonelective, surgical admissions from the ward, but were less likely to require high-dependency unit care and be invasively ventilated; admission to private units was also less likely

Table 1
Characteristics of admissions 2018–2020 by modality at admission.

Level	Long-term dialysis (n = 2826)	Transplant (n = 1194)	Non-KRT (n = 438,271)	p-value
Age, mean (SD)	63.5 (14.5)	57.8 (13.6)	62.8 (17.5)	<0.001
Age group at admission				<0.001
18-29	77 (2.7)	45 (3.8)	26,750 (6.1)	
30-39	126 (4.5)	102 (8.5)	30,927 (7.1)	
40-49	293 (10.4)	169 (14.2)	41,587 (9.5)	
50-59	551 (19.5)	267 (22.4)	64,836 (14.8)	
60-69	684 (24.2)	382 (32.0)	96,851 (22.1)	
70-79	791 (28.0)	208 (17.4)	109,566 (25.0)	
80+	304 (10.8)	21 (1.8)	67,754 (15.5)	
Male sex	1792 (63.4)	711 (59.5)	246,542 (56.3)	<0.001
Aboriginal & Torres Strait Islander	343 (12.6)	41 (3.6)	12,645 (3.1)	<0.001
Private unit	428 (15.1)	229 (19.2)	148,673 (33.9)	<0.001
Source of admission				<0.001
Theatre/recovery	1117 (39.5)	613 (51.3)	245,339 (56.0)	
Emergency	819 (29.0)	271 (22.7)	113,217 (25.8)	
Ward	736 (26.0)	270 (22.6)	53,833 (12.3)	
Other	145 (5.1)	39 (3.3)	24,842 (5.7)	
Planned after elective surgery	664 (23.5)	355 (29.7)	171,901 (39.2)	<0.001
High dependency unit	778 (27.5)	344 (28.8)	136,996 (31.3)	<0.001
Invasively ventilated	735 (26.0)	307 (25.7)	129,824 (29.6)	<0.001
Inotropes/vasopressors	1093 (38.7)	434 (36.3)	126,990 (29.0)	<0.001
Admission type				<0.001
Medical	1701 (60.3)	572 (48.0)	190,337 (43.6)	
Emergency surgical	451 (16.0)	262 (22.0)	71,105 (16.3)	
Elective surgical	670 (23.7)	357 (30.0)	175,572 (40.2)	
Diagnostic category[a]				<0.001
Cardiovascular M	484 (17.1)	92 (7.7)	33,964 (7.8)	
Cardiovascular S	409 (14.5)	100 (8.4)	68,164 (15.6)	
Sepsis	405 (14.3)	172 (14.4)	31,512 (7.2)	
Respiratory M	244 (8.6)	101 (8.5)	39,084 (8.9)	
Gastrointestinal S	194 (6.9)	113 (9.5)	61,788 (14.1)	
Metabolic S	168 (6.0)	19 (1.6)	3687 (0.8)	
Renal M	154 (5.5)	75 (6.3)	5704 (1.3)	
Metabolic M	150 (5.3)	47 (3.9)	28,476 (6.5)	
Orthopaedic S	142 (5.0)	62 (5.2)	29,979 (6.9)	
Neurological M	139 (4.9)	30 (2.5)	21,038 (4.8)	
Renal S	91 (3.2)	228 (19.1)	10,965 (2.5)	
Gastrointestinal M	81 (2.9)	30 (2.5)	13,038 (3.0)	
Neurological S	44 (1.6)	45 (3.8)	36,240 (8.3)	
Respiratory S	41 (1.5)	40 (3.4)	21,791 (5.0)	
Trauma M	27 (1.0%)	21 (1.8%)	13,891 (3.2%)	
Trauma S	19 (0.7%)	5 (0.4%)	7207 (1.6%)	
BMI, median (IQR)	27.9 (23.9, 33.0)	27.1 (23.8, 31.4)	27.8 (24.2, 32.8)	0.003
BMI				0.003
<25 kg/m^2	446 (32.7)	221 (34.6)	71,013 (30.8)	
25–30 kg/m^2	385 (28.2)	213 (33.3)	73,051 (31.7)	
≥30 kg/m^2	535 (39.2)	205 (32.1)	86,191 (37.4)	
Diabetes	1309 (57.7)	415 (45.0)	83,081 (25.3)	<0.001
Cardiovascular disease	313 (11.1)	85 (7.1)	39,079 (8.9)	<0.001
Respiratory disease	154 (5.4)	39 (3.3)	32,139 (7.3)	<0.001
APACHE III-j, median (IQR)	69.0 (57.0, 83.0)	59.0 (46.0, 76.0)	46.0 (34.0, 61.0)	<0.001
Modified APACHE III-j, median (IQR)	63.0 (50.0, 76.0)	55.0 (43.0, 70.0)	46.0 (34.0, 60.0)	<0.001
Highest creatinine, median (IQR)	592 (447, 764)	219 (125, 391)	80 (64, 110)	<0.001
Lowest albumin, median (IQR)	28 (24, 32)	27 (24, 31)	30 (26, 34)	<0.001
Lowest haematocrit, median (IQR)	0.30 (0.26, 0.34)	0.28 (0.24, 0.34)	0.34 (0.29, 0.38)	<0.001
Primary kidney disease				
Diabetic kidney disease	1134 (40.6)	246 (20.8)		
Glomerulonephritis	542 (19.4)	418 (35.3)		
Hypertension	330 (11.8)	82 (6.9)		
Polycystic disease	182 (6.5)	171 (14.5)		
Other	608 (21.7)	266 (22.5)		
Dialysis modality				
Facility HD	2196 (77.7)			
Home HD	185 (6.5)			
Peritoneal dialysis	445 (15.7)			
Dialysis vintage (years), median (IQR)	2.5 (1.0,5.1)			
Dialysis vintage				
<30 days	151 (5.3)			
30–365 days	578 (20.5)			
1–2 years	491 (17.4)			
2–3 years	381 (13.5)			
3+ years	1225 (43.3)			
Transplant vintage (years), median (IQR)		5.1 (0.1,11.8)		
Transplant vintage				
<30 days		299 (25.0)		

Table 1 (*continued*)

Level	Long-term dialysis (n = 2826)	Transplant (n = 1194)	Non-KRT (n = 438,271)	p-value
30–365 days		79 (6.6)		
1–5 years		216 (18.1)		
5–10 years		253 (21.2)		
10+ years		347 (29.1)		

Abbreviations: APACHE: Acute Physiology and Chronic Health Evaluation; BMI, body mass index; IQR, interquartile range; KRT, kidney replacement therapy; M, medical; S: surgical, SD: standard deviation.

[a] Not shown: haematological, musculoskeletal, gynaecological, other.

for KRT cohorts. Most long-term dialysis patients (77.5%) were receiving facility HD at admission. Median dialysis and transplant vintages were 2.5 years (interquartile range 1.0, 5.1) and 5.1 years (0.1, 11.8), respectively.

Overall unstandardised admission rates were highest for adults receiving long-term dialysis, 67.4 per 1000 persons per year (95% CI: 65.0,70.0) followed by KT recipients (32.0 [30.2,33.9]) and those not receiving KRT (7.40 [7.38,7.43]). Incidence rate ratios (IRRs), relative to the non-KRT cohort, exceeded 1 for all combinations of modality, sex, and age (Fig. 2); IRRs tended to be higher for females than for males, for both long-term dialysis and KT cohorts. For both sexes and for all age groups, IRRs were higher for adults receiving long-term dialysis than for KT recipients (Supplementary Table 2). Following age-sex standardisation, admission rates for long-term dialysis and KT cohorts relative to the non-KRT cohort were 10.18 (95% CI: 9.46,10.93) and 4.41 (4.05,4.78), respectively. Relative rates for adults receiving long-term dialysis were highest for medical admissions and for KT recipients for emergency surgical admissions; relative admission rates for long-term dialysis patients exceeded those for KT recipients across admission types (Table 2). For the subgroups defined by BMI and diabetes status, relative rates tended to be highest for those with a BMI <25 kg/m^2 and with diabetes respectively, for both long-term dialysis and KT cohorts (Supplementary Tables 3 and 4).

The highest relative admission rates for those receiving long-term dialysis were for surgical admissions with metabolic diagnoses (100.0, 95% CI [76,128])—of which 86% were for parathyroidectomy—and for those with a KT were sepsis-related (8.7 [7.0,10.8]) (Table 3). Almost all sepsis-related admissions for KT patients (171 of 172) occurred at least 30 days following their transplantation. For all nonsurgical diagnostic categories, relative admissions rates for long-term dialysis patients exceeded those for KT recipients. For all surgical diagnoses, relative rates were similar between the two KRT cohorts except for metabolic and cardiovascular diagnoses, where rates for long-term dialysis patients were higher. The most common diagnoses for medical admissions of long-term dialysis patients (excluding renal causes) were sepsis/septic shock, cardiac arrest, congestive heart failure, non-cardiogenic pulmonary oedema, and acid-base electrolyte disorders (collectively 49.0% of total); diagnoses overall for KT patients were similar but more diverse, with a lower proportion being cardiovascular.

Home HD and PD patients' admission rates were similar to or lower than those for facility HD, except for elective surgical admissions for home HD (Table 4). Admission rates for adults with a dialysis vintage >1 year were similar to those for 30 days to 1 year, except for an elevated elective surgical admission rate at 2–3 years (Table 5). Metabolic and respiratory diagnoses were particularly prevalent in this group. Surgical admission rates for transplant vintages >1 year were similar to those for 30 days to 1 year, whereas medical admission rates were consistently lower (Table 6).

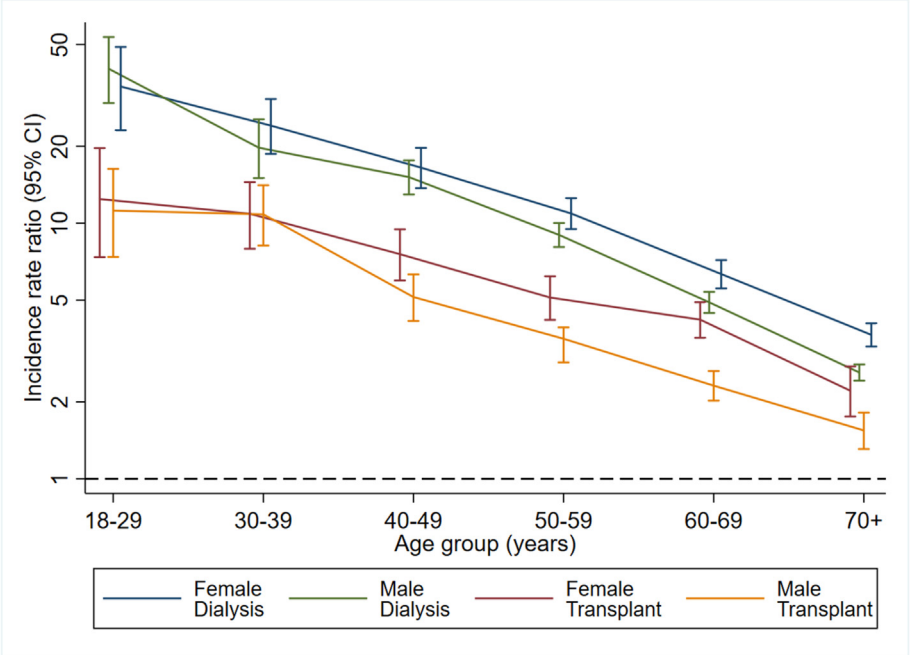

Fig. 2. Incidence rate ratios for long-term dialysis and transplant cohorts relative to the non-KRT population for 2018–2020, by modality at admission, sex, and age group.

Table 2
Age-sex-standardised admission rates (per 1000 persons per year) by modality and admission type. Relative rate denominator is non-KRT population.

		Long-term dialysis	Transplant	Non-KRT
Medical	N	1701	572	190,206
	Rate (CI)	43.4 (39.5,47.6)	14.2 (12.6,15.9)	2.96 (2.95,2.98)
	Relative rate (CI)	14.7 (13.3,16.1)	4.78 (4.30,5.40)	
Emergency	N	451	262	71,056
Surgical	Rate (CI)	10.6 (8.80,12.6)	6.98 (5.77,8.35)	1.09 (1.08,1.10)
	Relative rate (CI)	9.71 (8.07,11.56)	6.40 (5.30,7.66)	
Elective	N	670	357	175,356
Surgical	Rate (CI)	14.2 (12.2,16.4)	8.39 (7.17,9.77)	2.64 (2.63,2.66)
	Relative rate (CI)	5.37 (4.61,6.20)	3.17 (2.71,3.69)	

Abbreviations: CI, 95% confidence interval; KRT, kidney replacement therapy.

Table 3
Age-sex-standardised admission rates (per 1000 persons per year) by modality and APACHE III-j diagnostic category. Relative rate denominator is non-KRT population.

		Long-term dialysis	Transplant	Non-KRT
Sepsis	N	405	172	31,495
	Rate (CI)	8.00 (6.54,9.68)	4.12 (3.30,5.08)	0.47 (0.47,0.48)
	Relative rate (CI)	16.95 (13.86,20.52)	8.72 (6.98,10.77)	
Cardiovascular	N	484	92	33,945
M	Rate (CI)	11.23 (9.31,13.40)	1.99 (1.50,2.61)	0.51 (0.51,0.52)
	Relative rate (CI)	21.93 (18.18,26.18)	3.88 (2.93,5.09)	
Cardiovascular	N	409	100	68,097
S	Rate (CI)	7.00 (5.71,8.50)	2.07 (1.54,2.73)	0.99 (0.99,1.00)
	Relative rate (CI)	7.05 (5.75,8.56)	2.08 (1.55,2.75)	
Respiratory	N	244	101	39,051
M	Rate (CI)	6.83 (5.23,8.71)	2.61 (1.89,3.49)	0.6 (0.59,0.60)
	Relative rate (CI)	11.44 (8.76,14.6)	4.36 (3.17,5.85)	
Respiratory	N	41	40	21,764
S	Rate (CI)	1.41 (0.70,2.46)	1.03 (0.59,1.67)	0.34 (0.33,0.34)
	Relative rate (CI)	4.17 (2.07,7.25)	3.05 (1.74,4.92)	
Gastrointestinal	N	81	30	13,026
M	Rate (CI)	1.84 (1.14,2.79)	0.63 (0.39,1.01)	0.20 (0.20,0.20)
	Relative rate (CI)	9.26 (5.75,14.04)	3.16 (1.94,5.07)	
Gastrointestinal	N	194	113	61,736
S	Rate (CI)	3.43 (2.64,4.41)	2.59 (1.94,3.38)	0.94 (0.94,0.95)
	Relative rate (CI)	3.64 (2.80,4.67)	2.74 (2.05,3.58)	
Orthopaedic	N	142	62	29,923
S	Rate (CI)	2.54 (1.78,3.50)	1.34 (0.88,1.96)	0.44 (0.44,0.45)
	Relative rate (CI)	5.74 (4.03,7.93)	3.03 (2.00,4.43)	
Metabolic	N	150	47	28,448
M	Rate (CI)	6.22 (4.65,8.10)	1.50 (0.96,2.22)	0.48 (0.48,0.49)
	Relative rate (CI)	12.91 (9.64,16.81)	3.12 (2.00,4.62)	
Metabolic	N	168	19	3684
S	Rate (CI)	5.82 (4.43,7.47)	0.39 (0.20,0.73)	0.058 (0.056,0.060)
	Relative rate (CI)	100.0 (76.0,128.7)	6.76 (3.50,12.50)	
Neurological	N	139	30	21,028
M	Rate (CI)	3.67 (2.65,4.93)	0.72 (0.42,1.17)	0.33 (0.33,0.34)
	Relative rate (CI)	11.02 (7.95,14.82)	2.17 (1.27,3.53)	
Neurological	N	44	45	36,207
S	Rate (CI)	0.93 (0.55,1.51)	0.68 (0.48,1.01)	0.56 (0.56,0.57)
	Relative rate (CI)	1.64 (0.97,2.68)	1.21 (0.85,1.79)	
Trauma	N	27	21	13,882
M	Rate (CI)	0.28 (0.17,0.61)	0.47 (0.25,0.85)	0.23 (0.22,0.23)
	Relative rate (CI)	1.24 (0.74,2.70)	2.10 (1.10,3.79)	
Trauma	N	19	5	7203
S	Rate (CI)	0.26 (0.13,0.60)	0.23 (0.03,0.72)	0.12 (0.11,0.12)
	Relative rate (CI)	2.22 (1.16,5.20)	1.99 (0.22,6.25)	

Not shown: renal, haematological, musculoskeletal, gynaecological and orthopaedic.
Abbreviations: CI, 95% confidence interval; KRT, kidney replacement therapy; M, medical; S: surgical.

4. Discussion

4.1. Key findings

This is the first national Australian study to quantify and describe intensive care admissions for adults receiving KRT, reported relative to the general population. Although people receiving long-term KRT are approximately 0.1% of the Australian population, they comprised over 0.9% of ICU admissions in 2018–2020. The relative rates of medical, emergency surgical, and elective surgical admissions were all elevated for the KRT cohorts—at least 9- and 4-fold higher for adults receiving long-term dialysis and KT recipients, respectively. The high APACHE III-j scores found for KRT cohorts in this study (even when their KF was coarsely accounted for in their score) agree with those reported elsewhere.[23,24] Of the prevalent long-term dialysis and KT populations enumerated by the ANZDATA Registry,[25] approximately 14% and 5%, respectively, were admitted to ICU in each year of this

Table 4
Age-sex-standardised admission rates (per 1000 persons per year) by dialysis modality and admission type. Relative rate denominator is facility haemodialysis population.

		Facility haemodialysis	Home haemodialysis	Peritoneal dialysis
Medical	N	1386	74	241
	Rate (CI)	49.9 (44.6,55.6)	20.2 (14.2,28.1)	35.0 (27.4,43.9)
	Relative rate (CI)		0.40 (0.28,0.57)	0.70 (0.54,0.90)
Emergency	N	334	28	89
Surgical	Rate (CI)	10.9 (8.6,13.6)	9.04 (4.51,15.98)	10.51 (7.34,14.64)
	Relative rate (CI)		0.83 (0.40,1.55)	0.97 (0.63,1.46)
Elective	N	474	82	114
Surgical	Rate (CI)	14.1 (11.6,17.0)	23.9 (16.6,33.4)	10.01 (7.15,13.76)
	Relative rate (CI)		1.70 (1.12,2.51)	0.71 (0.48,1.04)

Abbreviations: CI, 95% confidence interval.

Table 5
Age-sex-standardised admission rates (per 1000 person dialysis years) by dialysis vintage and admission type. Relative rate denominator is 30-days-to-1-year population.

		Medical	Emergency surgical	Elective surgical
<30 days	N	100	21	30
	Rate (CI)	123 (87.1,169)	20.2 (9.6,38.8)	23.3 (14.5,38.9)
	Relative rate (CI)	2.52 (1.71,3.62)	1.76 (0.78,3.80)	1.89 (1.09,3.42)
≥30 days	N	337	92	147
To 1 year	Rate (CI)	49.1 (41.1,56.0)	11.45 (7.87,15.97)	12.35 (9.37,16.04)
≥1 year	N	299	76	115
To 2 years	Rate (CI)	45.6 (37.1,55.3)	9.20 (6.53,12.75)	11.42 (8.52,15.16)
	Relative rate (CI)	0.93 (0.71,1.21)	0.80 (0.50,1.33)	0.92 (0.62,1.38)
≥2 years	N	217	55	108
To 3 years	Rate (CI)	36.5 (28.1,46.6)	6.25 (4.23,9.46)	21.2 (14.2,30.2)
	Relative rate (CI)	0.74 (0.54,1.01)	0.55 (0.32,0.97)	1.72 (1.06,2.70)
≥3 years	N	748	207	270
	Rate (CI)	33.2 (28.1,38.9)	12.22 (8.60,16.69)	14.39 (10.70,18.85)
	Relative rate (CI)	0.68 (0.53,0.86)	1.07 (0.65,1.74)	1.17 (0.78,1.72)

Abbreviations: CI, 95% confidence interval.

Table 6
Age-sex-standardised admission rates (per 1000 person transplant years) by transplant vintage and admission type. Relative rate denominator is 30-days-to-1-year population.

		Medical	Emergency surgical	Elective surgical
<30 days	N	78	149	72
	Rate (CI)	279 (209,365)	521 (422,635)	293 (216,386)
	Relative rate (CI)	13.6 (8.86,21.2)	105 (52.4,252)	103 (43.8,292)
≥30 days	N	58	13	8
To 1 year	Rate (CI)	20.4 (14.5,27.9)	4.94 (2.12,9.56)	2.83 (1.05,6.23)
≥1 year	N	119	25	69
To 5 years	Rate (CI)	9.95 (7.85,12.4)	2.07 (1.11,3.48)	5.22 (3.77,7.06)
	Relative rate (CI)	0.49 (0.33,0.73)	0.42 (0.17,1.15)	1.84 (0.77,5.27)
≥5 years	N	137	36	76
To 10 years	Rate (CI)	11.16 (8.87,13.91)	2.93 (1.65,4.78)	5.37 (3.84,7.38)
	Relative rate (CI)	0.55 (0.37,0.82)	0.59 (0.24,1.60)	1.9 (0.79,5.47)
≥10 years	N	168	38	124
	Rate (CI)	11.84 (8.72,15.67)	3.38 (1.62,6.03)	6.94 (4.71,9.84)
	Relative rate (CI)	0.58 (0.37,0.91)	0.68 (0.25,1.93)	2.45 (1.00,7.11)

Abbreviations: CI, 95% confidence interval.

study. Given the projected expansion of these populations in Australia,[7] intensive care services in this country are likely to experience significant future demand from these complex cohorts.

Excess relative rates for KRT patients, especially those receiving long-term dialysis, were most strongly associated with medical admissions. The excess was spread across a diverse case mix, but relative rates were highest for cardiovascular, sepsis, respiratory, metabolic, neurological diagnoses (Table 3). This likely reflected several factors related to both the underlying kidney disease and treatment. The KRT cohort would have had a high prevalence of underlying cardiovascular disease as an associated comorbidity and CKD accelerates its progression.[26] Excess relative rates for respiratory diagnoses were associated with a higher proportion of pulmonary oedema in the long-term dialysis cohort compared with the non-KRT cohort (31% of respiratory diagnoses compared with 3.6%). Dialysis treatment in particular places stresses of volume overload on the patient. These would be expected to drive presentations with pulmonary oedema and possibly respiratory infection, which may require distinct management.[27] Among metabolic diagnoses, the modal diagnosis was acid-base electrolyte disturbance for long-term dialysis patients (45%) compared with drug overdose (56%) for the non-KRT cohort; among neurological diagnoses, intracerebral haemorrhage was distinct between groups (28% for long-term dialysis vs 13% for non-KRT). In contrast to the high relative rates for other diagnostic groups, those for trauma were lowest.

For surgical admissions, long-term dialysis and KT patients were equally likely to be admitted for a broad range of diagnoses, with the exception of cardiovascular and metabolic diagnoses, for which relative rates for long-term dialysis patients were elevated. Widely noted impacts of dialysis on parathyroid function and resultant surgery contributed to the admission rate we reported of over 100 relative to non-KRT patients.[28]

Admission rates for long-term dialysis patients (for both medical and surgical admissions) were highest in the month following commencement of KRT, in accord with the heightened risks at this time associated with haemodynamic instability and vascular access.[5] At a dialysis vintage of 2−3 years, relative rates of elective surgical admissions were elevated, when admissions following parathyroidectomy were prevalent (28%). Whether this reflected a trend of increasing admission burden due to disease associated with vintage is unclear, as this would be offset by the disproportionate rise in mortality rate after three years of vintage seen in national data.[22] Our finding of lower admission rates for adults receiving home HD and PD compared with those receiving facility HD is consistent with the higher overall survival rates reported for those cohorts.[29]

The risk of ICU admission was lower for KT recipients compared with adults receiving long-term dialysis, despite still being 4.4-fold that of the general population. They had less comorbidity, a case mix more similar to the non-KRT cohort, and admission rates were not as strongly associated with diabetes status. Those findings were not unexpected given the selection process for KT and the benefits it confers. A lower proportion of cardiovascular diagnoses in this cohort is likely owed to the routine cardiac evaluation and workup prior to KT. Admissions within a month of KT amounted to one quarter of all admissions for KT recipients, dominated by emergency surgical admissions (92% were transplant-related) for which relative rates were also highest.

The relatively low percentage of patients coded with 'chronic renal failure' in the ANZICS APD who were receiving long-term dialysis as reported to ANZDATA (2437/11,795 or 20.7%), obliged further investigation using creatinine-based eGFR. Calculating eGFR based on a single measure of creatinine at admission is likely to overestimate CKD stage, and yet we found that only 42.8% of all the patients coded with 'chronic renal failure' in the ANZICS APD could be defined as such by an eGFR <15 mL/min/1.73 m^2. Based on those data and our clinical experience, the most plausible source of the low percentage is the overcoding of 'chronic renal failure' in the ANZICS APD for patients who had CKD but had neither KF nor were receiving long-term dialysis. Patient groups that were considered less likely to contribute to error were those who (a) were receiving long-term dialysis but who did not receive any dialysis in the ICU, (b) were receiving short-term dialysis in the ICU who were coded as 'chronic renal failure', and (c) had received all of their KRT outside Australia. Given the near-universal coverage of the ANZDATA Registry, very few unreported long-term dialysis patients would have been admitted to ICU in the study period.

4.2. Implications

These results have implications at several levels. For health services planners, the projected increase in KRT numbers will mean increased demand for ICU admission and management of these cohorts. For clinicians and researchers, building on these findings and understanding outcomes (both short- and long-term) of these ICU admissions is an important step, followed by questions about whether earlier identification and intervention is possible and/or effective for these high-risk groups. Possible interventions are diverse, ranging from broad brush strategies, e.g. vaccination, to identification and targeted earlier intervention in specific populations. Pulmonary oedema, for which there are a number of preventable contributing factors, is perhaps the most obvious focus for intervention in dialysis patients. Early recognition and treatment of infection in KT patients is also crucial.

The probable overcoding of 'chronic renal failure' in the ANZICS APD has important implications for estimating predicted risk of death for patients and for comparing the risk-adjusted mortality of ICUs. Modification of the data collection system should be considered to clarify that this code is for long-term dialysis and not just CKD or KF. More broadly, there are implications for data quality, completeness, and benchmarking for the ANZICS APD. To substantiate and explore further the trends in the data reported in this study, future research could update the data linkage for the years following 2020, subject to further approvals.

4.3. Strengths and limitations

The principal strengths of this study are the size and scope of the dataset, i.e. thousands of patients receiving KRT from all Australian jurisdictions, and its source from two long-standing clinical quality registries. In particular, the ability to delineate and characterise in detail the population receiving KRT at the time of ICU admission highlights the benefit of data linkage between specialist registries and facilitates the development of methodology for future data linkage and collaboration. The national scope of the dataset allows for direct policy implications.

One limitation to the study was that data linkage was conducted with the statistical linkage key SLK-581 rather than identifying variables, although results have been shown to be comparable between the two approaches.[15] As a retrospective cohort study based on observational data, this study is limited by residual confounding and potential selection bias with individuals that are expected to have the best chance of survival admitted to intensive care.

4.4. Conclusion

In conclusion, data linkage between two clinical quality registries provided national Australian data for the first time that offers patients, clinicians and health service planners an appreciation of the health risks and acute care implications associated with KF requiring KRT. Admission rates for people receiving long-term dialysis or KT far exceeded those of the general population, with particularly increased relative risk among younger age groups and for key medical diagnoses. These data will aid in determining how best to prevent the need for ICU admission and optimise outcomes for the growing population of adults receiving KRT at the time of their presentation.

CRediT authorship contribution statement

Conceptualisation: S.M. and D.P.; Data curation: S.C.; Methodology: S.M., D.P. and P.S.; Formal analysis: C.D. and D.K.; Project administration: D.K.; Writing − original draft: D.K.; Writing − reviewing and editing: S.C., C.D., S.J., D.K., S.M., D.P., B.R. and P.S.

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Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Co-author David Pilcher is Associate Editor of Critical Care and Resuscitation. If there are other authors, they declare that they

have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

The datasets generated and/or analysed during the current study are not publicly available as these are linked from two registries (ANZICS APD and ANZDATA Registry), but are available from the corresponding author upon reasonable request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ccrj.2025.100099.

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