





Social determinants of health and intensive care unit admission rates and outcomes for children, Australia, 2013–2020: analysis of national registry data

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The known: Social determinants of health, such as socio-economic status, influence outcomes for people admitted to intensive care units (ICUs). Their influence on admission rates and survival for Australian children has not been investigated using registry data.

The new: Population-standardised ICU admission rates are higher for Indigenous children and children in areas of socio-economic disadvantage. Raw mortality during ICU admission is also higher for both groups, but the difference is statistically significant only for socio-economic status after adjusting for pre-illness, admission, and hospital factors.

The implications: Targeted interventions based on further research are needed to reduce differences associated with social determinants of health.

Social determinants of health are the conditions in which people live and work; they are non-medical factors and systems that have an impact on illness and wellness.¹⁻³ Ethnic background and cultural identity influence health outcomes through experiences of racism and colonisation, and are used as proxies for socio-economic, cultural, and environmental determinants of health.⁴⁻⁹

Social determinants have important influences on the disease characteristics, presentation, and outcomes of numerous medical conditions in children. The risks of intensive care unit (ICU) admission and of in-hospital death and post-discharge illness are greater for children with certain racial, ethnic, or cultural backgrounds, and for those from socio-economically disadvantaged communities or rural areas.¹⁰⁻¹⁷ Proposed explanations of differences in ICU patient outcomes have often focused on biological factors, such as differences in comorbidity burden and health behaviours, but more recent frameworks take into account the influence of up-, mid-, and downstream non-medical determinants.^{3,16,18} For children, these can include pre-admission factors, factors associated with the illness, and factors related to the ICU stay. Pre-illness factors include baseline health status, which is affected by food security, health beliefs, and behaviours (including vaccination), and structural factors. Admission factors include diagnoses and illness severity, and can include environmental components, such as experience of violence, housing adequacy, and smoke exposure, as well as timely critical care access, such as the availability of transportation. ICU and hospital stay factors include management approaches, which can reflect systematic or implicit biases.^{3,16,18}

Given the specific contexts of epidemiology and critical care service delivery, local data should be analysed to assess outcomes

Abstract

Objectives: To investigate the influence of non-medical social determinants of health on rates of admission and outcomes for children admitted to intensive care units (ICUs) in Australia.

Study design: Retrospective cohort study; analysis of Australian and New Zealand Paediatric Intensive Care Registry data.

Setting, participants: Children (18 years or younger) admitted to Australian ICUs during 1 January 2013 – 31 December 2020.

Main outcome measures: Population-standardised ICU admission rates, overall and by residential socio-economic status (Index of Relative Socio-Economic Disadvantage [IRSD] quintile) and Indigenous status; likelihood of mortality in the ICU by residential socio-economic status (continuous, and quintile 1 v quintiles 2–5) and Indigenous status, adjusted for pre-illness, admission, and ICU and hospital factors.

Results: Data for 77 233 ICU admissions of children were available. The ICU admission rate for Indigenous children was 1.91 (95% confidence interval [CI], 1.87–1.94), for non-Indigenous children 1.60 (95% CI, 1.57–1.64) per 1000 children per year. The rate was higher for children living in areas in the lowest IRSD quintile (1.93; [95% CI, 1.89–1.96]) than for those living in quintile 5 (1.26 [95% CI, 1.23–1.29] per 1000 children per year). Unadjusted in-ICU mortality was higher for Indigenous than non-Indigenous children (2.5% v 2.1%) and also for children living in the lowest IRSD quintile than in quintiles 2–5 (2.5% v 2.0%). After adjustment for all factors, mortality among Indigenous children was similar to that for non-Indigenous children (adjusted odds ratio [aOR], 1.15; 95% CI, 0.92–1.43); it was higher for children living in the lowest IRSD quintile than for those living in quintiles 2–5 (aOR, 1.18; 95% CI, 1.03–1.36). Remoteness and distance between home and ICU did not influence the likelihood of death in the ICU.

Conclusions: The population-standardised ICU admission rate is higher for Indigenous children and children residing in areas of greatest socio-economic disadvantage than for other children in Australia. Adjusted in-ICU mortality was higher for children from areas of greatest socio-economic disadvantage. Advancing health equity will require further investigation of the reasons for these differences.

and determine the drivers of inequitable outcomes.^{4,5,7,19} To advance health care equity, documenting disparities in access to and outcomes in ICU care should also assess whether non-medical factors influence outcomes so that targeted interventions can be developed. We therefore analysed national registry data to investigate the influence of non-medical social determinants on rates of admission and outcomes for children admitted to ICUs in Australia.

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Methods

For our national retrospective cohort study, we analysed Australian and New Zealand Paediatric Intensive Care Registry (ANZPICR) data. The ANZPICR is a jurisdiction-funded registry that prospectively records data for admissions of children to Australian and New Zealand paediatric and general ICUs; it includes data for more than 95% of critical care admissions of children in Australia.²⁰ In Australia, nine dedicated paediatric ICUs (PICUs) are located in large cities; children can also be admitted to general ICUs in regional areas. We analysed ANZPICR data for admissions of children (18 years or younger) to Australian ICUs during 1 January 2013 – 31 December 2020. Data for children transferred between ICUs were merged; data for the initial admission were used to characterise illness severity, and those for the final admission for defining the outcome. We report our study in accordance with the STROBE statement for reporting observational studies.²¹

The primary social determinant examined was socio-economic disadvantage, based on the Socio-Economic Indices for Areas (SEIFA) Index of Relative Socio-economic Disadvantage (IRSD) for the patients' residential postcodes.²² The IRSD ranks areas in Australia according to five-yearly Australian Bureau of Statistics Census of Population and Housing data for district characteristics. It comprises seventeen variables (Supporting Information, table 1); lower IRSD scores indicate greater relative socio-economic disadvantage. We report analyses by IRSD quintile (quintile 1 defined as greatest disadvantage), and with IRSD score as a continuous variable.

We also examined the influence of Indigenous status (Aboriginal or Torres Strait Islander identity). The term Indigenous is used in this article according to the ANZPICR data dictionary code.²³ We acknowledge this includes Aboriginal and Torres Strait Islander people who are the traditional custodians and original inhabitants of Australia. Indigenous status is a cultural identity, used in this study as a proxy variable for social determinants of health related to colonisation and discrimination, not biological determinism.⁴⁻⁹ People are coded in the ANZPICR as Indigenous if they are identified as such by the patient or their next of kin, or if this is recorded in hospital administrative datasets. Data are collected by trained data collectors using the ANZPICR data dictionary. Remoteness by residential postcode was classified as major cities, inner regional, outer regional, remote, or very remote according to the Australian Statistical Geography Standard Accessibility/Remoteness Index of Australia (ARIA+) 2016.²⁴ The linear distance from ICU postcode to residential postcode was calculated.

The primary study outcome was in-ICU mortality. The secondary outcomes were death within 30 days of ICU admission, ICU length of stay, and a composite measure: ICU length of stay longer than 90th centile value or death in hospital. Clinical variables assessed were pre-illness factors (age, medical conditions by major organ system, year), admission factors (diagnosis, Paediatric Index of Mortality 3 [PIM3; a mortality prediction model],²⁵ admission source), and ICU and hospital factors (organ support therapies: extracorporeal membrane oxygenation [ECMO], renal replacement therapy, mechanical ventilation) and ICU type (general/mixed ICU, PICU).

Statistical analysis

All available data were included in each analysis; all patients with recorded Indigenous status were included in analyses by Indigenous status; all patients with recorded residential

postcodes with associated IRSD scores were included in analyses by socio-economic disadvantage.

For population-based ICU admission rates, population by age and Indigenous status by postcode were derived from Australian Bureau of Statistics 2021 Census of Population and Housing data, tabulated in TableBuilder.²⁶ ICU use (mean number of admissions per thousand children per year) was calculated with exact binomial confidence intervals (CIs) overall, by IRSD quintile, and by Indigenous status.

For the ICU admission characteristics, we summarise categorical data as proportions, and continuous data as medians with interquartile ranges (IQRs). We assessed the statistical significance of between-group differences in distributions or proportions in χ^2 tests, and of differences in medians in Kruskal–Wallis tests.

We assessed associations between social determinants and in-ICU mortality in univariate analyses. We then included all clinical factors in a mixed effects logistic regression model, with centres (ICUs) as a random effect and all other covariates as fixed effects. The influence of socio-economic disadvantage and Indigenous status were assessed in separate models because collinearity between social determinants was anticipated; for example, Indigenous status was expected to be highly collinear with socio-economic status because of structural discrimination, and with remoteness because of cultural and environmental factors. Further, the IRSD takes into account the proportion of Aboriginal or Torres Strait Islander people in an area.²²

In sequential models to determine drivers of outcomes, variables that could be confounders or effect modifiers are iteratively added to the base model to assess their impact on the relationship between the factor of interest and the outcome.²⁷ We generated separate models for pre-illness factors, admission and illness factors, and ICU and hospital factors. The discrimination of risk adjustment models was assessed using area under the receiver operating characteristic curve, and their calibration with the Hosmer–Lemeshow test.

Statistical analyses were performed in Stata 18 and RStudio 4.2.2.

Ethics approval

The Central Australian Human Research Ethics Committee approved the study, and waived the requirement for individual approval by patients (HREC-CA-21-4097; 20 August 2021). Care was taken to comply with standards for retrospective observational studies that were acceptable at the time of study design and the application for human research ethics committee approval. Collaboration with the Indigenous Data Network through an existing memorandum of understanding between the Australian and New Zealand Intensive Care Society and the Indigenous Data Network facilitated access to Indigenous researchers (authors VR, DC) to collaborate closely with clinicians (authors KMM, AJS, PJS) and a biostatistician (author LS) to explore PICU outcomes and provide Aboriginal and Torres Strait Islander perspectives, voice, and leadership, as well as to ensure questions of Indigenous data sovereignty were respected.

Results

Data for 77 233 admissions of children to ICUs during 2013–2020 were available; IRSD scores could be determined for 75 970 (98.4%) and Indigenous status for 77 101 children (99.8%) (Box 1).

Population-based ICU admission rate for children

The overall ICU admission rate was 1.55 (95% CI, 1.52–1.58) per 1000 children per year; for Indigenous children, the rate was 1.91 (95% CI, 1.87–1.94), for non-Indigenous children 1.60 (95% CI, 1.57–1.64) per 1000 children per year. The ICU admission rate was highest for areas in the lowest IRSD quintile (1.93 [95% CI, 1.89–1.96] per 1000 children per year) and lowest in quintile 5 (1.26 [95% CI, 1.23–1.29] per 1000 children per year) (Box 2).

ICU admission characteristics, by outcome and social determinants

A total of 1649 admitted children died in the ICU (2.1%). By pre-illness factors, the proportion of neonates (under 28 days of age) was larger among the patients who died than among those who did not (16.4% v 8.1%), as were the proportions of patients with two or more medical conditions (20.6% v 13.3%). By admission factors, the median PIM3 was higher for children who died than for those who did not (11.2; IQR, 3.6–55.5 v 0.7; IQR, 0.2–1.4), and the proportions with admission diagnoses of cardiac arrest (30.4% v 1.1%), severe infection (13.2% v 9.3%) or cardiac medical conditions (10.9% v 4.6%) were larger for those who died, as were the proportions transferred to the ICU from other hospital wards (24.3% v 16.4%) or other hospitals (33.7% v 19.8%). By ICU/hospital factors, larger proportions of children who died had received organ support therapies than of those who survived, and a larger proportion had been admitted to PICUs (93.8% v 86.9%) (Box 3).

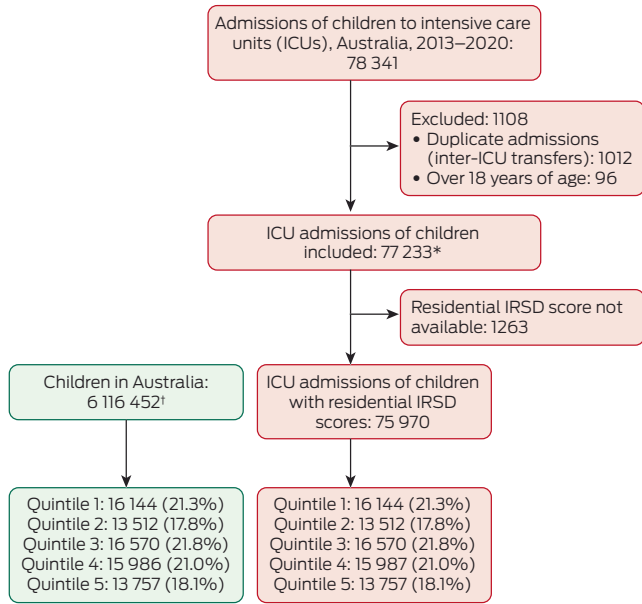
The median PIM3 was higher for children living in areas in the lowest IRSD quintile (0.8; IQR, 0.2–1.7) than for those living in areas in quintiles 2 to 5 (0.7; IQR, 0.2–1.5), and the proportions with respiratory diagnoses (27.9% v 25.6%), who had been transferred from other hospitals (25.0% v 18.8%), or who had received invasive ventilation (37.6% v 35.7%) were larger (Box 4).

The median PIM3 was higher for Indigenous children (0.9; IQR, 0.2–1.7) than for non-Indigenous children (0.7; IQR, 0.2–1.5); the proportion with two or more medical conditions was smaller (11.3% v 13.6%), the proportions with diagnoses of trauma (5.4% v 3.9%) or severe infection (11.2% v 9.2%) were larger, and the proportion admitted to PICUs was smaller (72.0% v 88.4%) (Box 4). The proportion of Indigenous children was 14.1% (2271 of 16 144) in the lowest IRSD quintile, and 6.3% (3764 of 59 826) in quintiles 2 to 5 ($P < 0.001$).

Social determinants, by ICU admission outcome

The median IRSD score was lower for children who died in ICUs (993; IQR, 940–1037) than for children who were discharged from the ICU alive (1000; IQR, 951–1040). Of the 16 144 patients from

1 Admissions of children to intensive care units (ICUs) in Australia, 1 January 2013 – 31 December 2020, and classification by Index of Socio-Economic Disadvantage (IRSD) quintile



* Missing data (excluded from relevant analyses): Paediatric Index of Mortality 3, one; Indigenous status, 132; distance from home to ICU, 1414. † IRSD values not available for 215 postcodes. ♦

2 Rates of admission of children to intensive care units (ICUs) in Australia, 1 January 2013 – 31 December 2020, overall and by Indigenous status and Index of Socio-Economic Disadvantage (IRSD) quintile*

Characteristic	Admission rate (95% CI)
All children	1.55 (1.52–1.58)
Indigenous status	
Aboriginal and Torres Strait Islander children	1.91 (1.87–1.94)
Non-Indigenous children	1.60 (1.57–1.64)
Index of Relative Socio-Economic Disadvantage	
Quintile 1 (most disadvantage)	1.93 (1.89–1.96)
Quintile 2	1.66 (1.63–1.70)
Quintile 3	1.53 (1.50–1.56)
Quintile 4	1.49 (1.46–1.52)
Quintile 5 (least disadvantage)	1.26 (1.23–1.29)

Admission rate (admissions per 1000 children per year)

* Overall and IRSD level rates restricted to ICU admissions of children for whom IRSD score could be determined; rates by Indigenous status include all ICU admissions of children for whom Indigenous status was recorded. ♦

3 Clinical variables and social determinants for admissions of children to intensive care units (ICUs) in Australia, 1 January 2013 – 31 December 2020, by ICU outcome (death or survival)

Characteristic	Survived	Died	P
All children admitted to ICUs	75 584	1649	
Pre-illness factors*			
Age group			< 0.001
Less than 28 days	6117 (8.1%)	271 (16.4%)	
28 days to one year	29 882 (39.5%)	575 (34.9%)	
2–5 years	15 175 (20.1%)	271 (16.4%)	
6–12 years	14 404 (19.1%)	279 (16.9%)	
13–18 years	10 006 (13.2%)	253 (15.3%)	
Medical conditions (number)			< 0.001
0	37 433 (49.5%)	709 (43.0%)	
1	28 159 (37.3%)	600 (36.4%)	
2	8984 (11.9%)	299 (18.1%)	
3 or more	1008 (1.4%)	41 (2.5%)	
Medical conditions (type)			
Cardiac disease	13 865 (18.3%)	323 (19.6%)	0.20
Chronic respiratory	11 291 (14.9%)	194 (11.8%)	< 0.001
Neurological	10 556 (14.0%)	287 (17.4%)	< 0.001
Cancer	4674 (6.2%)	145 (8.8%)	< 0.001
Prematurity	4111 (5.4%)	100 (6.1%)	0.27
Immunological	3881 (5.1%)	190 (11.5%)	< 0.001
Renal/liver failure	832 (1.1%)	85 (5.2%)	< 0.001
Admission factors			
Paediatric Index of Mortality 3, median (IQR)	0.7 (0.2–1.4)	11.2 (3.6–55.5)	< 0.001
Admission diagnosis			< 0.001
Respiratory	19 854 (26.3%)	226 (13.7%)	
Neurological	11 044 (14.6%)	215 (13.0%)	
Cardiac surgery	8943 (11.8%)	71 (4.3%)	
Severe infection	7036 (9.3%)	217 (13.2%)	
Cardiac medical	3499 (4.6%)	180 (10.9%)	
Trauma	3034 (4.0%)	76 (4.6%)	
Cardiac arrest	845 (1.1%)	501 (30.4%)	
Other diagnoses	21 329 (28.2%)	163 (9.9%)	
Admission source			< 0.001
Operating room	29 060 (38.4%)	187 (11.3%)	
Emergency department	18 502 (24.5%)	454 (27.5%)	
Inter-hospital transport	14 983 (19.8%)	555 (33.7%)	
Inpatient ward	12 408 (16.4%)	400 (24.3%)	
Neonatal/adult ICU	631 (0.8%)	53 (3.2%)	
Intensive care unit/hospital factors			
Invasive ventilation	26 525 (35.1%)	1510 (91.6%)	< 0.001

Continues

3 Continued

Characteristic	Survived	Died	P
Invasive ventilation duration (hours), median (IQR)	5.8 (0.0–38.0)	67.3 (17.9–210)	< 0.001
Renal replacement therapy	519 (0.7%)	223 (13.5%)	< 0.001
Extracorporeal membrane oxygenation	510 (0.7%)	247 (15.0%)	< 0.001
Admitted to paediatric intensive care unit	65 661 (86.9%)	1547 (93.8%)	< 0.001
Social determinants			
Index of Relative Socio-economic Disadvantage, median (IQR)	1000 (951–1040)	993.0 (940–1037)	< 0.001
Index of Relative Socio-economic Disadvantage, quintile 1	15 738 (21.2%)	406 (25.1%)	< 0.001
Aboriginal or Torres Strait Islander	6001 (8.0%)	156 (9.5%)	0.024
Distance from home to ICU (km)	25.1 (12.6–84.5)	26.1 (13.7–107)	0.007
Remoteness category			0.61
Major cities	52 598 (70.7%)	1141 (70.4%)	
Inner regional	12 514 (16.8%)	283 (17.5%)	
Outer regional	7402 (10.0%)	153 (9.4%)	
Remote	1233 (1.7%)	25 (1.5%)	
Very remote	603 (0.8%)	18 (1.1%)	

IQR = interquartile range. * Data by calendar year are included in the [Supporting Information](#), table 2. ♦

areas in the lowest IRSD quintile, 406 died (2.5%), and 1243 of 61 089 children from IRSD quintiles 2–5 (2.0%; $P < 0.001$). Median length of ICU stay was longer for children from areas in the lowest IRSD quintile (1.7 [IQR, 0.9–3.7] days *v* 1.5 [IQR, 0.9–3.1] days) and the proportions who received invasive ventilation (37.6% *v* 35.7%) or renal replacement therapy (1.1% *v* 0.9%) were slightly larger (Box 4).

Of the 6157 Indigenous children, 156 died (2.5%), and 1493 of 71 076 non-Indigenous children (2.1%; $P = 0.024$). The median ICU length of stay (1.6 [IQR, 0.8–3.4] days *v* 1.6 [IQR, 0.9–3.2] days) and the proportions who received invasive ventilation (38.5% *v* 36.1%) were similar for Indigenous and non-Indigenous children (Box 4).

The distance from home to ICU was similar for children who died or survived their ICU admission, as were their distributions by remoteness category (Box 3).

Multivariable analyses

The likelihood of dying in the ICU was greater for children from areas in the lowest IRSD quintile than for those from areas in quintiles 2 to 5 (aOR, 1.18; 95% CI, 1.03–1.36), and declined with increasing IRSD score (per point: aOR, 0.92; 95% CI, 0.85–0.99). The likelihood was similar for Indigenous and non-Indigenous children (aOR, 1.15; 95% CI, 0.92–1.43) (Box 5). Geographic remoteness and distance from home to ICU did not significantly influence the likelihood of in-ICU death (Box 6).

Similar findings regarding the influence of IRSD on the likelihood of in-ICU death were yielded by each sequential

4 Clinical variables for admissions of children to intensive care units (ICUs) in Australia, 1 January 2013 – 31 December 2020, by Indigenous status and Index of Socio-Economic Disadvantage (IRSD) quintile

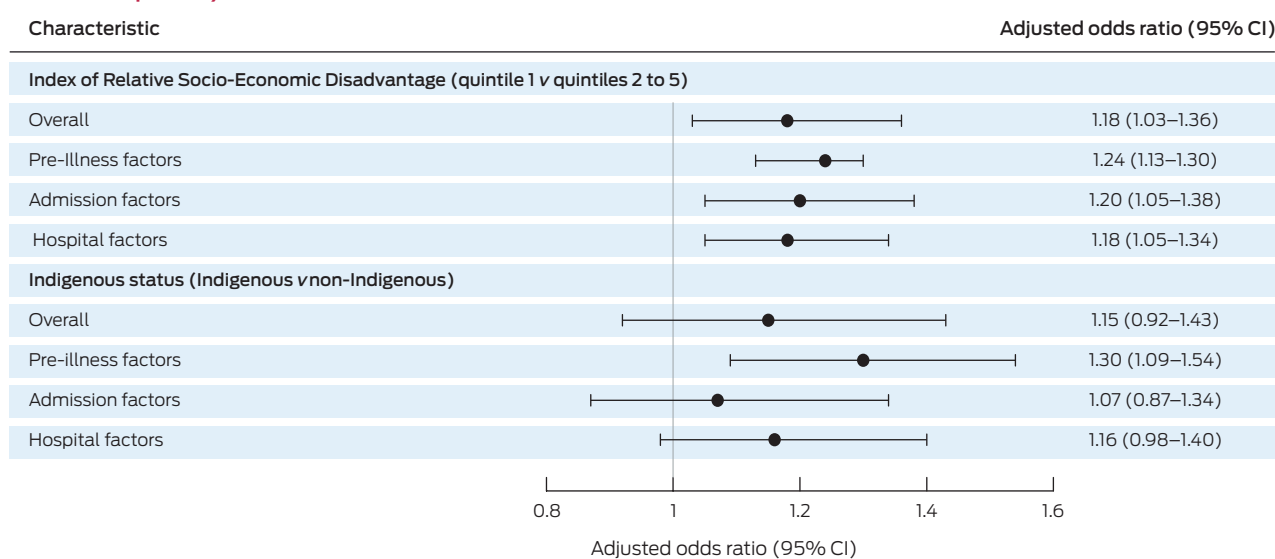
Characteristic	Socio-economic status		P	Indigenous status		P
	IRSD quintile 1	IRSD quintiles 2 to 5		Indigenous	Non-Indigenous	
All children admitted to ICUs	16 144	59 826		6 157	70 944	
Pre-illness factors*						
Age group			< 0.001			< 0.001
Less than 28 days	1541 (9.5%)	4747 (7.9%)		424 (6.9%)	5952 (8.4%)	
28 days to one year	6592 (40.8%)	23 343 (39.0%)		2595 (42.1%)	27 801 (39.2%)	
2–5 years	3085 (19.1%)	12 123 (20.3%)		1190 (19.3%)	14 241 (20.1%)	
6–12 years	2841 (17.6%)	11 595 (19.4%)		1119 (18.2%)	13 541 (19.1%)	
13–18 years	2085 (12.9%)	8018 (13.4%)		829 (13.5%)	9409 (13.3%)	
Medical conditions (number)			0.003			< 0.001
0	8015 (49.6%)	29 509 (49.3%)		3347 (54.4%)	34 691 (48.9%)	
1	5926 (36.7%)	22 350 (37.4%)		2110 (34.3%)	26 626 (37.5%)	
2	1947 (12.1%)	7194 (12.0%)		630 (10.2%)	8648 (12.2%)	
3 or more	256 (1.5%)	773 (1.3%)		70 (1.14%)	979 (1.4%)	
Medical conditions (type)						
Cardiac disease	3079 (19.1%)	10 769 (18.0%)	0.002	1062 (17.2%)	13 121 (18.5%)	0.015
Chronic respiratory	2434 (15.1%)	8927 (14.9%)	0.62	900 (14.6%)	10 576 (14.9%)	0.54
Neurological	2145 (13.3%)	8575 (14.3%)	< 0.001	700 (11.4%)	10 134 (14.3%)	< 0.001
Cancer	1074 (6.7%)	3892 (6.5%)	< 0.001	250 (4.1%)	4566 (6.4%)	< 0.001
Prematurity	1074 (6.7%)	3084 (5.2%)	< 0.001	420 (6.8%)	3786 (5.3%)	< 0.001
Immunological	802 (5.0%)	3191 (5.3%)	0.06	193 (3.1%)	3876 (5.5%)	< 0.001
Renal/liver failure	227 (1.4%)	672 (1.1%)	0.003	57 (0.9%)	860 (1.2%)	0.047
Admission factor						
Paediatric Index of Mortality 3, median (IQR)	0.8 (0.2–1.7)	0.7 (0.2–1.5)	< 0.001	0.9 (0.2–1.7)	0.7 (0.2–1.5)	< 0.001
Admission diagnosis			< 0.001			< 0.001
Respiratory	4497 (27.9%)	15 332 (25.6%)		1606 (26.1%)	18 428 (26.0%)	
Neurological	2188 (13.6%)	8893 (14.9%)		808 (13.1%)	10 435 (14.7%)	
Cardiac surgery	1809 (11.2%)	6970 (11.7%)		643 (10.4%)	8371 (11.8%)	
Severe infection	1501 (9.3%)	5634 (9.4%)		689 (11.2%)	6545 (9.2%)	
Cardiac medical	804 (5.0%)	2804 (4.7%)		317 (5.1%)	3358 (4.7%)	
Trauma	618 (3.8%)	2420 (4.0%)		331 (5.4%)	2773 (3.9%)	
Cardiac arrest	309 (1.9%)	1005 (1.7%)		121 (2.0%)	1224 (1.7%)	
Other	4418 (27.4%)	16 768 (28.0%)		1642 (26.7%)	19 810 (27.9%)	
Admission source			< 0.001			< 0.001
Operating room	5828 (36.1%)	22 916 (38.3%)		2128 (34.6%)	27 109 (38.2%)	
Emergency department	3468 (21.5%)	15 205 (25.4%)		1529 (24.8%)	17 402 (24.5%)	
Inter-hospital transport	4038 (25.0%)	11 253 (18.8%)		1331 (21.6%)	14 120 (19.9%)	
Inpatient ward	2647 (16.4%)	9953 (16.6%)		1126 (18.3%)	11 673 (16.5%)	
Neonatal/adult ICU	163 (1.0%)	499 (0.8%)		43 (0.7%)	640 (0.9%)	
Intensive care unit/hospital factors						
Invasive ventilation	6073 (37.6%)	21 371 (35.7%)	< 0.001	2370 (38.5%)	25 639 (36.1%)	< 0.001
Invasive ventilation duration (hours), median (IQR)	6.7 (0.0–43.3)	6.3 (0.0–40.7)	0.34	7.0 (0–43.4)	6.4 (0–41.5)	0.39

4 Continued

Characteristic	Socio-economic status			Indigenous status		
	IRSD quintile 1	IRSD quintiles 2 to 5	P	Indigenous	Non-Indigenous	P
Renal replacement therapy	179 (1.1%)	550 (0.9%)	0.028	55 (0.9%)	686 (1.0%)	0.57
Extracorporeal membrane oxygenation	165 (1.0%)	578 (1.0%)	0.52	50 (0.8%)	707 (1.0%)	0.16
Admitted to paediatric intensive care unit	14 207 (88.0%)	51935 (86.8%)	< 0.001	4431 (72.0%)	62 696 (88.4%)	< 0.001
Outcomes						
Deaths in ICU	406 (2.5%)	1213 (2.0%)	< 0.001	156 (2.5%)	1490 (2.1%)	0.024
Death within 30 days of admission to ICU	397 (2.5%)	1211 (2.0%)	< 0.001	153 (2.5%)	1481 (2.1%)	0.038
Composite outcome [†]	2132 (13.2%)	6887 (11.5%)	< 0.001	779 (12.7%)	8438 (11.9%)	0.08
ICU length of stay, median (IQR)	1.7 (0.9–3.7)	1.5 (0.9–3.1)	< 0.001	1.6 (0.8–3.4)	1.6 (0.9–3.2)	0.45

IQR = interquartile range. * Data by calendar year are included in the [Supporting Information](#), table 3. † ICU length of stay longer than 90th centile value or death in hospital. ◆

5 Influence of residential socio-economic status and Indigenous status on the likelihood of dying in intensive care for children admitted to intensive care units (ICUs) in Australia, 1 January 2013 – 31 December 2020: multivariable logistic regression analyses (overall and sequential)*



CI = confidence interval. * Mixed effects logistic regression models, with ICU as a random effect and all other covariates as fixed effects. Overall analysis includes all clinical covariates; sequential analyses only include pre-illness, admission, or intensive care unit and hospital characteristics. The influence of individual clinical factors on the likelihood of death for children living in areas in the socio-economically most disadvantaged quintile and for Aboriginal and Torres Strait Islander children is depicted in the [Supporting Information](#), figure 1. ◆

model including pre-illness, admission, or intensive care unit and hospital characteristics only. After adjusting for pre-illness factors only, the likelihood of death was greater for Indigenous than non-Indigenous children (aOR, 1.30; 95% CI, 1.09–1.54) (Box 5).

Discussion

Our study of more than 75 000 intensive care unit admissions of children in Australia during 2013–2020 is the first ANZPIC registry study to investigate the influence of social determinants on the use of intensive care by Australian children and their outcomes. ICU admission rates were higher for Indigenous than non-Indigenous children, and for children from areas in the quintile of greatest socio-economic disadvantage than for other children. Their clinical characteristics also differed, in that median illness severity (PIM3 score) was greater for Indigenous

children and for children living in the quintile of greatest socio-economic disadvantage than for critically ill children in the respective comparator groups. The raw proportions of children who died in ICUs for children living in areas in the lowest IRSD quintile and for Aboriginal or Torres Strait Islander children were larger than other patients. The likelihood of dying in the ICU was higher for children living in areas of greatest disadvantage in analyses that incorporated pre-illness, illness and admission, and hospital factors. The likelihood of dying in the ICU was only higher for Indigenous children in analyses adjusted for pre-illness factors only, but not those adjusted for admission or hospital factors, such as illness severity. Distance between home and the ICU and remoteness did not significantly influence the likelihood of in-ICU death. Our findings indicate that the burden of critical illness, ICU admission rates, presentation characteristics, and likelihood of in-ICU death for critically ill Australian children differ according to social determinants.

6 Influence of social determinants on the likelihood of dying in intensive care for children admitted to intensive care units (ICUs) in Australia, 1 January 2013 – 31 December 2020: multivariable logistic regression analyses (overall and sequential)*

Characteristic	Adjusted odds ratio (95% confidence interval)			
	Overall	Pre-illness factors	Admission factors	Hospital factors
Index of Relative Socio-economic Disadvantage				
Quintile 1	1.18 (1.03–1.36)	1.24 (1.13–1.30)	1.20 (1.05–1.38)	1.18 (1.05–1.34)
Quintiles 2 to 5	1	1	1	1
Per unit	0.92 (0.85–0.99)	0.88 (0.83–0.93)	0.91 (0.84–0.98)	0.92 (0.86–0.98)
Indigenous status				
Indigenous children	1.15 (0.92–1.43)	1.30 (1.09–1.54)	1.07 (0.87–1.34)	1.16 (0.98–1.40)
Non-Indigenous children	1	1	1	1
Distance from home to ICU, per km	1.01 (0.98–1.04)	1.01 (0.99–1.04)	1.02 (1.00–1.06)	0.97 (0.94–0.99)
Remoteness category				
Major cities	1	1	1	1
Inner regional	1.08 (0.92–1.28)	1.07 (0.93–1.23)	1.08 (0.92–1.28)	0.98 (0.85–1.13)
Outer regional	1.13 (0.90–1.43)	1.12 (0.91–1.34)	1.06 (0.84–1.34)	1.02 (0.84–1.24)
Remote	1.13 (0.70–1.84)	0.99 (0.66–1.50)	1.04 (0.64–1.68)	0.83 (0.55–1.26)
Very remote	1.28 (0.71–2.30)	1.48 (0.91–2.40)	1.25 (0.70–2.23)	1.00 (0.60–1.67)

* Mixed effects logistic regression models, with ICU as a random effect and all other covariates as fixed effects. Overall analysis includes all clinical covariates; sequential analyses include pre-illness, admission, or intensive care unit and hospital characteristics only. The results of the univariate analyses of the influence of pre-illness, admission, and ICU and hospital clinical variables on mortality in the ICU are reported in the [Supporting Information](#), table 5; the area under the receiver operating characteristic curves for the models are reported in the [Supporting Information](#), table 6. ♦

Socio-economic status

Lower socio-economic status is associated with more adverse outcomes and higher ICU admission rates for critically ill children.^{10,12,16,28,29} However, most relevant studies were undertaken in the United States, and conflicting findings have been reported, particularly for children with extremely severe illness. Studies in the United States of children with sepsis or who required ECMO or invasive ventilation after acute respiratory failure did not detect any associations between mortality and socio-economic status.^{17,29,30} Australian findings are similarly inconsistent. Adult ICU patients from disadvantaged areas were more likely to be admitted non-electively with greater illness severity and a greater number of medical conditions, but the incidence of death after hospital discharge was not influenced by socio-economic status.³¹ In analyses of data for critically ill children, socio-economic status did not influence PICU re-admission in New South Wales,³² but school results for children admitted to Queensland ICUs were lower for children from lower socio-economic status areas.^{14,15}

Compared with critically ill children from the four socio-economically less disadvantaged quintiles, the proportions who were infants, had diagnoses of chronic respiratory disease, or had been transferred from other hospitals were larger for children living in the IRSD quintile of greatest disadvantage; the median PIM3 score was higher, and raw mortality in the ICU and within 30 days of ICU admission were each higher for children in the most disadvantaged quintile. The proportions of children from IRSD quintiles 1 and 2–5 who received organ support therapies were similar. In analyses adjusted for all clinical covariates, having a residential postcode in the lowest IRSD quintile was independently associated with greater likelihood of dying in the ICU. Further, ICU admission rates increased continuously from IRSD quintiles 1 to 5, suggesting that the burden of critical illness is greater for children from

socially disadvantaged communities. Although greater illness severity could reflect delayed hospital presentation, higher ICU admission rates suggest access to ICU resources is not the key barrier to equitable health care for children in families in low socio-economic status communities in Australia.³³

Indigenous status

Contemporary data for PICU use and outcomes for critically ill Australian Indigenous children are very limited.³⁴ We found that the proportions of children admitted to ICUs with severe infections or trauma were larger for Indigenous than non-Indigenous children. An analysis of 2002–2013 ANZPICR data found that invasive infections were more frequent among Indigenous than non-Indigenous children;³⁴ larger proportions of trauma-related ICU admissions have been reported for Indigenous adults^{31,35,36} and of hospitalisations of Indigenous children with injuries or burns.^{37,38} However, the proportion of Indigenous children in our study with two or more medical conditions was smaller than for non-Indigenous children. Indigenous adults are overrepresented among people admitted to ICUs;³⁵ we also found that the ICU admission rate was higher for Indigenous than non-Indigenous children (1.91 *v* 1.60 per 1000 children per year). This could suggest that the critical illness burden is 19% greater for Indigenous children, but, given similar median lengths of stay and proportions receiving ICU organ support therapy, it could also reflect collective efforts to improve timely health care access and community measures to improve the acceptability of and trusting relationships with Western health care^{9,19} and the public hospital system.³³ Analyses of registry data for adults have found no association between Indigenous status and mortality without adjustment for both clinical and socio-demographic variables; such studies, however, have inherent selection and survival biases.^{31,35,36,39}

The ANZPICR invasive infections study found that crude and risk-adjusted ICU mortality were similar for Indigenous and non-Indigenous children.³⁴ These findings contrast with our finding that raw in-ICU mortality was higher for Indigenous children, but the difference was not statistically different after adjusting for all clinical variables, which suggests the covariates are potential cofounders that may mask or drive associations between Indigenous status and outcomes.^{27,40} The likelihood of in-ICU death was higher for Indigenous than non-Indigenous children in analyses adjusted for pre-illness factors only, but not after adjusting for admission and illness or ICU and hospital factors. This finding offers insights into mechanisms for the difference in raw mortality, suggesting that illness severity and specific admission diagnoses are the key factors that influence survival for Indigenous children admitted to ICUs.

Remoteness

Given the vast geographic area and highly centralised health care resources in Australia, it is surprising that remoteness and distance between home and ICU did not statistically significantly influence the likelihood of in-ICU death. We found that a larger proportion of Indigenous children than of non-Indigenous children were admitted to general ICUs (rather than PICUs), and that a larger proportion of children living in the most disadvantaged communities were transported from another hospital to the ICU. For Indigenous children, this may reflect the fact that a larger proportion of Indigenous people live in remote areas.¹⁹ The fact that geographic barriers to intensive care access for Indigenous communities and socially disadvantaged areas are effectively overcome despite fewer resources is a strength to build upon. Other potential contributors include high quality skilled transport teams and regional adult ICU resources.⁴¹ Survivor bias is an alternative explanation (ie, a larger proportion of children from remote areas die before reaching the ICU). Given the greater median illness severity at presentation for Indigenous children and children from disadvantaged areas, further population-level analyses are needed to accurately assess service provision.

Implications

Health disparities are systematic, avoidable differences in health care access or outcomes; as they are substantially influenced by historical and socio-political factors and health-service delivery, local epidemiological data should be analysed.^{1,3} In line with international calls for transparency and to advance health equity,^{1,5-7} we report the first national registry study to examine relationships between social determinants and ICU admission rates and in-ICU mortality for critically ill Australian children. We found that in-ICU mortality was higher for Indigenous children than for non-Indigenous children, and for children from the socio-economically most disadvantaged areas than those living elsewhere, their population-standardised admission rates were also higher. More detailed analyses could delineate how systematic factors drive health inequities, including how they relate to environmental exposures or shape access to care, and could also identify strengths and protective factors that can overcome barriers.^{9,42} Such analyses require more detailed disease-level data, as has been examined for injuries and burns.^{37,38,43,44} Documentation of disparities is needed to inform prospective research and to guide targeted public health solutions.^{2,19} Our identification that clinical presentation characteristics differ according to social determinants suggests opportunities for preventive measures; the large proportion of neonates among admissions of children from the most disadvantaged areas could indicate the need for more intensive

postnatal follow-up for children in these communities. Our findings suggest that infection and trauma prevention should be a focus in health care for Indigenous children.

Limitations

Identifying Indigenous status in ANZPIC records depends on trained data collectors; while the ANZPIC data dictionary assists, accurate identification of Indigenous people in administrative datasets is difficult.⁴⁵ Both over- and under-identification of Indigenous people is possible, but the ANZPIC registry provides the best data available; however, Indigenous status is the only reliably captured ethnic background variable. The ANZPICR is a Western biomedical epidemiological data repository; a memorandum of understanding has been agreed with the Indigenous Data Network, and further collaborative work is being undertaken to increase Aboriginal and Torres Strait Islander representation and ensure that Indigenous data sovereignty is respected in registry research publications.⁴⁶ For example, retrospective registry research identifies groups at risk of disease using indicators based on Western cultural norms, without incorporating concepts such as land, relationships, and family support that are fundamental to good health outcomes for Indigenous people.⁹ The matching process for transported patients used three anchoring variables, but may not be completely accurate. IRSD scores were based on postcodes, aggregating a range of socio-economic status, environmental, and education variables for the included area. Our study period included the coronavirus disease 2019 pandemic period, which may affect the generalisability of our findings. Finally, as some records for people aged 16–18 years admitted to general ICUs are recorded in adult patient databases, we may have underestimated admission rates.

Conclusions

The ICU admission rates for critically ill Aboriginal and Torres Strait Islander children and children residing in socially disadvantaged communities are higher than for non-Indigenous children in less disadvantaged areas, and their clinical presentations are different. Lower postcode-based socio-economic status was an independent predictor of death in the ICU. Raw mortality was higher for Indigenous than non-Indigenous children, and greater median illness severity and need for invasive hospital interventions may contribute to this difference. The disparities we report justify investigation of their drivers to guide targeted interventions for advancing health equity.

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Supporting Information

Additional Supporting Information is included with the online version of this article.