

# A brief review of recent trends in Victorian intensive care, 2000–2011

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There are useful insights to be gained from long-range retrospective analysis of intensive care outcomes at state and national level. Such an overview may provide unique insights into resources and outcomes and help in future planning. One way to assess this is to interrogate large datasets collected over many years. This type of analysis has previously been undertaken in a select population of intensive care unit patients in Australia and New Zealand (in 1993–2003),<sup>1</sup> and more recently in the United Kingdom (in 1998–2006).<sup>2</sup> Both studies showed a sustained improvement in hospital outcome for patients receiving intensive care. Extrapolation from results based on voluntary data submission,<sup>1</sup> overseas data,<sup>2</sup> or weakly calibrated risk adjustment<sup>3</sup> may be misleading.

We undertook a 12-year retrospective cohort study of adult ICU admissions in Victoria to confirm previous research findings and identify temporal trends in access, resource utilisation and mortality. We recently showed that the Critical Care Outcome Prediction Equation (COPE) model may be a reliable predictor of inhospital mortality<sup>3,4</sup> and is comparable to the Acute Physiology and Chronic Health Evaluation (APACHE) III-j model<sup>5</sup> in major hospitals. Both these risk adjustment tools are used in monitoring of patient safety and quality of care in Victoria.<sup>6</sup>

## Methods

### Source data

Adult population data were extracted from the Australian Bureau of Statistics (ABS).<sup>7</sup> Age-related data were used to estimate population-based access rates. Hospital data were extracted from the Victorian Admitted Episodes Dataset (VAED), an administrative database of all public hospital admissions in Victoria.<sup>8</sup> These data are used primarily for epidemiology and casemix-based funding purposes and contain limited clinical data. The VAED diagnostic codes are based on the International Classification of Diseases, 10th revision, Australian modification (ICD-10-AM).<sup>9</sup>

Consecutive hospital records over 12 years, from 1 July 1999 to 30 June 2011, were included in the analysis. Eligible centres were public hospitals with an accredited adult ICU.<sup>10</sup> ICU admissions were identified from the VAED "ICU hours" field. Paediatric admissions (for patients < 17 years) and ICU readmissions during the

## ABSTRACT

**Background:** Review of resource use and patient outcomes of intensive care unit services over time provides insights into service delivery and safety.

**Objective:** To examine temporal trends in resource consumption and risk-adjusted mortality of adult ICU patients in Victoria.

**Design, participants and setting:** Retrospective cohort study of 214 619 adult ICU admissions recorded from 23 major hospitals over 12 years from 1 July 1999 to 30 June 2011.

**Outcomes:** Primary outcomes were population rates of ICU admission and mechanical ventilation (MV), ICU and hospital length of stay, and hospital survival. Secondary outcomes included average ICU and MV bed numbers. Administrative data were derived from the Victorian Admitted Episodes Dataset and the Australian Bureau of Statistics. The Critical Care Outcome Prediction Equation informed estimates for risk-adjusted mortality. Temporal mortality trends were evaluated for outcome estimates and hierarchical logistic-regression trends were evaluated for risk-adjusted mortality.

**Results:** Of ICU admissions, 104 103 (48.5%) were patients who received MV, and 87.6% ICU admissions were adults who survived to hospital discharge. There was a decline in the risk-adjusted mortality (odds ratio, 0.967 per year; 95% CI, 0.963–0.971;  $P < 0.001$ ). Similar results were found in 17 hospitals (74%) and in nine of 10 major diagnostic subgroups. There was an increase of 5.2 occupied ICU beds per year (range,  $\pm 4.2$  ICU beds per year;  $P = 0.002$ ). Despite ICU admissions being a minority cohort (2.5% of public hospital admissions) this group used 8.6% of hospital bed-days and attracted 19.5% of funding.

**Conclusions:** There was an increase in ICU resource availability and evidence of improvement in hospital survival, suggesting improved quality of care. These evaluation methods may be useful in monitoring statewide capacity, service delivery and patient safety.

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same hospital stay were not included in admission numbers. There were no exclusions based on diagnosis or duration of ICU stay.

**Table 1. Victorian population data, 1 July 1999 to 30 June 2011**

Variable	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11
Age-matched population, x 10 <sup>6</sup>	3.78	3.84	3.90	3.96	4.01	4.08	4.15	4.24	4.33	4.44	4.52	4.60
Study hospital admissions, x 10 <sup>6</sup>	0.52	0.56	0.60	0.66	0.67	0.70	0.72	0.75	0.77	0.78	0.81	0.85
ICU admissions, adults	16 090	16 467	16 329	17 139	17 944	17 941	17 937	18 085	18 176	18 492	19 535	20 484
Prevalence rate,* per 10 <sup>5</sup>	425.2	428.4	418.7	433.0	447.0	439.3	432.0	428.7	419.6	416.1	433.8	447.2
Total ICU bed-days, x 10 <sup>3</sup>	55.8	56.1	58.4	59.0	62.4	63.6	62.3	65.7	67.5	69.6	73.6	76.3
Fatalities	2101	2098	2069	2180	2192	2186	2231	2299	2355	2275	2323	2373
ICU admissions, MV	7883	7950	7746	8183	8562	8574	8810	9010	9062	9207	9397	9719
Prevalence rate,* per 10 <sup>5</sup>	208.3	206.8	198.6	206.5	213.3	209.8	212.9	209.2	207.2	208.1	210.2	208.7
ICU bed-days, x 10 <sup>3</sup>	41.1	40.9	41.9	44.5	45.9	44.4	47.2	48.6	50.4	52.4	52.2	53.0

ICU = intensive care unit. MV = mechanically ventilated patients. \* Admission rate per 100 000 age-matched population; *P* < 0.001 for all prevalence trends.

The average number of occupied beds (total bed-days divided by the number of calendar days) was used to assess resource utilisation. Population data were used to derive rates of utilisation.<sup>6</sup>

Casemix-based recurrent funding was employed as a simple surrogate for expenditure using Weighted Inlier Equivalent Separation (WIES) units<sup>11</sup> allocated to each admission. WIES units are allocated according to a funding formula based on diagnoses, comorbidities and procedures. The exact formula and the actual monetary value of a WIES unit are revised each year.

### Subgroups

The following a priori subgroups were selected:

- 23 individual hospitals
- 12 fiscal year cohorts
- three hospital peer groups
- admissions for patients receiving mechanical ventilation (MV) in the ICU
- 10 high-mortality diagnosis groups.

Peer grouping included tertiary referral ("tertiary", *n* = 6), non-tertiary metropolitan ("metropolitan", *n* = 7), and regional hospitals ("regional", *n* = 10). The MV cohort included most high-acuity admissions and thus excluded low-acuity (eg, high-dependency) admissions.

### COPE model benchmarks

The detailed methodology and validation of the COPE model has been published previously.<sup>3,4</sup> The COPE model predicts hospital mortality from six admission variables:

patient age, admission (principal) diagnosis, admission type, hospital peer group, cardiac surgical procedure and the use of MV. To facilitate a longitudinal, temporal trend analysis, each cohort was compared with a historical state benchmark estimated from the application of the COPE model to the central 2-year cohort (1 July 2004 to 30 June 2006).

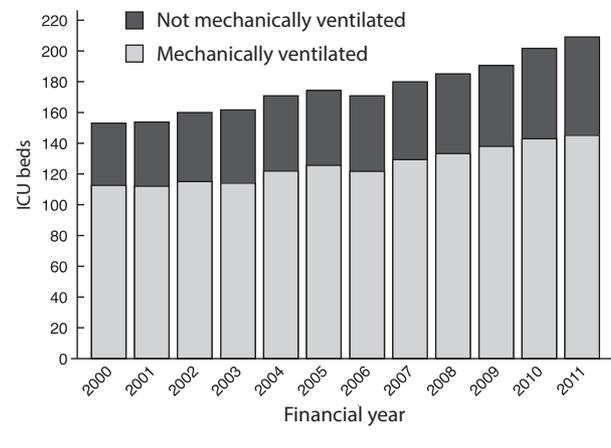
### Statistics

Data were interrogated using repeated-measures analysis of variance or Poisson regression to assess annual trends in population demographics. We used hierarchical logistic-regression models,<sup>12</sup> adjusted for clustering at the hospital level, to evaluate temporal trends in risk-adjusted mortality. We determined risk-adjusted mortality using logistic-regression models to adjust for patient characteristics included in the COPE model. Logistic-regression modelling using the COPE model variables was repeated on the entire population to identify temporal trends, for the outcome of interest, with the financial year included as a continuous variable. Temporal trends were significant if the *P* value for the odds ratio (OR) for "year" was < 0.05. We used Stata/MP version 11 software (StataCorp) for data analysis.

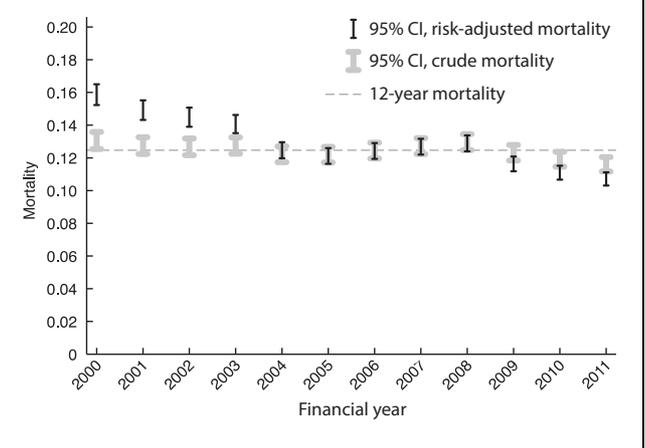
### Approval

The Victorian Department of Health provided the dataset and approved this publication. Because individual patients and hospitals were not identified, the need for a full ethics approval submission was waived by the Northern Health Human Research and Ethics Committee.

**Figure 1. Average number of occupied intensive care unit beds per year, 2000–2011**



**Figure 3. Annual crude and risk-adjusted population mortality rates, 2000–2011**



**Results**

**Study population**

Victoria has 141 public hospitals serving a population of about 5.64 million people, and over the 12 years from 1 July 1999 to 30 June 2011 there were 15.23 million hospital admissions. Twenty-three hospitals (16.3%) had onsite adult ICU services and reported 8.61 million (56.5%) hospital admissions, including 214 619 admissions (1.41%) for patients who received intensive care (our study population) during their hospital stay (Table 1). A total of 104 103 ICU admissions (48.5%) were patients who received MV, and 87.6% ICU admissions were adults who survived to hospital discharge. The mean annual mortality rate for the

MV cohort was 19.1% (SD,  $\pm 3.5\%$ ), and for the non-MV cohort was 6.2% (SD,  $\pm 2.7\%$ ).

Tertiary referral hospitals accounted for the largest ICU and MV populations (50.4% and 71.4%, respectively), followed by regional hospitals (26.5% and 8.3%, respectively) and metropolitan hospitals (23.1% and 20.2%, respectively).

**Demographic trends**

Over 12 years, the prevalence of ICU and MV admissions increased by an average of 2.5% per year (range,  $\pm 2.8\%$  per year) and 2.1% per year (range,  $\pm 2.3\%$  per year), respectively ( $P < 0.001$ ). The number of occupied ICU beds increased by an average of 5.2 beds per year (range,  $\pm 4.2$  beds per year;  $P = 0.002$ ), most of which were beds for mechanically ventilated patients (3.1 beds per year [range,  $\pm 3.5$  beds per year;  $P = 0.001$ ]) (Figure 1).

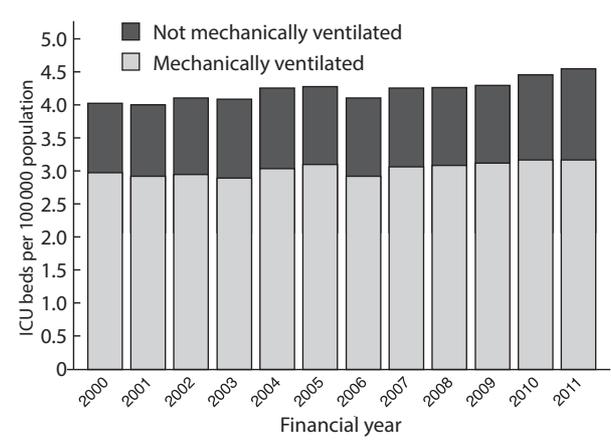
ICU bed resources increased faster than age-matched population, from 4.03 to 4.55 ICU beds per 100 000 people ( $P < 0.001$ ) over the 12 years (Figure 2). MV beds increased from 2.96 to 3.17 per 100 000 persons ( $P < 0.001$ ).

Over the 12-year period, there was a small but significant increase in median ICU length of stay (LOS), of 7 hours ( $P = 0.001$ ), but no significant change in hospital LOS ( $P = 0.22$ ). Changes of similar magnitude were observed in all subgroups.

Mean patient age (62.8 years; range,  $\pm 17$  years) did not change over the 12-year period ( $P = 0.26$ ) but there was an apparent biphasic pattern. In the first 4 years, mean age increased by 1.86 years ( $P < 0.001$ ) to 63.4 years (range,  $\pm 17.6$  years) and then remained static ( $P = 0.09$ ).

There were several noteworthy changes in the casemix. There was a decline in the proportion of cardiac-related diagnostic categories, including a 26% fall in elective

**Figure 2. Average number of occupied intensive care unit beds per 100 000 age-matched population, 2000–2011**



**Table 2. Top 10 diagnostic groups for ICU admissions with the most fatalities, and mortality and P values for decline in annual risk-adjusted mortality over 12 years**

Principal diagnosis*	Fatalities	Mortality (%)	P
Haematological malignancy (C81–C96)	1604	37.9%	0.003
Cerebrovascular disease (I6)	7642	34.8%	0.086
Bacterial disease (A30–A41)	5808	25.8%	0.003
Pneumonia (J12–J18)	6526	23.7%	<0.001
Other respiratory disease (J6–J9)	5338	22%	<0.001
Gastrointestinal disease (K25–K27, K55, K56, K63, K65–K67, K9)	8609	20.1%	<0.001
Head injury (S0)	6149	18%	0.031
Other heart disease (I26–I52)	14 212	16.1%	0.003
Acute myocardial infarction (I21)	15 129	13%	<0.001
Chronic respiratory disease (J4)	7853	12.5%	0.007

ICU = intensive care unit. \* ICD-10-AM code prefix.

cardiac surgical admissions ( $P < 0.001$ ). This was offset by a rise in respiratory-related admissions (9.8% of all admissions) and cancer-related admissions (8.4%). The proportion of major trauma admissions (8.2%) and poisoning-related admissions (3.9%) remained unchanged. Interhospital transfers rose by 28% and emergency (unplanned) admissions rose by 5% ( $P < 0.001$ ) over the 12 years.

### Hospital resource consumption

Within the 23 major (study) hospitals, 2.3% of beds were classified as adult ICU beds and 2.5% of major hospital admissions were admitted to an adult ICU (Table 1). This small group used 8.6% of total hospital bed-days and attracted 19.5% of total hospital casemix-based funding, of which 84% was linked to ICU survivors (87.6% of the ICU population). Average funding (per hospital bed-day) rose by 2.6% per year for MV admissions and 1.8% per year for non-MV ICU admissions ( $P < 0.001$ ).

### Patient outcome

Over the 12-year period, there was a small but significant fall in the observed (raw) hospital mortality (OR, 0.991; 95% CI, 0.988–0.996 per year,  $P = 0.016$ ) and risk-adjusted mortality (OR, 0.967; 95% CI, 0.963–0.971 per year;  $P < 0.001$ ) (Figure 3).

Of the top 10 diagnostic categories with the highest fatalities, all but one category (cerebrovascular disease)

were associated with a temporal decline in risk-adjusted mortality (Table 2). Similar trends in mortality were found in the three hospital peer groups and the MV cohort ( $P < 0.001$ ).

Seventeen hospitals (74%) also showed a decline in risk-adjusted mortality over the 12 years ( $P < 0.01$ ). No hospital experienced a rise in mortality for ICU or MV admissions. The remainder (one metropolitan hospital and five regional hospitals) had no change in mortality rates.

### Discussion

The primary purpose of this investigation was the assessment of temporal trends in use and outcomes associated with adult ICU services in Victoria over the past 12 years. We found an increase in the prevalence of ICU admissions (Figure 2) and a fall in crude and risk-adjusted mortality. Similar trends were noted in individual hospitals. These results concur with previous data based on the Australian and New Zealand Intensive Care Society (ANZICS) Centre for Outcome and Resource Evaluation (CORE) data.<sup>1</sup>

The ICU population (particularly the MV cohort) was found to be a minority (2.5%) of total hospital admissions, but these patients consumed a substantial proportion of health care resources (8.6% of hospital bed-days and 19.5% of casemix funding). The growth in service provision and ICU utilisation per head of population (2.3% per year) suggests that there has been a growth in demand<sup>13</sup> and in funding directed to these services.

These results suggest improved efficacy (as shown by the decline in mortality) but not necessarily efficiency (as shown in LOS data). The temporal decline in hospital mortality was mirrored in most institutions and diagnostic groups (Table 2). Hospital LOS did not increase despite the increase in survivors. We did not have complete data on ICU "exit block"<sup>13</sup> to determine if this factor was responsible for the small increase in ICU LOS.

There are several plausible explanations for an improvement in patient outcomes, including recent health care initiatives. For example, in 2001 the Victorian Department of Health established a statewide major trauma system that led to a redistribution and centralisation of management of severe trauma. In 2002, a statewide collaboration focused on development and promulgation of best practices in the ICU. Expansion of, and improved access to, interventional cardiology services and services for acute cardiac problems may explain the 26% fall in demand for cardiac surgical services. Medical emergency<sup>14</sup> and rapid response teams, nurse practitioner and nurse liaison services, and advance care planning and patient advocacy have all been promoted over recent years.

Our findings have several important implications. First, analysis of administrative datasets provides useful insights into resource availability, use and efficiency. Second, identifying improved outcomes reassures the community and health care funding sources. Third, a jurisdiction-wide outcome analysis such as this may provide another method for assessing the effectiveness of novel system-wide health care initiatives and complement standard research methods based on multicentre randomised controlled trials.

There are several advantages to using administrative data (such as the VAED) for monitoring critical care services. This database is simple, comprehensive, well resourced, regularly audited and readily available in New Zealand and all Australian states. The VAED and COPE model complement the ANZICS CORE dataset and APACHE III-j model. Both are now incorporated into the annual Victorian Intensive Care Services reports.<sup>6</sup>

Our methodology has several limitations and potential sources of error, including model stability, coding shift and selection bias. We have found the COPE model to be well calibrated to the dataset<sup>4</sup> and comparable to APACHE III-j.<sup>3,6</sup> We are unable to exclude coding drift as an explanation for improved outcomes but we found no casemix shift to support this. Data extraction is performed by qualified health information personnel and we undertake regular data quality audits.

Improvement in patient outcomes may simply reflect a shift in triage or admission criteria. Those who are “too sick” or “too well” to benefit from the ICU are triaged to be managed outside the ICU. We did not audit the criteria for ICU admission, nor did this investigation include the outcome of patients not admitted to ICU, and therefore we cannot exclude this as a possible source of bias.

## Conclusions

This large retrospective analysis shows an increase in ICU service demand, substantial resource use and clinically significant improvements in hospital survival, suggesting improvement in the quality of care. Monitoring of ICU resource use, patient safety and outcomes are important components of service delivery.

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## Competing interests

None declared.

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