Tasman JOURNALS
tasmanjournals.com
Open access medical and scientific journals from Down Under

TASMAN MEDICAL JOURNAL
ISSN 2652-1881
Volume 2 (4): 74-79; (2020)

RESEARCH

Targeted testing safely reduces diagnostic tests in the intensive care unit: An interventional study

Edward Litton, Katherine Hooper, Cyrus Edibam

Intensive Care Unit, Fiona Stanley Hospital, Robin Warren Drive, Murdoch, Western Australia 6150, and School of Medicine, University of Western Australia, Crawley, Western Australia, 6009

Abstract

Background For patients admitted to the Intensive care unit (ICU), diagnostic testing is often conducted routinely and at set intervals. However, compared to ordering tests in response to specific clinical questions, routine ordering may result in substantial unnecessary testing and be associated with adverse consequences including diversion of clinician time, iatrogenic anaemia and false positive results.

Aim To assess the effect of introducing a targeted testing intervention on the number of routine diagnostic tests performed in the ICU. Clinical outcomes included blood product use, length of stay and mortality.

Methods A single centre, before and after study conducted in the adult ICU of a tertiary hospital in Perth, Western Australia. The targeted testing intervention included a diagnostic testing guideline, clinician education, and feedback of tests conducted. All patients admitted in the 12 months before and following introduction of the intervention were compared using aggregated laboratory and other data obtained routinely and contained in clinical registries. The primary outcome was reduction in total tests conducted per ICU admission. Secondary outcomes included blood product ordered and intensive care unit and hospital length of stay and mortality.

Results All 2477 patients in the 12-month pre-intervention period and 2625 patients in the 12-month post-intervention period were included in the study. Clinical characteristics of the groups were similar. Routine diagnostic tests per ICU admission were 47.0 (SD 6.4) pre-intervention and 24.9 (6.5) post-intervention [mean reduction 22.1 (95% CI 16.6-27.6), P<0.0001], a difference of 49,452 fewer tests overall. Clinical outcomes including length of stay and mortality were unchanged.

Conclusion An ICU targeted testing intervention resulted in substantial decrease in routine diagnostic testing and ordered blood products without any detriment to clinical outcomes. *Tasman Medical Journal 2020; 2: 74-79*

INTRODUCTION

The operational cost of a single day in an Australian intensive care unit (ICU) is approximately $5000 AU$, of which diagnostic costs account for approximately 30% of all consumable costs.[1] Given total annual operations costs for ICU care in Australia of $2119 million AU$ (approximately 0.15% of gross domestic product), international recommendations for ICUs to reduce waste by not ordering diagnostic tests at regular intervals, but rather based on responses specific clinical questions, may result in substantial savings.[2] Furthermore, routine testing that is unnecessary may be associated with adverse consequences including diversion of clinician time, iatrogenic anaemia and false positive results.[3-5] However, existing evidence for targeted testing interventions is limited by failing to take into account secular trends, and examining only selected diagnostic tests and clinical outcomes.[6]

The aim of this study was to assess the effect of introducing a targeted testing intervention on the number of routine diagnostic tests performed in the ICU, taking into account secular trend, all relevant tests, and clinical outcomes. The primary hypothesis was that a targeted

testing intervention will be associated with a reduction in unnecessary routine diagnostic tests in patients admitted to the ICU. A secondary hypothesis was that the targeted testing reduction would be associated with a decrease in blood products administered, without adverse effects on clinical outcomes.

METHODS

This before-and-after study was designed to assess the effect of an intervention to reduce unnecessary routine diagnostic testing (institutional ethical approval was obtained as a quality assurance activity ref 35553). It was conducted in the ICU of the Fiona Stanley Hospital, a tertiary hospital caring predominantly for general medical, surgical and cardiothoracic patients in the southern metropolitan area of Perth, Western Australia. The 30-bed ICU receives approximately 2500 admissions annually and uses an electronic clinical information system, which includes a function for the ordering of diagnostic tests. The ICU is staffed by specialist clinicians who conduct ward rounds twice daily and supervise junior medical staff including ICU trainees and non-training resident medical officers. All mechanically ventilated patients receive a nurse:patient ratio of 1:1. All patients admitted to the ICU for the twelve months immediately prior to and immediately following implementation of the intervention were included in the study.

The study intervention had three components: 1. A diagnostic testing guideline specific for ICU; 2. Education for staff required to order laboratory tests; and 3. Feedback of ordering trends. The major strategy to reduce unnecessary testing was to amend the testing guideline from an opt-out to an opt-in default, by changing the default settings for routine diagnostic testing ordering in the clinical information system. The pre-intervention ICU guideline involved conducting a routine panel of diagnostic tests on admission to ICU in addition to scheduled daily (morning) tests, unless otherwise directed by the treating team. Post-intervention, the guideline was changed for admission and daily testing, so that only diagnostic tests deemed clinically indicated and explicitly suggested by the treating ICU team were requested. This usually occurred during the consultant ward round. In addition, and where considered clinically appropriate, duplicate tests were eliminated (for example, arterial blood gas values sufficient to exclude a need for other tests) and targeted rather than untargeted tests were conducted (e.g. international normalised ratio rather than a full coagulation profile). Education was provided to junior medical and nursing staff to consider the clinical need for testing and to reinforce the new testing guidelines. Support of senior ICU staff was maintained at monthly consultant meetings and non-ICU clinicians admitting patients to the ICU were encouraged to provide written documentation of specific blood tests required. Regular feedback on the number of tests conducted was delivered to clinical staff during the 12-month post-implementation period.

The primary outcome was the number of routine diagnostic tests conducted per ICU admission. This was the composite number of tests including full blood counts (FBC), urea and electrolytes (U&E), magnesium, calcium, liver function tests (LFT), arterial blood gas (ABG), coagulation profile (COAG), international normalised ratio (INR), activated thromboplastin time (APTT), C reactive protein, procalcitonin, troponin, rotational thromboelastometry (rotem) and chest radiographs (CXR). For the purposes of this study, the pathology tests considered routine were those that comprised the pre-intervention order set and the tests that could plausibly increase in order frequency as a result of focused or alternative testing (INR, APTT, rotem and procalcitonin). Although the predominant aim of the intervention was to reduce unnecessary routine pathology testing, CXR were included in the primary outcome as it was hypothesised that the intervention may also have an effect on other routine diagnostic test ordering. Secondary outcomes were the individual components of the primary composite outcome, ICU length of stay, ICU mortality, hospital length of stay and mortality, and number of blood products transfused per ICU admission including red blood cell (RBC) units, fresh frozen plasma, lyophilised concentrate of human coagulation factors (Prothrombinex®), cryoprecipitate and platelets.

Baseline and outcome data were acquired by merging clinical quality registry data to provide aggregate demographic, illness severity, and ICU and hospital outcome data from the Australian and New Zealand Intensive Care Society Adult Patient Database (ANZICS APD), with local hospital pathology, radiology and transfusion medicine databases. All data were collected in aggregate without patient identifiers. Categorical data were presented as count and percentage and analysed using the Chi^2 test. Continuous data were presented as mean and standard deviation (SD) where normally distributed, or median and interquartile range (IQR) where skewed, and compared using Students t test or Wilcoxon rank sum test respectively. A P value of <0.05 was considered statistically significant. To account for secular trends, the primary outcome was assessed by interrupted time series analysis, with monthly time periods and assessment for autocorrelation.[7] The outputs on an interrupted time series analysis include an estimated line of best fit for the pre- and post-intervention periods to provide a measure of the magnitude, confidence and significance of the trend over time prior to the intervention, the immediate change associated with the

intervention and the change in trend post-intervention. All analyses were performed using Stata SE 14 (4905 Lakeway Dr, College Station TX 77845).

RESULTS

The intervention was started on 1 July 2017. All patients admitted to the Fiona Stanley Hospital ICU (n = 5102) between 1 July 2016 and 30 June 2018 were included in the study, being 2477 patients in the 12-month -- intervention period and 2625 patients in the 12-month post-intervention period.

The clinical characteristics of the patients in the pre- and post-implementation periods were similar, except for a slightly and non-significantly higher number and proportion of patients receiving mechanical ventilation in the pre-implementation (n = 1221 (49%)) compared with post-implementation (n = 1187 (45.2%)) periods (Table 1) period.

Characteristic	Pre- n=2477	Post- n=2625	P
Age (y): mean±SD	58.8 ± 17.4	58.7 ± 17.9	0.795
Male	1463 (59.1)	1506 (57.4)	0.221
APACHE II median (IQR)	14 (11-19)	14 (10-18)	0.008
Admission type:			
Medical	1107 (44.7)	1207 (46.0)	0.355
Surgical	1370 (55.3)	1418 (54.0)	
Emergency admission	1484 (59.9)	1561 (59.5)	0.746
Invasive ventilation	1221 (49.3)	1187 (45.2)	0.004

Table 1. Clinical characteristics of patients by phase (Pre- and Post-) of study implementation [n (%) except where stated]. SD = Standard deviation; IQR = Interquartile range; APACHE = Acute Physiology And Chronic Health Evaluation score.

There was a significant decrease in routine diagnostic tests per ICU admission from 47.0±6.4 (SD) pre-intervention to 24.9±6.5 post-intervention, a mean reduction of 22.1 (95% CI 16.6-27.6; P<0.0001). This is equivalent to 49,452 fewer routine diagnostic tests being ordered per annum (Table 2). Conservatively, this would have resulted in an annual saving of $794,349.15 AUD (based on a hospital cost per included test of $30.33 AUD for arterial blood gases, $15.26 for full blood count, $15.93 for urea and electrolytes and $8.73 AUD for all other tests).

Interrupted time series analysis of aggregate monthly tests demonstrated a significant trend of decreasing monthly tests in the preintervention period of 0.92 (95% CI 0.41-1.41, P=0.01) tests per ICU admission per month (Fig. 1). The intervention resulted in a decrease in 10.91 (95% CI 2.37-19.46, P=0.015) tests per ICU admission. There was no significant difference in trend of tests per ICU admission over time in the two intervention periods 0.19 (95%CI -0.99-1.03, P=0.968).

There were significant decreases in the number of tests per ICU admission for ABG, COAG, LFT, FBC, CXR and U&Es. APTT ordering was unchanged and INR ordering was increased in the post-implementation period (Table 2).

ICU and hospital mortality were similar in the pre- and post-implementation periods, as were ICU and hospital length of stay. There were significantly fewer red blood cell and fresh frozen plasma transfusions per ICU admission in the post compared to the pre-intervention periods (Table 3). In a post-hoc interrupted time series analysis of RBC units per ICU admission, there was no association between RBC transfusion and time in the pre-intervention period, (0.00 RBC units per admission per month, 95% CI −0.05-0.04, P=0.920), or associated with initiating the intervention (−0.15 RBC units per admission per month, 95% CI −0.50-0.21, P=0.400), or in difference in trend between intervention periods (−0.01, 95%CI −0.07-0.05, P=0.726) (not shown).

DISCUSSION

In this before and after study, introduction of a multicomponent ICU targeted testing intervention resulted in a significant and substantial decrease in laboratory tests and transfusions of red blood cells and fresh frozen plasma, without any difference in ICU or hospital length of stay or mortality. The findings of significant decrease in total tests ordered per ICU admission were robust to secular trend, despite a significant decrease in testing over time prior to introduction of the intervention.

These findings support views calling into question the value of 'protocolised' medicine in ICU.[8] In this study, targeted testing rather than protocolised routine testing resulted in nearly 50,000 fewer tests conducted in a single ICU over a calendar year. Consistent with the available evidence for effecting behaviour change amongst healthcare professionals,[9] the targeted testing intervention was multifaceted. The conservative estimate of annual savings of over three quarters of a million dollars approaches the estimated annual operational costs of a tertiary ICU bed.[2]

Several reasons may account for the lower number of red blood cell and fresh frozen plasma transfusions. The decrease occurred without increase in other blood component use. Decreased testing may have resulted in a significantly lower volume of blood drawn from patients, resulting in less iatrogenic anaemia, the most common

	Tests per ICU admission Pre- n=2477	Tests per ICU admission Post- n=2625	Net reduction in total tests over 12 m	Mean reduction in tests per ICU admission (95% confidence interval)	P
Total*	47.0 (6.4)	24.9 (6.5)	49,452	22.1 (16.6-27.6)	<0.0001
Full blood count	4.7 (0.5)	3.3 (0.5)	2,696	1.3 (0.9-1.78)	<0.0001
Urea and electrolytes	4.7 (0.5)	3.4 (0.4)	2,510	1.3 (0.9-1.7)	<0.0001
Magnesium	4.4 (0.5)	2.4 (0.6)	4,374	2.0 (1.5-2.4)	<0.0001
Calcium	4.0 (0.6)	1.0 (0.8)	7095	3.0 (2.4-3.6)	<0.0001
Liver function tests	4.0 (0.7)	1.5 (0.6)	5,899	2.5 (2.0-3.1)	<0.0001
Coagulation profile	4.1 (0.6)	1.5 (0.6)	5,941	2.5 (2.0-3.1)	<0.0001
INR	0.03 (0.02)	0.25 (0.13)	−548	−0.21 (0.29- −0.13)	<0.0001
ATT	0.44 (0.15)	0.42 (0.11)	9	0.02 (−0.09-0.14)	0.666
Arterial blood gas	14.3 (2.2)	7.7 (2.6)	14,723	6.7 (4.6-8.7)	<0.0001
CRP	1.6 (0.4)	0.8 (0.3)	1838	0.8 (0.5-1.1)	<0.0001
Procalcitonin	0.5 (0.2)	0.1 (0.1)	1112	0.5 (0.3-0.6)	<0.0001
Troponin	0.8 (0.1)	0.4 (0.2)	701	0.3 (0.2-0.4)	<0.0001
Rotem	0.2 (0.06)	0.12 (0.04)	107	0.10 (0.05-0.14)	0.0002
Chest radiographs	3.4 (0.5)	2.1 (0.45)	2905	1.3 (0.9-1.7)	<0.0001

Table 2 Routine diagnostic tests per ICU admission Pre- and Post-intervention. Data are shown as mean and standard deviation (SD) unless otherwise stated. ICU = intensive care unit; INR = International Normalised Ratio; ATT = Activated thromboplastin time; CRP = C-reactive protein *Combination of full blood count, urea and electrolytes, liver function tests, coagulation profile, INR, APTT, arterial blood gases, chest radiographs

	PRE n=2477	POST n=2625	*OR or difference in means (95% CI)	P
Mortality [n (%)]				
ICU	164 (6.6)	174 (6.6)	*1.00 (0.80-1.25)	0.991
Hospital	218 (8.8)	232 (8.8)	*1.01 (0.83-1.22)	0.953
Length of stay – median days (IQR)				
ICU	1.9 (1.0-3.7)	1.9 (1.0-3.7)		0.878
Hospital	8.4 (5.2-16.2)	8.4 (5.2-15.7)		0.600
Blood products – mean per ICU admission (SD)				
Red blood cells	0.77 (0.20)	0.54 (0.16)	0.23 (0.07-0.38)	0.005
Platelet transfusion	0.16 (0.05)	0.13 (0.04)	0.02 (-0.01-0.06)	0.122
Fresh frozen plasma	0.18 (0.11)	0.09 (0.80)	0.09 (0.01-0.18)	0.027
Prothrombinex ®	0.26 (0.10)	0.28 (0.14)	−0.02 (-0.12-0.08)	0.693
Cryoprecipitate	0.07 (0.03)	0.07 (0.05)	0.00 (−0.03-0.03)	0.882

Table 3 Clinical outcomes PRE and POST implementation of study procedures. OR = odds ratio; CI = confidence interval; ICU = intensive care unit; SD = standard deviation.

indication for ICU transfusion. In addition, decreased testing may have resulted in fewer apparently abnormal coagulation results.

The relative contribution to the decrease in total tests performed was not uniform. Rather, several tests contributed the majority of the decrease in absolute and relative terms. ABGs, LFT and COAG tests each compelled to act despite lack of clinical indication. Alternatively, lower transfusion may have been part of a temporal trend, or a chance finding as suggested by the non-significant association observed in the interrupted time series analysis of red blood cell transfusion contributed more than 10% to the total decrease in test number, suggesting that for other ICUs seeking to reduce testing, these may be the tests to prioritise. Interestingly, despite CXR not being a focus for the targeted testing reduction, there was a significant decrease over the post-implementation period, perhaps reflecting a general shift in the approach to diagnostic test decision-making.

Although major reductions were observed in the number of ordered tests and blood products, no significant differences in ICU or hospital length of stay or mortality were observed. Whilst this is reassuring, the confidence interval around the point estimate of the differences between the two periods was wide, including clinically important benefit or harm. The success of using information available from clinical registries and databases exclusively for study data collection suggests that a large-scale, multicentre trial designed to assess the safety and efficacy of targeted testing in ICU may be feasible.

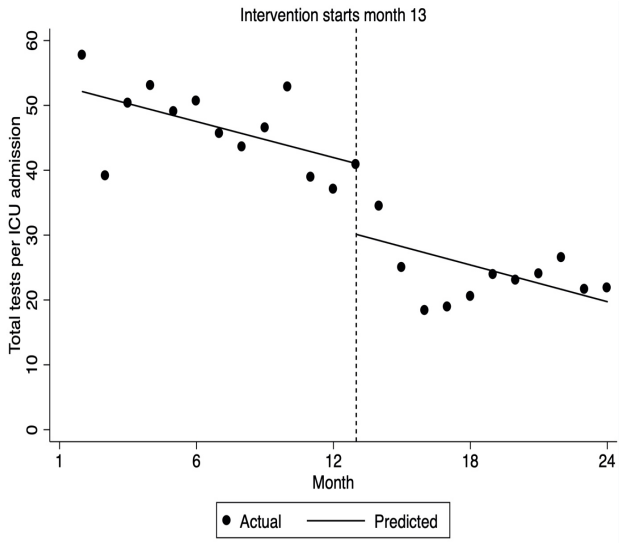

Fig. 1. Interrupted time series analysis of monthly total diagnostic tests per ICU admission pre- and post-intervention

Limitations

This study has several limitations. It was a single-centre study, which may limit generalizability. However, the findings are consistent with other similar studies.[6] Despite significant decreases in ordered tests that were robust to interrupted time series analysis, the before and after study design precludes definitive causal inference being drawn and randomised trials are necessary to provide pivotal evidence.[10,11] Longer pre- and post-intervention sampling periods may have allowed more precise estimates of any underlying trend over time, and difference in trend associated with the intervention. In addition, the association between differences between the cohorts in APACHE scores and tests ordered is uncertain. Finally, although no individual instances of adverse events related to diagnostic testing were found, and no differences were seen in clinical outcomes, study-related adverse events were not collected prospectively.

CONCLUSION

A targeted testing intervention in ICU resulted in substantial decrease in routine diagnostic testing and ordered blood products without any change in clinical outcomes.

Provenance: Externally reviewed
Ethics: Approved as Quality Assurance Activity by SMHS Ethics Committee according to NH&MRC (Australia) guidelines.
Disclosures: None
Acknowledgements: The authors would like to thank staff and patients of the Fiona Stanley Intensive Care Unit for their contribution to the project.

Editor's note: *This article is considered part of a future special issue (Vol. 3 (1) 2021) of the Journal devoted to research being conducted at hospitals within the South Metropolitan Health Service (Fiona Stanley Hospital and Fremantle Hospital), Perth, Western Australia, but is being published in the previous issue (Vol. 2 (4) 2020) at the authors' request.*

Corresponding Author: Dr Edward Litton, Intensive Care Unit, Fiona Stanley Hospital, Robin Warren Drive, Murdoch, Western Australia 6150. *Edward.Litton@health.wa.gov*.

References

1. Hicks P, Huckson S, Fenney E, Leggett I, Pilcher D, Litton E. The financial cost of intensive care in Australia: a multicentre registry study. Med J Aust. 2019; 211:324-5. https://doi.org/10.5694/mja2.50309.
2. Halpern SD, Becker D, Curtis JR, Fowler R, Hyzy R *et al*. An official American Thoracic Society/ American Association of Critical-Care Nurses/ American College of Chest Physicians/Society of Critical Care Medicine policy statement: the Choosing Wisely® Top 5 list in Critical Care Medicine. Am J Resp Crit Care Med 2014; 190: 818-26.
3. Eaton KP, Levy K, Soong C, Pahwa AK, Petrilli C *et al*. Evidence-Based Guidelines to Eliminate Repetitive Laboratory Testing. JAMA Internal Medicine. 2017; 177: 1833-9.
4. Flabouris A, Bishop G, Williams L, Cunningham M. Routine blood test ordering for patients in intensive care. Anaesthesia and Intensive Care. 2000; 28: 562-5.
5. Oliveira A. Prevalence of unnecessary laboratory tests and related avoidable costs in intensive care unit. J Bras Patol Med Lab 2014; 50: 410-6.
6. Hooper KA, M. Litton, E. Safety and efficacy of routine diagnostic test reduction interventions in patients admitted to the intensive care unit: A systematic review and meta-analysis Anaesthesia and Intensive Care. 2020; In the Press.
7. Bernal JL, Cummins S, Gasparrini A. Interrupted time series regression for the evaluation of public health interventions: a tutorial. Int J Epidemiol. 2017; 46: 348-55.
8. Delaney A, Hammond N, Litton E. Checklists and protocols in the ICU: less variability in care or more unnecessary interventions? Intensive Care Med. 2020; 46: 1249-51.
9. Johnson MJ, May CR. Promoting professional behaviour change in healthcare: what interventions work, and why? A theory-led overview of systematic reviews. BMJ Open. 2015;5(9):e008592.
10. Grantham KL, Kasza J, Heritier S, Hemming K, Litton E, Forbes AB. How many times should a cluster randomized crossover trial cross over? Stat Med. 2019; 38: 5021-33.
11. Young PJ, Bagshaw SM, Forbes AB, Nichol AD, Wright SE *et al.* Opportunities and challenges of clustering, crossing over, and using registry data in the PEPTIC trial. Critical care and Resuscitation : J Australas Acad Critical Care Medicine. 2020; 22: 105-9.