"The ICU efficiency plot": a novel graphical measure of ICU performance in Australia and New Zealand

Aidan JC Burrell, Andrew Udy, Lahn Straney, Sue Huckson, Shaila Chavan, Jostein Saethern and David Pilcher

There is growing interest in not only intensive care unit (ICU) outcomes but also the resources required to deliver this care and its cost-effectiveness.[1] The most available metric of resource utilisation is ICU length of stay, which is influenced by casemix, illness severity, and institutional characteristics, including delays in discharge. For instance, ICU length of stay is generally longer for more severely ill patients. Comparison of length of stay between units must therefore account for differences in baseline patient characteristics.

Recently, the Australian and New Zealand Intensive Care Society (ANZICS) Centre for Outcome and Resource Evaluation (CORE) developed a model to predict ICU length of stay[2] based on baseline patient demographic information, illness severity and diagnosis. Actual length of stay can be compared with predicted values to identify ICUs with longer or shorter length of stay than expected. When this marker of resource use is combined with a measure of outcome such as in-hospital mortality, an assessment of ICU efficiency can be inferred.[3]

In 2018, "ICU efficiency plots" were introduced into routine ANZICS reporting.

Definition of an ICU efficiency plot

The ICU efficiency plot combines the standardised mortality ratio (SMR) — the ratio of observed to predicted deaths — plotted against the risk-adjusted length of stay ratio (LOSR). The risk-adjusted LOSR is a ratio of the geometric means of observed and predicted length of stay. The geometric mean can be considered the most typical length of stay for a patient group and is usually close to the median value.

Although there has been some controversy about which measures to use,[4,5] the ICU efficiency plot (using risk-adjusted ICU length of stay and risk-adjusted in-hospital mortality) is now routinely reported in multiple countries[6,7] and has been incorporated into ANZICS paediatric reporting since 2011.[6]

In this article, we provide a brief review of this performance metric for adult intensive care clinicians and tips on how these data may be interpreted. Clinicians can review their own ICUs' performance by logging into the ANZICS CORE portal.

Figure 1. "Intensive care unit (ICU) efficiency plot", with two examples highlighted to illustrate the most and least efficient ICUs

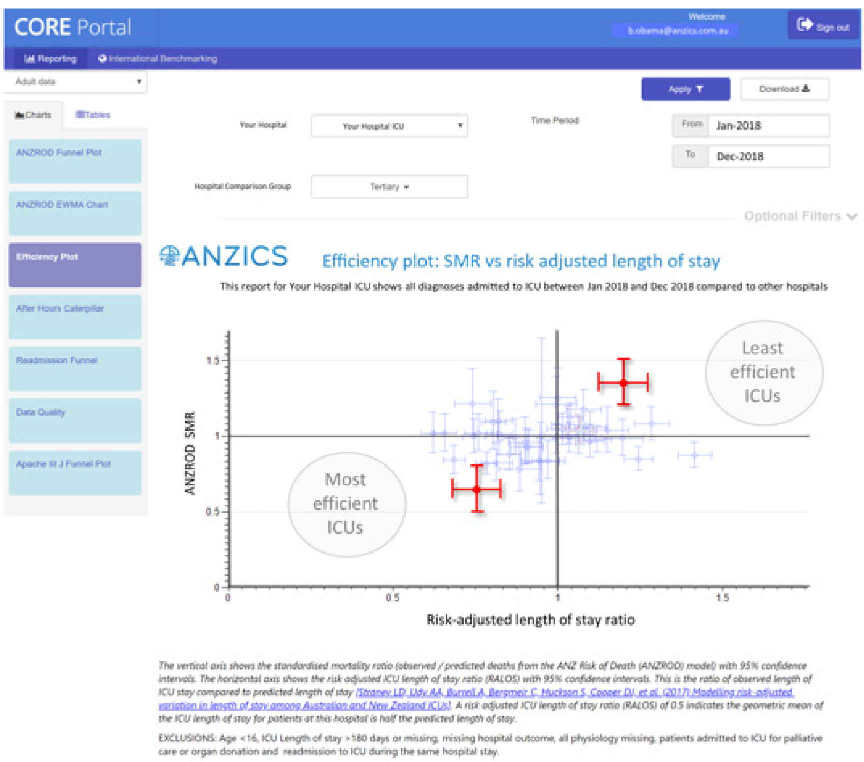


Table 1. Observed and predicted length of stay of all admissions to Australian and New Zealand intensive care units (ICUs) in 2018

	Number of ICU admissions*	Observed ICU length of stay (hours)		Predicted ICU length of stay (hours)	
		Median (IQR)	Geometric mean (95% CI)	Geometric mean (95% CI)	Risk-adjusted LOSR (95%CI)
All ICU admissions	167 014	40.7 (21.5–73.6)	42.1 (41.9–42.3)	42.2 (42.1–42.3)	1.00 (0.99–1.01)
Cardiovascular diagnoses					
Cardiac surgery (CABG and valves)	17 496	47.2 (25.6–73.1)	48.8 (48.3–49.3)	46.4 (46.2–46.6)	1.05 (1.04–1.06)
Cardiac diagnoses	9630	44.2 (21.5–87.3)	42.5 (41.6–43.4)	42.4 (42.0–42.7)	1.00 (0.98–1.02)
Cardiac arrest	3474	64.9 (26.8–122.3)	52.3 (50.0–54.7)	56.3 (55.5–57.2)	0.93 (0.89–0.97)
Aortic aneurysms	2325	41.5 (22.7–85.8)	44.8 (43.0–46.7)	43.7 (42.8–44.6)	1.03 (0.99–1.06)
Other cardiovascular surgery	15 127	24.4 (19.8–47.5)	32.0 (31.6–32.4)	31.7 (31.5–31.9)	1.01 (1.00–1.02)
Respiratory diagnoses					
Chronic obstructive pulmonary disease	2950	56.9 (31.6–98.1)	54.7 (53.0–56.5)	50.0 (49.3–50.6)	1.09 (1.06–1.13)
Other respiratory diagnoses	7410	48.9 (24.9–94.5)	50.5 (49.3–51.6)	51.9 (51.4–52.5)	0.97 (0.95–0.99)
Admissions due to infection					
Pneumonia	6076	74.6 (40.6–144.5)	74.8 (73.0–76.7)	76.4 (75.5–77.2)	0.98 (0.96–1.00)
Other infections (including sepsis)	14 114	62.2 (34.5–112.0)	60.7 (59.8–61.7)	58.2 (57.8–58.7)	1.04 (1.03–1.06)
Other medical diagnoses					
Overdose	5774	34.0 (18.8–55.8)	33.2 (32.5–34.0)	37.0 (36.6–37.3)	0.90 (0.88–0.92)
Other medical diagnoses	8236	44.6 (23.8–76.5)	44.3 (43.4–45.2)	44.8 (44.4–45.1)	0.99 (0.97–1.01)
Gastrointestinal diagnoses					
Gastrointestinal (medical)	5212	52.8 (27.0–99.4)	52.2 (50.7–53.8)	56.1 (55.3–56.9)	0.93 (0.91–0.96)
Gastrointestinal surgery	20 650	28.8 (20.3–65.0)	36.9 (36.5–37.4)	37.2 (36.9–37.4)	0.99 (0.98–1.00)
Neurological and neurosurgical diagnoses					
Cerebrovascular accidents†	2591	41.0 (21.6–78.6)	40.7 (39.0–42.5)	40.9 (40.2–41.7)	0.99 (0.96–1.03)
Seizures	2160	44.0 (23.7–83.3)	45.6 (43.8–47.6)	43.8 (43.0–44.7)	1.04 (1.00–1.08)
Subarachnoid haemorrhage	1708	65.9 (25.0–187.0)	69.1 (65.2–73.2)	70.2 (68.7–71.7)	0.98 (0.94–1.04)
Other neurological diagnoses	8273	26.7 (20.5–65.2)	38.2 (37.4–39.0)	38.1 (37.7–38.5)	1.00 (0.98–1.02)
Other surgical diagnoses					
Orthopaedic surgery	8733	23.5 (19.1–41.3)	27.8 (27.4–28.2)	25.5 (25.4–25.7)	1.09 (1.07–1.10)
Spinal surgery	5884	22.5 (18.5–32.8)	26.2 (25.9–26.6)	26.3 (26.2–26.5)	1.00 (0.98–1.01)
Trauma (excluding head injuries)	5300	46.6 (23.9–95.7)	50.7 (49.3–52.2)	60.4 (59.7–61.1)	0.84 (0.82–0.86)
Head injury (+/- multitrauma)	2414	70.8 (33.6–180.2)	73.2 (69.6–76.8)	76.2 (74.8–77.6)	0.96 (0.92–1.00)

(*Continues*)

Table 1. Observed and predicted length of stay of all admissions to Australian and New Zealand intensive care units (ICUs) in 2018 (*continued*)

		Observed ICU length of stay (hours)		Predicted ICU length of stay (hours)	
	Number of ICU admissions*	Median (IQR)	Geometric mean (95% CI)	Geometric mean (95% CI)	Risk-adjusted LOSR (95%CI)
Other surgical diagnoses	11 477	24.1 (19.0–45.8)	30.4 (30.0–30.9)	30.8 (30.6–31.1)	0.99 (0.97–1.00)
Type of ICU admission					
Elective surgical admissions	64 931	25.1 (20.4–48.3)	32.9 (32.7–33.1)	32 (31.9–32.1)	1.03 (1.02–1.03)
Emergency admissions	101 998	47.5 (23.9–93.6)	49.2 (48.9–49.6)	50.3 (50.1–50.4)	0.98 (0.97–0.99)
Source of admission to ICU					
Operating theatre/ recovery	89 506	26.7 (20.5–55.4)	35.8 (35.6–36.0)	35.1 (35.0–35.2)	1.02 (1.01–1.02)
Emergency department	42 770	46.7 (24.2–88.6)	46.5 (46.1–47.0)	48.1 (47.9–48.3)	0.98 (0.97–0.99)
Ward	24 854	55.1 (27.2–109.3)	53.4 (52.7–54.1)	54.9 (54.6–55.2)	0.99 (0.98–1.00)
Other hospital	9255	61.7 (30.9–125.9)	63.0 (61.7–64.4)	66.4 (65.7–67.1)	0.95 (0.93–0.97)
Therapies provided					
Not ventilated	114 276	29.0 (20.2–62.6)	35.3 (35.1–35.5)	35.1 (35.0–35.2)	1.00 (1.00–1.01)
Ventilated	52 737	57.8 (30.6–117.0)	61.7 (61.1–62.2)	62.6 (62.3–62.8)	0.99 (0.98–0.99)
Inotropes	42 676	67.3 (38.9–124.1)	68.4 (67.8–69.1)	56.9 (56.7–57.2)	1.20 (1.19–1.21)
Renal replacement therapy	5245	123.2 (55.2–264.3)	118.3 (114.6–122)	72.9 (72.0–73.9)	1.62 (1.58–1.67)

CABG = coronary artery bypass graft; IQR = interquartile range; LOSR = length of stay ratio. * With available information. † It includes thrombotic cerebrovascular accidents and intra-cerebral haemorrhage.

Interpreting an ICU's position on the ICU efficiency plot

The SMR and risk-adjusted LOSR make up the two axes on the graph (Figure 1). Each ICU is displayed as a point estimate with 95% confidence intervals. Each unit falls within one of four quadrants, representing different outcome and resource use combinations. The "most efficient" ICUs are in the lower left quadrant, with both low SMR and a shorter ICU length of stay than predicted (the risk-adjusted LOSR is less than one). The "least efficient" ICUs are in the upper right quadrant, with both high SMR and a longer ICU length of stay than predicted (the risk-adjusted LOSR is greater than one).

A risk-adjusted LOSR greater than one indicates a longer observed length of stay than predicted. Patients who deteriorate after admission would be expected to have a longer observed length of stay than predicted and would lead to a higher risk-adjusted LOSR for an ICU. However, individual patients with a very long length of stay generally do not affect the risk-adjusted LOSR because most ICUs have few of these atypical patients.[8,9]

Causes of a longer observed length of stay than predicted

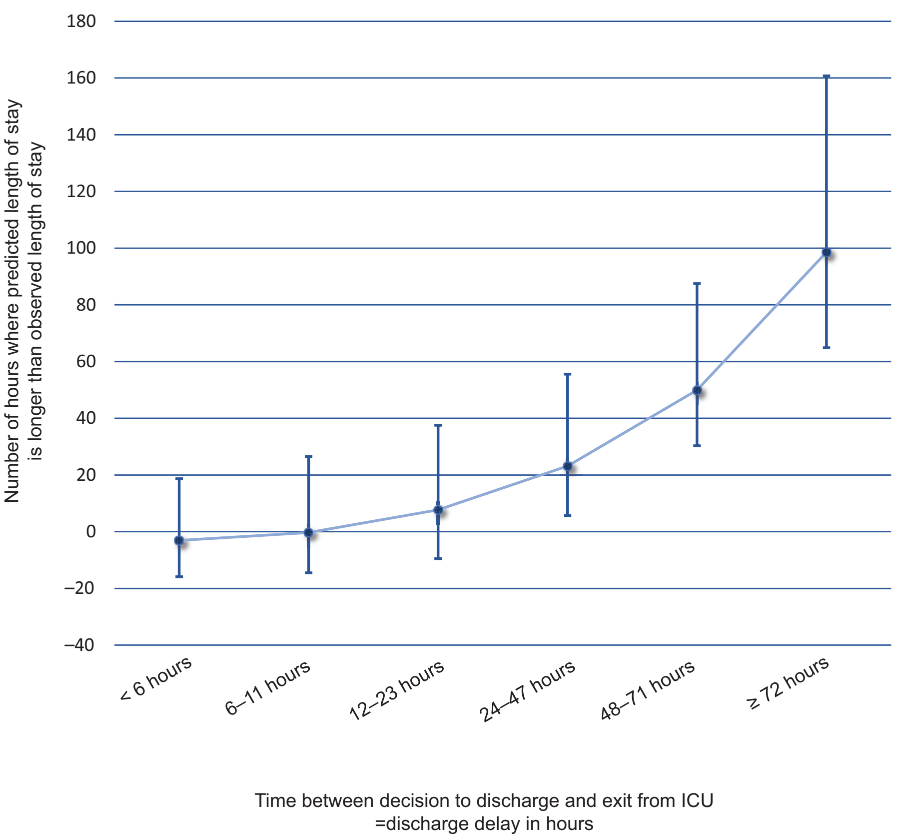
An analysis of 167 014 ICU admissions to 42 rural/regional, 32 metropolitan, 42 tertiary and 63 private ICUs in Australia and New Zealand between January and December 2018 showed statistically significant but clinically small differences between observed and predicted length of stay, typically less than 4 hours for most diagnoses and patient types. Exceptions included non-head injury trauma admissions, where observed length of stay was typically almost 10 hours shorter than predicted, and patients who required renal replacement therapy, in whom the observed length of stay was almost 2 days longer than predicted (Table 1).

The most common factor associated with a high risk-adjusted LOSR was discharge delay (ie, a prolonged time in the ICU after being deemed ready for discharge), which is dependent on both ICU and hospital-wide practices (Figure 2).

Implications

The ICU efficiency plot is an innovative display of overall ICU performance. It provides the opportunity to benchmark

Figure 2. Number of hours that predicted length of stay is longer than observed length of stay plotted against discharge delay in hours (time between decision to discharge and exit from the intensive care unit) ($P < 0.001$) for increasing difference between predicted and observed length of stay, with increasing discharge delay in hours



institutional resource utilisation against mortality. It updates quarterly as ANZICS data are submitted but will require scrutiny to determine overall accuracy of predictions.[10] In the future, it may also facilitate monitoring of interventions to improve overall ICU performance. This information will hopefully stimulate review of hospital-wide processes that affect ICU length of stay, patient disposition, and workflow.

Competing interests

No relevant disclosures.

Author details

Aidan JC Burrell[1,2]
Andrew Udy[1,2,3]
Lahn Straney[2]
Sue Huckson[3]
Shaila Chavan[3]
Jostein Saethern[3]
David Pilcher[1,2,3]

1 Department of Intensive Care, Alfred Hospital, Melbourne, VIC, Australia.
2 School of Public Health and Preventive Medicine, Monash University, Melbourne, VIC, Australia.
3 Australian and New Zealand Intensive Care Society Centre for Outcome and Resource Evaluation, Melbourne, VIC, Australia.

Correspondence: aidan.burrell@monash.edu

References

1 Rothen HU, Stricker K, Einfalt J, et al (2007) Variability in outcome and resource use in intensive care units. *Intensive Care Med* 33: 1329-36.
2 Straney LD, Udy AA, Burrell A, et al. Modelling risk-adjusted variation in length of stay among Australian and New Zealand ICUs. *PLoS ONE* 2017; 12: e0176570.
3 Rapoport J, Teres D, Zhao Y, Lemeshow S. Length of stay data as a guide to hospital economic performance for ICU patients. *Med Care* 2003; 41: 386-97.
4 Teres D, Higgins T, Steingrub J, et al: Defining a high performance ICU system for the 21st century: a position paper. *J Intensive Care Med* 1998; 13: 195-205.
5 Rapoport J, Teres D, Lemeshow S, Gehlbach S. A method for assessing the clinical performance and cost-effectiveness of intensive care units: a multicenter inception cohort study. *Crit Care Med* 1994; 22: 1385-91.
6 Straney LD, Clements A, Alexander J, Slater A. Measuring efficiency in Australian and New Zealand paediatric intensive care units. *Intensive Care Med* 2010; 36: 1410-6.
7 Niskanen M, Reinikainen M, Pettilä V. Case-mix-adjusted length of stay and mortality in 23 Finnish ICUs. *Intensive Care Med* 2009; 35: 1060-7.
8 Crozier TM, Pilcher DV, Bailey MJ, et al. Long-stay patients in Australian and New Zealand intensive care units: demographics and outcomes. *Crit Care Resusc* 2007; 9: 327-33.
9 Iwashyna TJ, Hodgson CL, Pilcher D, et al. Timing of onset and burden of persistent critical illness in Australia and New Zealand: a retrospective, population-based, observational study. *Lancet Respir Med* 2016; 4: 566-73.
10 Kramer AA. Are ICU length of stay predictions worthwhile? *Crit Care Med* 2017; 45: 379-80.