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**J. Renton, D. V. Pilcher,
J. D. Santamaria, P. Stow, M. Bailey,
G. Hart & G. Duke**

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J. Renton
D. V. Pilcher
J. D. Santamaria
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M. Bailey
G. Hart
G. Duke

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J. Renton (✉)
Department of Intensive Care, Allamanda Private Hospital, Southport, QLD, Australia
e-mail: james.renton@bigpond.com
Tel.: +61-4-21073257
Fax: +61-7-33196176

D. V. Pilcher
Department of Intensive Care, Alfred Hospital, Melbourne, VIC, Australia

J. D. Santamaria
Department of Intensive Care, St. Vincent's Hospital, Melbourne, VIC, Australia

P. Stow
Department of Intensive Care, Geelong Hospital, Geelong, VIC, Australia

D. V. Pilcher · M. Bailey · G. Hart
Australia and New Zealand Intensive Care Society (ANZICS) Centre for Outcomes and Resource Evaluation (CORE), Carlton, VIC, Australia

M. Bailey
Department of Epidemiology and Preventive Medicine, Monash University, Melbourne, VIC, Australia

G. Hart
Department of Intensive Care, Austin Hospital, Melbourne, VIC, Australia

G. Duke
Department of Intensive Care, The Northern Hospital, Melbourne, VIC, Australia

Abstract Purpose: To determine the epidemiology, in-hospital mortality, trends, patient characteristics and predictors of intensive care unit (ICU) readmission in Australia. **Methods:** A retrospective longitudinal study of data for 38 Australian ICUs extracted from the Australian and New Zealand Intensive Care Society Adult Patient Database (ANZICS-ADP) for the years 2000–2007. Demographic, diagnostic, physiological and outcome data were analysed. A multivariate model was constructed to identify risk factors for ICU readmission. Outcomes examined included observed and risk-adjusted in-hospital mortality. **Results:** A total of 247,103 patients were discharged alive from their first ICU admission; 13,598 (5.5%) were readmitted at least once. Variables associated with an odds ratio greater than 1.05 for readmission ($p < 0.001$) were an initial ICU admission source other than elective surgery, any

chronic health variable on severity scoring, tertiary hospital ICU and discharge between 6 p.m. and 6 a.m. Five initial diagnoses were associated with an odds ratio (OR) greater than 2 for readmission ($p < 0.001$). In-hospital mortality in readmitted patients was 20.7% compared with 4.4% in those not readmitted. Readmission rates have not changed over the study period. After adjustment for illness severity and readmission propensity, ICU readmission remained significantly associated with in-hospital mortality (OR 5.4, 95% confidence interval (CI) 5.1–5.7). **Conclusions:** Many risk factors for increased ICU readmission were identified in this study including ICU discharge between 6 p.m. and 6 a.m. This was the only modifiable variable studied. Prospective studies are required to identify other factors and to determine whether interventions may reduce ICU readmission and its high associated in-hospital mortality.

Keywords Intensive care unit · Readmission · Mortality · Database · Australia

Introduction

The need for intensive care unit (ICU) readmission during a single hospital stay reveals a patient population discharged from ICU with a high risk of death or further critical illness.

There have been many previous studies examining ICU readmission (Table 1) [1–19]. Five studies have examined over 10,000 ICU admissions [4, 9, 11, 13, 15]. The only large Australian study reported is a retrospective database-linked cohort study of 16,926 ICU admissions from a single centre, focused on co-morbidities [15]. Two small Australian single centre studies have been published [20, 21]. There is a paucity of large prospective studies of ICU readmission in the literature [22].

The incidence of ICU readmission has been reported from 0.89 to 19.0%, depending on case-mix, location and organisational context [1–19]. Reported incidence is dependent on inclusion criteria and study design. One outlying study has reported a readmission rate of 0.89%. This study excluded readmissions later than 48 h after initial ICU discharge and was conducted in a single ICU [19]. Australian readmission rates have been reported from 3.9 to 10.5% [15, 20, 21]. A recent systematic review of 20 studies estimated the incidence of readmission at 7.8% [12]. It is not clear whether this is increasing [5, 12, 23].

All studies have demonstrated an association between readmission and increased in-hospital mortality, with reported rates of 26–58% in readmitted patients [12]. In a large retrospective multicentre study in the USA, Cooper et al. [4] showed a sevenfold increase in risk-adjusted in-hospital mortality associated with readmission. Other studies have shown an increase of from two- to almost

tenfold [24, 25]. Hospital and ICU length of stay is also increased [3, 6, 25].

The interval between initial ICU discharge and readmission may impact on in-hospital mortality. One study found that readmission more than 72 h after initial discharge does not confer an increased in-hospital mortality [5]. An increased risk of readmission has been shown in those initially admitted from general wards [4, 26] and in patients with a non-operative origin [2].

Readmission diagnoses have been reported to be predominantly pulmonary and cardiac [5, 7, 14]. Approximately 50% of patients are readmitted with the same or a related diagnosis [14]. It has been suggested that those readmitted with a different diagnosis may have poorer outcomes [24]. Patient co-morbidities have been shown to be predictive of readmission [12, 15].

Staffing levels and other organisational factors may impact on readmission [27]. It has been reported that patients who are discharged from ICU 'after-hours' are more likely to be readmitted than those discharged in daylight hours [5, 6]. This has been confirmed in an Australian context for patients discharged at between 6 p.m. and 6 a.m. and at weekends [28].

The relationship between physiological indices at the time of initial ICU discharge and readmission risk is becoming clearer. A recent meta-analysis of 220,866 patients discharged from ICU has suggested an association between illness severity scoring and risk of readmission [22] independent of whether the scoring was performed at initial ICU admission or discharge. However only 6.5% of this cohort had APACHE II or III data reported at time of ICU discharge [6, 13, 17, 25].

Table 1 Major studies of ICU readmission

References	Year	Admitted (n)	Readmitted (n)	Readmitted (%)	Type of study
Baigelman et al. [1]	1983	640	75	11.7	Single ICU, Boston, USA
Franklin and Jackson [2]	1983	300	36	12.0	Single medical ICU, USA
Chen et al. [3]	1998	5,127	235	4.6	Multicentre, Canada
Cooper et al. [4]	1999	103,984		6.5	Multicentre, USA
Rosenberg and Watts [5]	2000			4–14	Systematic review
Rosenberg et al. [6]	2001	3,310	317	9.6	Single medical ICU, USA
Levy et al. [7]	2001	1,197	227	19.0	Liver transplant ICU, USA
Kogan et al. [8]	2003	1,613	53	3.3	Cardiac single centre, Israel
Metnitz et al. [9]	2003	15,180	780	5.1	Multicentre, France
Bardell et al. [10]	2003	2,117	75	3.6	Single centre, Canada
Nishi et al. [11]	2003	10,840	97	0.89	Single surgical ICU, USA
Elliott [12]	2006	–	–	7.8 (mean)	Systematic review
Alban et al. [13]	2006	10,840	296	2.7	Single surgical ICU, USA
Campbell et al. [14]	2008	4,376	385	8.8	Single mixed ICU, UK
Ho et al. [15]	2008	16,926	654	3.9	Single mixed ICU, Australia
Conlon et al. [16]	2008	1,061	73	6.9	Single ICU, Ireland
Gajic et al. [17]	2008	1,131	100	8.8	Dual centre, USA
Chan et al. [18]	2009	945	110	11.6	Single ICU, Taiwan
Kaben et al. [19]	2008	2,852	381	13.4	Single surgical ICU, Germany

Aim

The aim of our study was to:

1. Describe the frequency, in-hospital mortality and characteristics of ICU readmission.
2. Investigate the relationship between readmission and outcome.
3. Determine if there has been any change in frequency or outcome over the time period examined.
4. Identify modifiable factors which might be targeted to reduce ICU readmission and influence outcome.

Methods

We performed a retrospective analysis of prospectively collected data submitted to the Australian and New Zealand Intensive Care Society (ANZICS) Adult Patient Database (APD) [29]. This database captures 69% of the ICU admissions in Australia and New Zealand. It commenced in 1987 and includes over 900,000 admissions from 140 hospitals.

Access to de-identified data from the database was pursuant to ANZICS CORE published terms of reference [30].

Data were extracted from the ANZICS-APD for the period January 2000 to December 2007 for Australian ICUs with at least 200 admissions per year that had submitted complete data for each year of the study period.

ICUs in Australia require a minimum of 200 admissions annually to be classified as being capable of more than short-term ventilation [31]. Institutions reporting lower volumes were considered to be likely to have poorer data fidelity and were thus excluded from this study. For included hospitals, data fidelity was audited directly and as part of the ANZICS-APD Data Audit Program [32]. The inception cohort consisted of patients aged 16 or more, who survived their first ICU admission.

Demographic, diagnostic, physiological and outcome data were retrieved. Data included age, gender, primary admission diagnosis, source of initial ICU admission, mechanical ventilation, severity of illness on ICU admission (APACHE II, APACHE III and SAPS) and discharge. Dates and times were extracted to determine length of stay and interval between initial ICU discharge and readmission. Outcomes examined were crude and risk-adjusted in-hospital mortality.

Patients readmitted to ICU were compared to those not readmitted during their single hospital stay. Although the in-hospital mortality associated with multiple readmissions was determined, only the first readmission was used in our analyses.

Patients were dichotomised into subgroups on the basis of the source of their initial ICU admission (elective surgery and other). Two further subgroups were defined using variables from the initial admission APACHE III assessment: "chronic health condition" (all patients with one or more of the seven chronic health conditions incorporated in the APACHE III score) and "cancer" (metastatic disease, leukaemia or lymphoma). These subgroups were not mutually exclusive. Details of APACHE definitions have been published elsewhere [33].

Incidence and associated in-hospital mortality were determined in yearly cohorts in order to investigate trends in rates. Variables were examined to determine their association with increased odds of ICU readmission and death.

Data were analysed using SAS Version 9.1 (SAS Institute Inc, Cary, NC, USA). Univariate comparisons were performed using Student *t* tests, analysis of variance (ANOVA), Wilcoxon rank-sum, Kruskal–Wallis test and chi-square test of equal proportion according to data type. Parametric and non-parametric tests for trends over time were performed. Parametric data are presented as mean \pm standard deviation (SD). Non-parametric data are expressed as median and interquartile range (IQR). A *p* value of less than 0.001 was considered as evidence of association. Severity-adjusted rates were calculated using a method adapted from Cooper et al. [4]: severity-adjusted rate = (observed subgroup rate/predicted subgroup rate) \times overall rate from study sample.

Two multivariate logistic regression models were constructed. Stepwise forward and backward selection procedures for available parameters were used before undergoing a final assessment for clinical and biological plausibility.

The first model was constructed in order to identify variables which were associated with ICU readmission (the dependent variable). Variables initially considered for inclusion in this model included SAPS II score, APACHE III diagnosis, chronic health conditions, ICU duration of stay, admission after elective surgery, discharge from ICU between 6 p.m. and 6 a.m. and hospital type. Hospital type is classified by ANZICS into 'rural', 'metropolitan', 'tertiary' or 'private' on the basis of location and services available [34].

The SAPS II score was used to adjust for severity of illness in this model. This allowed incorporation of diagnosis without confounding the effect of severity of illness (as would have occurred had APACHE been used). This model was also used to derive a propensity score for readmission using variables identified in the logistic regression. This propensity score was used to adjust in-hospital mortality for likelihood of readmission (separately from severity of illness). A second model was then developed to examine the association between readmission and in-hospital mortality at a univariate level

Table 2 Number of ICU admissions per patient and crude in-hospital mortality

Number of ICU admissions	Number of patients (n = 270,479)	Hospital deaths (n = 36,698)	In-hospital mortality (%)	95% CI
1	256,881	33,651	13.1	12.7–13.5
2	11,869	2,552	21.5	19.9–23.1
3	1,420	386	27.2	22.8–31.7
4	241	68	35.3	24.9–45.7
5	44	26		
6	14	8		
7	3	2		
8	4	2		
9	0	0		
10	1	1		
11	2	2		

247,103 survived to be discharged from initial ICU admission

and after adjustment for both severity of illness (using APACHE III-j) and likelihood of readmission (using the propensity score).

Results

Data from 38 of the 140 hospitals contributing to the ANZICS-APD met the inclusion criteria (2/30 rural, 9/32 metropolitan, 20/36 tertiary and 7/42 private). These accounted for 46% (247,103/542,286) of all ANZICS-APD captured patients who survived their initial ICU admission. One hundred and two hospitals were excluded for not submitting 200 admissions annually for all 8 years of the study (2000–2007).

A total of 270,479 patients had 286,232 ICU admissions; 23,376 (8.6%) died during their first ICU admission. Of the 247,103 patients remaining, 13,598 (5.5%) patients were subsequently readmitted at least once. Table 2 shows the number of ICU admissions per patient and associated in-hospital mortality.

Organ system diagnosis responsible for readmission

Eighty-two per cent of readmissions were due to cardiovascular disease (27%, n = 3,620), respiratory disease (25%, n = 3,341), post-operative gastrointestinal problems (12%, n = 1,563), neurological issues (8%, n = 1,069) and all causes of sepsis (9%, n = 1,178).

Trends over time

Figure 1 shows the proportion of patients readmitted and APACHE III-j risk-adjusted in-hospital mortality in yearly cohorts between 2000 and 2007. There has been no

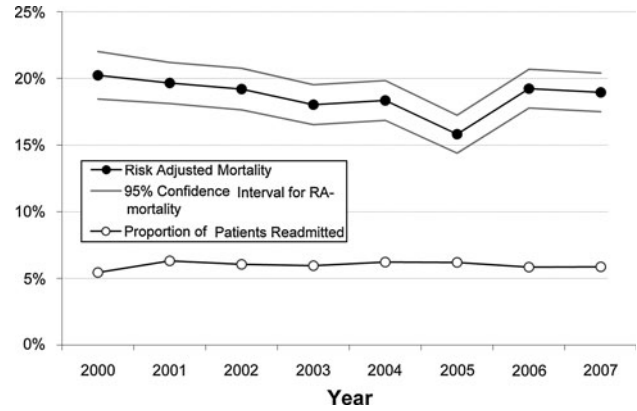


Fig. 1 Proportion of patients readmitted to ICU and risk adjusted in-hospital mortality by year. There was no significant change in proportion of admissions to ICU ($p = 0.39$). There has been a small reduction in risk-adjusted in-hospital mortality ($R^2 = 0.203$, $p < 0.001$)

change in the proportion of patients readmitted to ICU (p value for trend 0.39), but a small decline in the in-hospital mortality of those readmitted was observed over the study period ($R^2 = 20.3\%$, p value for trend less than 0.001).

Characteristics

Table 3 shows a univariate comparison of patients readmitted and those not. Those readmitted had a higher in-hospital mortality, higher initial severity of illness indices, were older and had longer initial ICU stays. Patients with chronic health conditions or cancer and those discharged between 6 p.m. and 6 a.m. were more likely to be readmitted. An elective surgery initial ICU admission source conferred lower odds of readmission; however, other sources accounted for 79.3% of all readmissions but only 46.2% of the initial cohort ($p < 0.001$).

Interval between initial ICU discharge and readmission

Figure 2 shows the distribution of time interval between ICU discharge and subsequent readmission by initial ICU admission type. Approximately one-third of readmissions (34.6%) occurred within 72 h of initial ICU discharge (22% of elective surgery and 40% of other initial admission subgroup). Sixty per cent occurred within 1 week. The modal time for readmission was between 24 and 48 h post-ICU discharge. Figure 3 shows in-hospital mortality with time interval between initial ICU discharge and readmission. The in-hospital mortality of patients readmitted to ICU varied with initial ICU admission type and was lower for those with an elective surgery source

Table 3 Univariate characteristics of readmitted and not readmitted patients

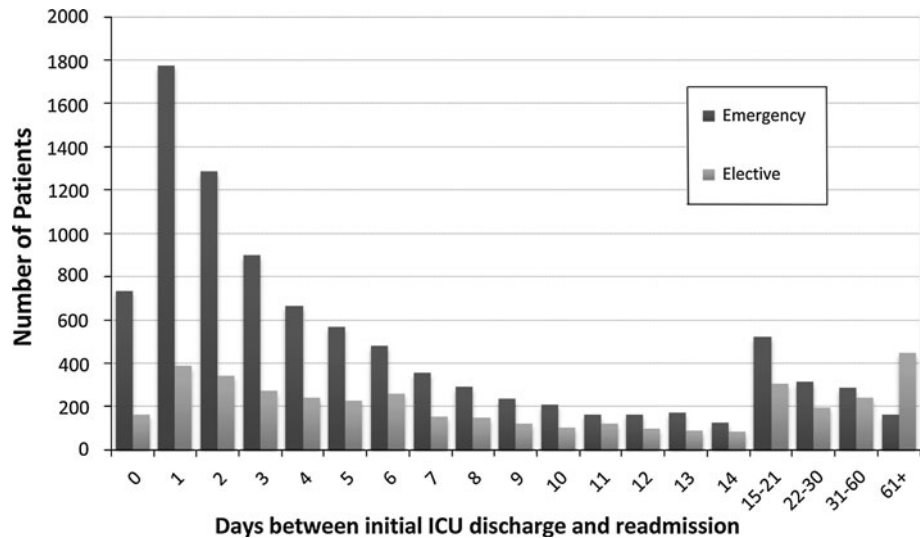
	Not readmitted (n = 233,505)	Readmitted (n = 13,598)	p value for difference
In-hospital mortality	10,274 (4.4%)	2,815 (20.7%)	<0.001
SAPS II score ^a	26 (19–36)	31 (23–41)	<0.001
APACHE III score ^a	47 (34–64)	56 (42–73)	<0.001
APACHE III risk of death (%) ^a	4.1 (1.3–13.6)	9.3 (3.3–24.1)	<0.001
APACHE III risk of death (%) ^b	11.7 ± 17.7	17.7 ± 20.7	
Duration of 1st ICU admission (days) ^a	1.8 (0.9–3.4)	2.2 (1.0–5.7)	<0.001
Age (years) ^b	59.9 ± 18.3	62.5 ± 16.8	<0.001
Proportion initial ICU discharge between 6 p.m. and 6 a.m.	16.5%	18.8%	<0.001
Proportion initial ICU admission from elective surgical source	47.7%	20.7%	<0.001
Proportion ventilated within first 24 h	48.6%	48.8%	0.649
Proportion with chronic conditions	19.7%	25.9%	<0.001
Proportion with cancer	3.6%	5.4%	<0.001

All values refer to the first ICU admission

^a Median and interquartile range

^b Mean ± standard deviation

Fig. 2 Interval between ICU discharge and readmission for elective surgical and other initial ICU admission source subgroups. 70% of all readmissions to ICU are emergency readmissions



($p < 0.001$). In this subgroup, this remained constant with increasing time interval between ICU discharge and readmission (p value for trend 0.66). This contrasts with those readmitted from other initial ICU admission sources, where in-hospital mortality rises progressively with increasing time interval (p value for trend less than 0.001).

severity scoring, tertiary hospital ICU and discharge between 6 p.m. and 6 a.m. Five initial diagnoses as defined by APACHE III were associated with increased readmission ($OR \geq 2$, $p < 0.001$): subarachnoid haemorrhage, non-operative gastrointestinal disorders, other haematological conditions, isolated cervical spine injury and hepatic failure.

Multivariate analysis

Table 4 shows a multivariate analysis of factors significantly associated with increased odds of ICU readmission. Variables associated with readmission ($OR \geq 1.05$, $p < 0.001$) were an initial ICU admission source other than elective surgery, any chronic health variable on

Readmission and in-hospital mortality

The association between readmission and in-hospital mortality is demonstrated in Table 5. In-hospital mortality for readmitted patients was 20.7% compared with 4.4% in those not readmitted. After adjustment for severity of illness (using APACHE III-j) and propensity

Fig. 3 Mortality (and 95% confidence intervals) with interval between initial ICU discharge and readmission by initial ICU admission type. There is a progressive increase in mortality for patients whose initial ICU admission was due to a non-elective surgical condition ($p < 0.001$) but no change in mortality for those with an elective surgical source ($p = 0.66$)

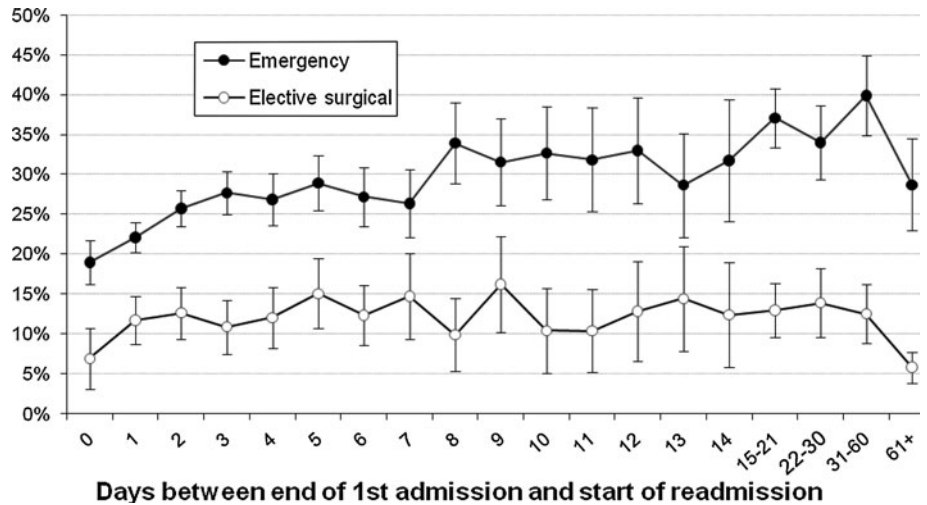


Table 4 Multivariate analysis of factors associated with increased risk of ICU readmission

	Odds ratio	95% CI	p value
Patient factors			
Any chronic health variable	1.372	1.311–1.435	<0.001
Non-elective surgical initial ICU admission source	1.114	1.065–1.167	<0.001
SAPS II score	1.015	1.014–1.017	<0.001
Age	1.008	1.006–1.009	<0.001
Diagnosis at 1st ICU admission			
Subarachnoid haemorrhage	2.376	2.103–2.685	<0.001
Non-operative gastrointestinal disorders ^a	2.255	1.879–2.707	<0.001
Other haematology conditions	2.251	1.645–3.082	<0.001
Isolated cervical spine injury	2.140	1.463–3.131	<0.001
Hepatic failure	2.009	1.645–2.465	<0.001
Burns	1.936	1.591–2.355	<0.001
ICU and hospital factors			
Tertiary hospital ICU ^b	1.210	1.131–1.294	<0.001
Discharge from ICU between 6 p.m. and 6 a.m.	1.134	1.080–1.191	<0.001
Length of stay in ICU in days	1.017	1.015–1.019	<0.001

Readmissions = 11,037/233,945, AUC = 0.623

^a Inflammatory disease, perforation or obstruction

^b Referenced against private hospital ICUs

to be readmitted (using our multivariate model), ICU readmission remained significantly associated with in-hospital mortality (OR 5.4, 95% CI 5.1–5.7).

Discussion

At 38 hospitals over an 8-year period, 5.5% of patients who survived their first ICU admission were subsequently readmitted. The four largest comparable studies in the literature have reported rates of readmission between 2.7 and 6.5% [4, 9, 13, 15]. Our study demonstrates no change in ICU readmission rate between 2000 and 2007. There is a small decrease in risk-adjusted in-hospital mortality in those readmitted over the study period.

Our findings are compatible with previous smaller studies [12] and identify the sick, elderly and chronically unwell patient, progressing slowly and in a tertiary hospital, to have greater odds of readmission. Patients with specific primary diagnoses on initial ICU admission (Table 4) also have greater odds of readmission.

Our data also support earlier work in demonstrating significant but small increased odds in those discharged between 6 p.m. and 6 a.m. [28]. This was the only directly modifiable factor studied. Interpretation requires caution as avoidance of these discharges may have significant effects on ICU bed availability. The effect of targeted follow-up of patients in this group needs further investigation.

Readmissions were most commonly seen on the second day after initial discharge. They were predominantly

Table 5 ICU readmission and in-hospital mortality

	Odds ratio	95% CI	AUC
Crude in-hospital mortality	5.692	5.428–5.968	0.699
In-hospital mortality adjusted for severity of illness (APACHE III-j)	5.537	5.239–5.852	0.840
In-hospital mortality adjusted for severity of illness (APACHE III-j) and for propensity to be readmitted	5.431	5.138–5.741	0.843

Hospital deaths = 13,158/233,945. All models adjusted for site. Site effect was tested for in the multivariate model for readmission and found to be effectively controlled for by the inclusion of

hospital type. Tertiary hospitals had an increased risk of readmission in comparison to other hospital types. (OR 1.21, 95% CI 1.13–1.29, $p < 0.001$)

patients whose initial ICU admission was due to non-elective surgery. In this subgroup, in-hospital mortality rose progressively with increasing interval between initial ICU discharge and readmission. Reasons for this are unknown. This finding contrasts with that of Rosenberg et al. [6], who found no additional risk of death with ICU readmission after 72 h. This relationship was not found in the cohort of patients with an initial ICU admission source from elective surgery. Indeed, it has been suggested that because their characteristics are so different, readmissions following an initial elective surgery source should be considered and studied as de novo admissions [12].

ICU readmission conferred an approximately fivefold increase in crude in-hospital mortality and after adjustment for illness severity (APACHE III) and propensity to be readmitted. An assumption that this increase in risk-adjusted in-hospital mortality is due to premature discharge is problematic [5, 9]; however, there are some data to support the contention that a longer initial ICU stay reduces readmission [35] and in-hospital mortality [36].

Our model used severity scoring at initial admission as the risk adjuster, an approach that will clearly underestimate in-hospital mortality due to lead-time bias [37]. It is likely that there are other factors not accounted for in this analysis that may explain the increased in-hospital mortality. Our assumption is that for any ICU readmission, it is felt that the odds of the individual dying would be greater if not readmitted.

The Australian Council on Healthcare Standards (ACHS) provides national healthcare quality guidelines. The rate of unplanned ICU readmission within 72 h of discharge is defined as a clinical performance indicator. The ACHS rationale is that it may represent poor patient management, result from early discharge due to resource issues or from poor general hospital ward care [38]. This indicator uses an arbitrary 72-h cut-off in an attempt to separate “deficiencies in management” from “complications/progression” of the disease process. There are scant published data to support this approach. A high rate of readmission may represent high-quality care rather than

leaving patients in a less acute care setting [14]. Furthermore the ACHS clinical indicator fails to capture approximately two-thirds of all the readmissions in our cohort.

The multifactorial causation of ICU readmission has led to doubt as to whether readmission rates are a useful quality indicator or a reasonable surrogate for premature discharge [14, 37, 39]. This doubt is reinforced by our study, which demonstrates increasing in-hospital mortality associated with increasing interval between initial discharge and readmission. We found no change in readmission rate between 2000 and 2007. Our study cannot determine whether this stability represents a failure of hospitals to implement changes informed by a valuable clinical indicator to improve outcome or provides evidence of lack of utility of this indicator due to multiple confounding variables.

This is the largest longitudinal analysis of ICU readmission yet published and is part of a series of pilot studies [28, 40] informing the design of an Australasian prospective multicentre study into the causes of preventable deaths after discharge from ICU. Although not representing all Australian hospitals, 46% of all submissions to the ANZICS-APD came from the 38 hospitals studied. It is unknown whether the exclusion of smaller ICUs that admitted less than 200 patients annually has affected our results.

The study has clear limitations. It is a retrospective analysis of prospectively collected data and cannot demonstrate causality. It examines a small number of variables and is limited by the dataset of the AZICS-APD. There is a clear selection bias as larger ICUs with a long history of participation in the ANZICS-APD were over-represented. Rural and private hospitals were relatively under-represented. This may limit the generalizability of this study.

Our data do not capture the patient's physiological state or the clinical and organisational context at initial ICU discharge. We have no information regarding the course of the patients outside ICU. Thus it is not possible to determine the relative importance of factors related to

the original admission and those arising after discharge. Patients discharged with treatment limitations are not identified and thus form part of the inception cohort despite having less likelihood of being readmitted. Expectation of outcome at time of discharge is also unknown.

Caution is required in assessing the clinical relevance of our findings. This large study is powered such that statistical significance is achieved for subgroup differences in many extracted variables and their association with ICU readmission. The magnitude of associated increased risk may be small. There was a significant difference in age between those readmitted to ICU and those not. However the difference in mean age was less than 3 years.

In the absence of cost/benefit analyses, it remains difficult to guide targeted outreach and resource allocation strategies such as liaison nurse or routine post-ICU physician follow-up.

Conclusions

ICU readmission is associated with increased in-hospital mortality. The rate has not changed between 2000 and 2007. It was possible to identify multiple risk factors for readmission, of which only the timing of discharge is modifiable. Altering the time of discharge and targeting management and outreach for particular at-risk diagnostic groups may form the basis of strategies to reduce readmission and its associated increased in-hospital mortality.

Only a suitably powered prospective study is likely to provide organisational and patient data adequate to identify other modifiable risk factors, further delineate the relationship between readmission and outcome, and develop improved tools to promote safer discharge. The utility of current performance indicators also requires further exploration.

Conflict of interest None.

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