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Potentially redundant repeat liver function test ordering practices in australian hospitals: A 5-year multicentre retrospective observational study

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Abstract

Background: Repeat Liver Function Tests (LFTs) are often necessary for monitoring purposes, but retesting within a short time interval may suggest potentially redundant repeat test (PRRT) ordering practices. We aimed to determine the proportion of potentially redundant repeat LFT ordering and identify associated factors in hospitals.

Methods: A 5-year (2014-2018) retrospective cohort study in six hospitals in New South Wales, Australia. A total of 131 885 patient admissions with repeat LFTs in the general ward (n = 102 852) and intensive care unit (ICU) (n = 29 033) met the inclusion criteria. Existing guidelines do not support retesting LFT for at least 48-72 hours. We used 24 hours as a conservative minimum retesting interval to examine PRRT ordering. We fit binary logistic regression to identify factors associated with PRRT ordering in two conditions with the highest repeat LFTs.

Results: There were a total of 298 567 repeat LFTs (medians of 2 repeats/admission and retesting interval of 25.6 hours) in the general ward and 205 929 (medians of 4 repeats/admission and retesting interval of 24.1 hours) in the ICU. The proportions of PRRT ordering were 35.2% (105 227/298 567) and 47.7% (98 307/205 929) in the general ward and ICU, respectively. The proportions of patients who received at least one PRRT were 52.3% (53 766/102 852) and 83.9% (24 365/29 033) in the general ward and ICU, respectively. Age, gender and the number of comorbidities and procedures were associated with the likelihood of ordering PRRT depending on the settings.

Conclusion: Repeat LFT testing is common in Australian hospitals, often within 24 hours, despite guidelines not supporting too-early repeat testing. Further research should be conducted to understand whether better adherence to existing guidelines is required, or if there is any case for guidelines to be updated based on certain patient subpopulations.

1 | INTRODUCTION

Over the past decades, pathology test ordering has increased substantially, both in Australia and worldwide, resulting in increased expenditure and also increased workload for hospital laboratories and clinicians. While we know that pathology testing is a key element in the diagnostic pathway when used appropriately, it is estimated that around 28% of testing is ordered inappropriately, including tests without a clear indication, that are not recommended according to guidelines, or repeat tests performed at too short interval to be of clinical value.[1,2] This suggests that a large portion of increase in test ordering may represent inappropriate test ordering, and low value care for patients. Inappropriate testing presents a risk not only to patients because of phlebotomy risks such as hospital-acquired anaemia,[3,4] but also places a burden on resources and finances for hospitals for both testing and unwarranted downstream medical interventions,[1,5] as well as a strain on cognitive load for physicians.

A key area that has been suggested to target for quality improvement is repeat testing,[5-9] with one study showing repeat tests accounted for 17% of laboratory workload.[2] Reasons for repeat testing may include monitoring changes in condition in unstable patients. However, they are also often potentially because of the convenient, but often too-frequent, clinical practice of "standing orders" for routine daily tests,[5] because of previous results being unavailable, or because of the clinician being unaware that the test had been recently undertaken. Studies have shown that even once a previously unstable patient stabilises, repeat testing often continues.[1,2,10,11] Adding to the confusion of when to repeat tests, guidelines for repeat test ordering may differ between hospitals, or may be non-existent.

Among the most commonly ordered tests for inpatients are liver function tests (LFTs).[5,12,13] Reasons for liver function tests in hospitalised patients vary, but some general guidelines can be found in the literature. In the acute inpatient setting, LFTs are not considered to be an indicator of an immediately life-threatening condition but are important in monitoring conditions such as poisoning, acute liver injury and response to certain drugs.[14] Repeat LFTs are often necessary to monitor disease and treatment outcomes. Existing guideline recommendations for repeating LFT ranges from 48-72 hours.[14-16] While most guidelines focus on management and do not give specific timeframes during hospital stay,[17] others from the UK have recommended a minimum re-test interval for stable inpatients of 48 hours,[15] or even 72 hours in the case of the Royal College of Pathologists "National minimum retesting intervals in pathology".[14,16] An Australian study has recommended that anything less than one calendar day (or 24 hours) is considered inappropriate for repeat LFT testing.[12] Whilst repeating LFT is necessary in hospitals, retesting within a short time-interval may suggest potentially redundant repeat test (PRRT) ordering practices.[18] The aim of this study is twofold: (1) to determine the proportion of potentially redundant repeat LFT ordering practices and (2) to identify factors associated with PRRT ordering in general inpatient wards and Intensive Care Units (ICUs).

What's known

- It is estimated that over a quarter of laboratory tests are ordered inappropriately, potentially putting patients at risk.
- Repeat testing sooner than recommended can be considered a type of inappropriate testing that represents low value care for patients as well as putting strain on hospital resources.

What's new

- Patients who received at least one potentially redundant repeat test (PRTT) were 52.3% in general wards and 83.9% in ICU. Age, gender and number of comorbidities and procedures were associated with the likelihood of ordering PRRT depending on the settings.
- High levels of PRTT in Australian hospitals indicate that quality improvements to ordering systems, acknowledgement systems or decision support will improve value of care and may have a positive impact on patient outcomes.

# 2 | METHODOLOGY

2.1 | Study design and setting

We conducted a multicentre, retrospective observational study using routinely collected health data from six public hospitals' inpatients (Hospital A-F) in New South Wales, Australia. The study period was from Jan 2014-Dec 2018 (5 years). Hospitals A-C are located in a metropolitan Sydney Local Health District, while Hospitals D-F are located within regional Local Health District. All hospitals have ICUs except Hospital E. In 2016/17,[19] the hospitals had total admissions of 65 793 (Hospital A), 48 151 (Hospital B), 28 772 (Hospital C), 51 659 (Hospital D), 16 603 (Hospital E) and 21 266 (Hospital F).

2.2 | Participants

The study participants included all patients who were admitted to the general inpatient wards or ICUs during the study period and received at least one repeat LFT (>one tests/admission) during their hospital stay (Figure 1). No other exclusion criteria were applied in this study.

2.3 | Data sources

The data used in this study were obtained by linking the Laboratory Information System (LIS) and Admitted Patient Data Collection (APDC). The data linkage procedures have been reported
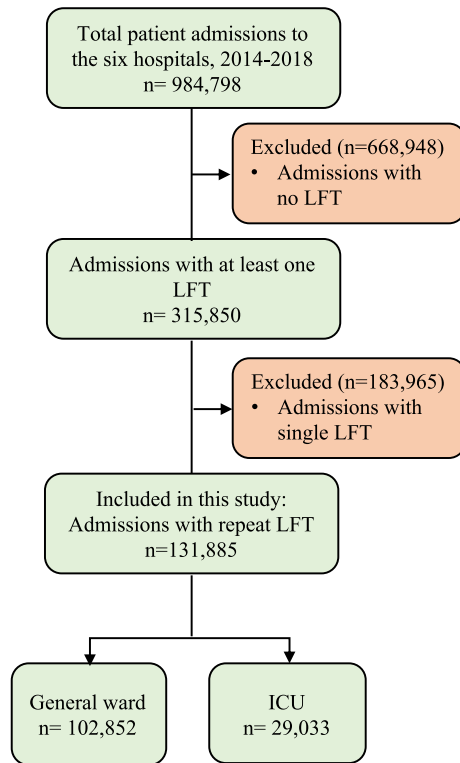
FIGURE 1 Patient selection flow chart

previously.[20-24] The LIS contains laboratory data such as types of test ordered (eg LFT), hospitals that ordered the test and location of the order [eg ICU, general inpatient wards). LFT is usually ordered in the form of a panel containing multiple components. The components of LFT may include alanine transaminase (ALT), aspartate transaminase (AST), alkaline phosphatase (ALP), albumin and total protein, bilirubin, gamma-glutamyl transferase (GGT) and prothrombin time.

The APDC contains data about admission and demographics characteristics (eg age, patient source of referral, urgency on admission), clinical characteristics (eg Australian Refined Diagnosis-Related Group (AR-DRG), procedure conducted, diagnosis codes), throughput indicators (eg times of admission and departure), patient disposition (eg mode of separation) for each patient admission. The International Classification of Diseases version 10 with Australian Modification (ICD-10-AM) codes were used to define the diagnosis[25] and to calculate the modified version of the Charlson comorbidity index[26] and number of comorbidities.

2.4 | Outcome measures

The outcome measure for the second objective was PRRT ordering (ie retesting LFT within 24 hours of the previous test). We used a 24-hour repeat interval as this is a conservative minimum time interval to flag 'too-early retesting' and thus may suggest PRRT ordering practices if retesting occurred within 24 hours.

2.5 | Statistical analysis

Summary statistics including median with inter-quartile range (IQR) for continuous data and frequency with percentages for categorical data were reported as appropriate. The demographic and clinical characteristics of patients who received single vs repeat LFT were compared using χ^2 statistics for categorical variables and Wilcoxon rank-sum test for continuous variables Cumulative proportion plots were created both at the test and patient admission levels to present the proportions of repeat tests and patients receiving the repeat tests by time-intervals.

Factors associated with PRRT ordering were determined as follows. Firstly, for each setting we identified the top principal diagnosis with the highest number of repeat LFT requests. Secondly, we determined whether retesting occurred within or after 24 hours of the previous test. Then, we fit a separate multivariate logistic regression model for each of the two conditions to determine the demographic and clinical factors associated with PRRT ordering. The potential factors assessed were gender, age group, source of referral, urgency on admission, AR-DRG and Charlson comorbidity index while also adjusting for year and hospital of admission. The strength of association was estimated using odds ratio (OR) with 95% confidence intervals (CI). All P-values were 2-tailed and $P < .05$ was considered statistically significant. Analyses were conducted using Stata v16 (StataCorp LP, College Station, TX).

2.6 | Ethical approval

This study has received ethical approval (information removed for double blinding).

3 | RESULTS

3.1 | Participants

There were 984 798 patient admissions during the study period of which 32.1% (n = 315 850) received LFT at least once. Of the 315 850 patients who received LFT, a total of 131 885 (41.8%) patient admissions with repeat LFT in general inpatient wards (n = 102 852) or ICUs (n = 29 033) met the inclusion criteria (Figure 1). The rate of ordering repeat LFT across the study hospitals is shown in Table S1. The risk-adjusted rate of ordering repeat LFT ranged from 36.1% (Hosp E) to 49.2% (Hosp D) (Table S1).

Table 1 compares patient characteristics between the two settings. The distributions of all characteristics were significantly different ($P < .01$ for all comparisons). For instance, ICU patients had relatively higher median numbers of comorbidities and procedures, longer hospital length of stay but slighter lower median age (67 vs 70 years) compared to general ward patients.

TABLE 1 Comparison of patient characteristics between general ward and ICU, 2014-2018

Patient characteristic	Overall (n = 131 885)	Setting[†]	
		General ward (n = 102 852)	ICU (n = 29 033)
Gender, n (%)			
Male	68 026 (51.6)	51 242 (49.8)	16 784 (57.8)
Female	63 859 (48.4)	51 610 (50.2)	12 249 (42.2)
Age in year, median (IQR)	70 (53-81)	70 (53-82)	67 (53-77)
Age group in year, n (%)			
<65	53 818 (40.8)	40 867 (39.7)	12 951 (44.6)
65-80	40 855 (31.0)	30 396 (29.6)	10 459 (36.0)
>80	37 212 (28.2)	31 589 (30.7)	5623 (9.4)
Source of referral, n (%)			
Emergency department (ED)	102 665 (77.8)	84 058 (81.7)	18 607 (64.1)
Other (eg medical practitioner)	29 220 (22.2)	18 794 (18.3)	10 426 (35.9)
Urgency on admission, n (%)			
Urgent	109 884 (83.3)	89 497 (87.0)	20 387 (70.2)
Non-urgent	22 001 (16.7)	13 355 (13.0)	8646 (29.8)
Hospital length of stay (days), median (IQR)	7.7 (4.1-15.2)	6.9 (3.8-13.8)	11.2 (6.3-21.1)
Hospital mode of separation, n (%)			
Discharged by hospital	100 877 (76.5)	80 815 (78.6)	20 062 (69.1)
Transferred to another setting	21 566 (16.4)	16 218 (15.8)	5348 (18.4)
Died in the hospital	6533 (5.0)	3600 (3.5)	2933 (10.1)
Other (eg type change)	2909 (2.2)	2219 (2.1)	690 (2.4)
Charlson comorbidity index, median (IQR)	1 (0-3)	1 (0-2)	1 (0-3)
No. of comorbidities, median (IQR)	8 (4-14)	8 (4-13)	12 (7-19)
No. of procedures, median (IQR)	3 (1-5)	2 (1-4)	5 (2-8)

ED, Emergency department.

[†] P < .01 for all comparisons.

TABLE 2 The frequency of repeat LFTs and time intervals between repeats, 2014-2018

Setting	No. of patient admissions	No. of repeat LFTs	Median (IQR) repeats per admission	Median (IQR) interval between repeats (hr)
General ward	102 852	298 567	2 (1-3)	25.6 (23.2-55.0)
ICU	29 033	205 929	4 (2-8)	24.1 (19.9-32.4)
Overall	131 885	504 496	2 (1-4)	24.7 (22.5-48.4)

The top ten principal diagnoses with the highest repeat LFTs are shown in Table S2. *Unspecified pneumonia* (ICD-10-AM code J18.9) in the general ward and *atherosclerotic heart disease of native coronary artery with angina pectoris (AP)* (ICD-10-AM code I25.11) in the ICU were the leading principal diagnoses with the highest repeat LFTs.

3.2 | Potentially redundant repeat LFT ordering practices

There were a total of 298 567 repeat LFTs with a median of two repeats per admission in the general ward and 205 929 repeat LFTs with a median of four repeats per admission in the ICU. The median

repeat testing interval was 25.6 hours in the general ward (24.1 hours in the ICU) indicating that half of the repeat tests (149 284/298 567) were requested within 25.6 hours of the previous LFT (Table 2).

Figure 2A shows the cumulative proportion of repeat tests by time intervals. The proportions of PRRT ordering (repeating LFT within 24 hours) were **35.2%** (105 227/298 567) and **47.7%** (98 307/205 929) in the general ward and ICU, respectively. The proportions of repeat tests requested within 72 hours were 80.3% and 88.3% in the general ward and ICU, respectively.

Figure 2B shows patient admission-level data. In the general ward, the proportions of patients who received PRRT at least once during their hospital stay were 52.3% (53 766/102 852). Of the 53 766 patients receiving at least one PRRT, 60.2% (n = 32 351) received PRRT only once and 39.8% (n = 21 415) received more than one PRRT In the ICU, PRRT ordering was high with 83.9% (24 365/29 033) of patients receiving at least one PRRT. Of this, 33.5% (n = 8 154) received PRRT only once while 66.5% (n = 16 211) received more than one PRRTs The proportions of patients who received at least one repeat test within 30 hours were 61.7% (63 443/102 852) and 88.7% (25 762/29 033) in the general ward and ICU, respectively. The proportions of patients who received at least one repeat test within 72 hours were 84.5% (86 891/102 852) and 95.3% (27 667/29 033) in the general ward and ICU, respectively.

The PRRT ordering practices across the study hospitals is shown in Table 3. The rate of PRRT ranged from 38.4% to 55.1% across the hospitals in the general ward and from 74.6% to 90.2% in the ICU.

3.3 | Factors associated with PRRT ordering

Figure 3A-B presents factors associated with PRRT ordering (repeating LFT within 24 hours at least once) in two principal diagnoses with the highest repeat LFTs (top one from each setting): *unspecified pneumonia* (n = 3300) in the general ward and *atherosclerotic heart disease of native coronary artery with AP* in the ICU (n = 1037) (Table S2). The rates of ordering PRRT for these

conditions were 43.8% (n = 1445) and 88.7% (n = 920) in the general ward and ICU, respectively. In both settings, there were no significant associations of PRRT ordering with patient source of referral, urgency on admission, AR-DRG and Charlson comorbidity index.

In the general ward (Figure 3A), age group, gender and the number of comorbidities were associated with PRRT ordering for *unspecified pneumonia*. After adjusting for other factors, age > 80 years was associated with lesser likelihoods of ordering PRRT (47.3% vs 42.1%) compared to patients aged < 65 years (adjusted OR 0.79; 95% CI 0.65-0.96; P = .02) while being male was associated with a slightly greater likelihood of ordering PRRT (45.6% vs 41.7%) compared to female (adjusted OR 1.18; 95% CI 1.02-1.35; P = .02). For every five additional comorbidities, the likelihood of ordering PRRT increased by a factor of 1.09 (adjusted OR 1.09; 95% CI 1.01-1.18; P = .03). This is equivalent to a 9% increase in the likelihood of ordering PRRT (Figure 3A).

In the ICU (Figure 3B), the *number of procedures* conducted was the only factor associated with the likelihood of ordering PRRT for *atherosclerotic heart disease of native coronary artery with AP*. For every five additional procedures, the likelihood of ordering PRRT increased by a factor of 1.78 (adjusted OR 1.78; 95% CI 1.13-1.28; P = .01) which is equivalent to a 78% increase in the likelihood of ordering PRRT (Figure 3B).

4 | DISCUSSION

4.1 | Key findings

This study addressed the need for evidence about the occurrence of PRRT testing in hospital general wards and ICUs, and in doing so, uncovered factors associated with PRRT ordering across six Australian hospitals. The major findings are that: (1) nearly one-third (35.2%) of the repeat LFTs in the general ward and half (47.7%) in the ICU were requested within 24- hour of the previous test indicating
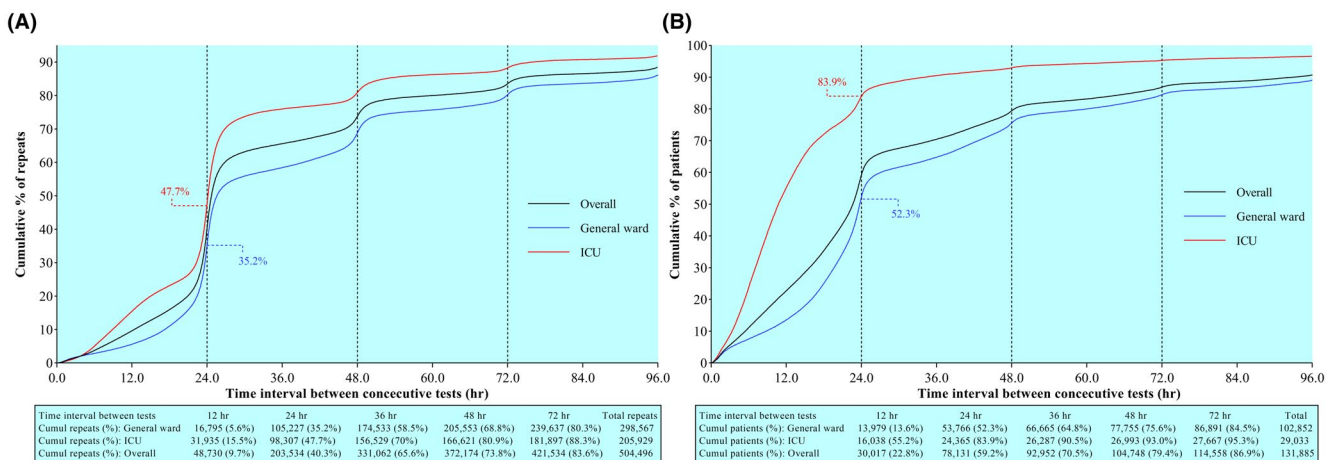

FIGURE 2 LFT repeat testing patterns. A, Cumulative proportion of repeats by repeat testing intervals; B, Cumulative proportion of patient admissions by repeat testing intervals. The vertical line at 24 hours was used to determine the PRRT ordering

TABLE 3 The proportion of patients who received PRRT ordering practices across the study hospitals

| | Admissions with repeat LFTs | | PRRT, n (%) | | | |
| | | | General ward | | ICU | |
Hospital	General ward	ICU	N	%	N	%
A	28 397	11 132	15 638	55.1	9851	88.5
B	22 590	7239	12 392	54.9	5804	80.2
C	15 369	3386	7923	51.6	3053	90.2
D	24 649	4897	12 812	52.0	3882	79.3
E*	5731	–	2203	38.4	–	–
F	6116	2379	2798	45.7	1775	74.6
Overall	**102 852**	**29 033**	**53 766**	**52.3**	**24 365**	**83.9**

*Hospital E does not have ICU.
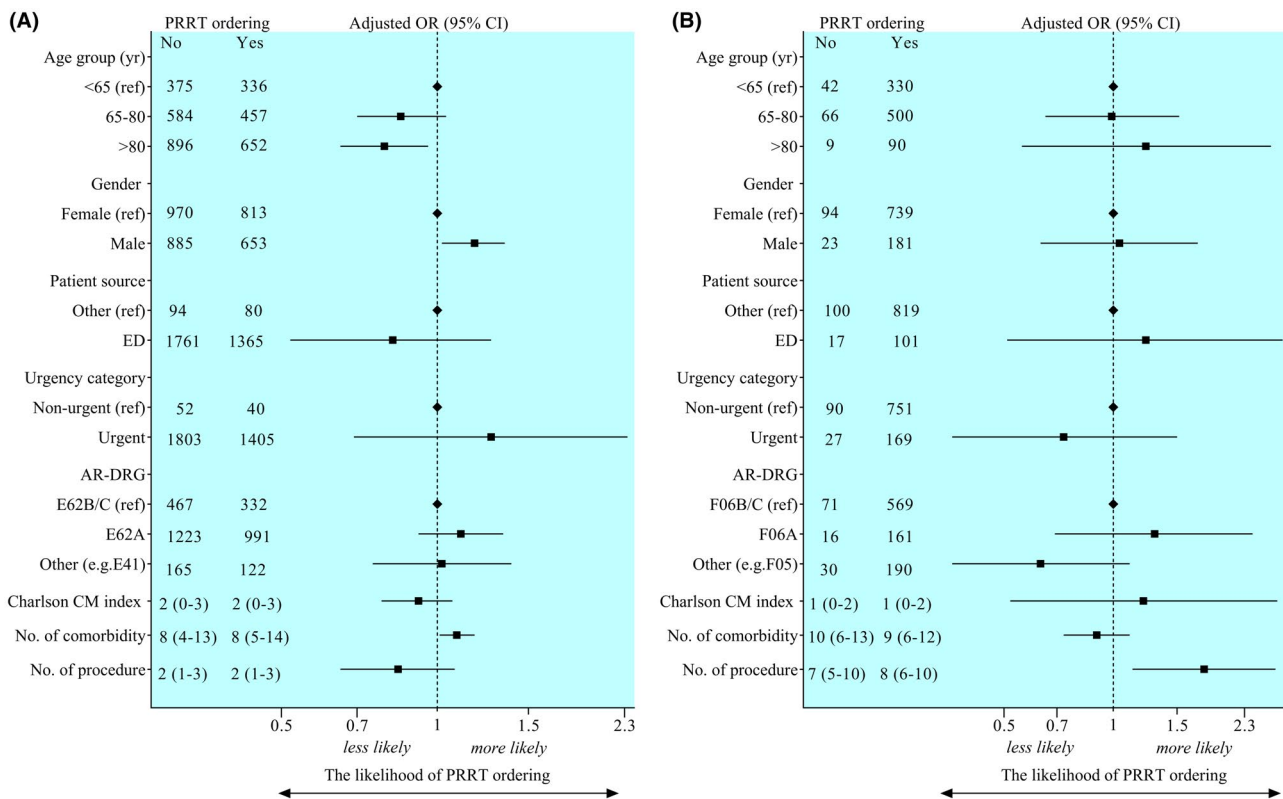
FIGURE 3 Multivariate logistic regression showing factors associated with the likelihood of PRRT ordering (retesting LFT within 24 hours). Patients admitted to (A) General wards with *unspecified pneumonia* and (B) ICUs with *atherosclerotic heart disease of native coronary artery with AP* (B). AR-DRG, Australian refined diagnosis-related groups. The models were adjusted for year and hospital of admission in addition to the variables in the graph. The middle square shows the adjusted OR and the horizontal line shows the 95% CI of the OR. The inclusion of "1" in the 95% CI indicates a non-significant difference. Charlson comorbidity index, the number of comorbidity and procedures were presented as median (IQR) and their respective adjusted ORs are interpreted for every 5 unit increase. AR-DRG definition: E62A, Respiratory infections/inflammations, major complexity/with catastrophic complication or comorbidity (CC); E62B, Respiratory infections/inflammations, minor complexity/with severe or moderate CC; E62C, Respiratory infections/inflammations without CC; E41, Respiratory system disorders with non-invasive ventilation; F06A, Coronary bypass with/without invasive cardiac investigation, major complexity; F06B/C, Coronary bypass with/without invasive cardiac investigation, minor/intermediate complexity; F05, Coronary bypass with invasive cardiac investigation, major complexity

a high level of PRRT ordering practices in the study hospitals; (2) at patient-level, 52.3% (general ward) and 83.9% (ICU) received PRRTs at least once during the hospital stay and (3) age, gender and the number of comorbidities and procedures were associated with greater likelihood of ordering PRRT depending on the settings.

4.2 | Interpretation and comparison with existing literature

We found that repeat LFT testing is common practice in Australian hospitals, often within 24 hours, although guidelines do not support

repeat testing for at least 48-72 hours.[12,14-16] Contributing to the basis of these guidelines is the half-life of liver enzymes, which in circulation is about 47 hours for ALT, 17 hours for total AST, a week for ALP, 20 days for albumin and on average 87 hours for mitochondrial AST.[27,28] The potential for redundant test ordering may be because of communication issues, such as clinicians missing the previous test result, repeat tests ordered during transfers of care, or being unaware that the test has already been ordered by someone else.[2] Communication issues may also be involved in the practice of add-on testing (on an existing specimen) which can be expensive from both a cost and personnel perspective if performed because of the clinician being unaware of a previous test already recently performed.[29] Similarly, reliance on practices supporting recurring of routine order sets in hospital electronic medical systems[30] may also contribute to instances of repeat LFT ordering where it may not be needed.

We showed that a much higher proportion (83.9%) of patients in ICUs received repeat testing within 24 hours compared to patients in the general wards (52.3%). This may be at least partially explained by the more intensive nature of the care required by ICU patients, which in our study revealed more comorbidities, more procedures, longer LOS and greater in-hospital mortality compared to general ward patients. While it is widely accepted that patients in ICU receive many diagnostic investigations on a daily basis, including pathology tests and chest x-rays, the routine ordering of some of these investigations are now considered to represent low-value care,[31-33] defined as care that confers little to no benefit to patients and risk of harm exceeds likely benefit.[34] Online information for the NSW Government's Intensive Care NSW indicates that LFTs are "usually done daily", suggesting it is included in routine daily ordering. One study in Canada showed that increased test ordering in ICU was associated most highly with hospital length of stay, then teaching hospital status, only then followed by the severity of physiological derangement- suggesting that interventions to improve testing should consider the different types of caregivers who order tests.[35] Another study showed that abnormal liver function results were highly prevalent amongst ICU patients and, were nonetheless associated with clinical events and increased 30-day mortality outcomes and thus may be more clinically relevant in this setting.[36] How routine test ordering practices impact on patient care still may vary based on setting. There may also be some exceptions to guidelines (such as severe liver injury because of toxins) that warrant more regular testing, however, these do not form the majority of cases in our study. Therefore, a more targeted and evidence-based recommendation for LFT testing in ICU, taking into account a patients' changing conditions, may support quality improvements such as decision support. Additionally, this may result in less wastage as well as being a more patient-centred approach instead of a one-size-fits-all ordering approach.

When considering factors associated with PRRT ordering, we showed that for patients admitted to general wards with pneumonia, age, gender and number of comorbidities were associated with likelihood of PRRT ordering. Interestingly, elderly patients (>80 years) had less tests repeated within 24 hours (but more likely to receive after 24 hours) compared to patients aged <65 years. One explanation for this could be the presence of hospital policies on blood draws for elderly patients because of risk of anaemia. Repeated blood draws, especially in elderly, very ill patients, may cause pain, discomfort, anxiety, and there is potential for patient harm such as anaemia, thrombus, hematoma, nerve damage and vasovagal reaction, and syncope.[37-41] It is not clear why males had a higher likelihood of PRRT ordering, but greater comorbidities may imply a more complicated medical history and may indicate multiple conditions for liver testing, perhaps ordered by different specialists. In the ICU, for patients with *atherosclerotic heart disease of native coronary artery with AP*, only the number of procedures performed had significant association with PRRT ordering. The absence of any clear indicator for increased PRRT in ICU may be explained by an overall higher prevalence of repeat and daily testing observed amongst most patients in ICU. This higher overall prevalence may be because of a combination of the widespread practice of routine testing/monitoring in the ICU, as well as follow-up of abnormal LFTs.[42] LFT tests may be ordered not only for primary liver diseases but also as a marker of dysregulated systemic inflammation[43] in very ill patients. Thus, the importance of monitoring LFT in the ICU more regularly than inpatient guidelines may warrant further research.

4.3 | Implications for practice and policy

The findings from this study provide key evidence about potentially redundant repeat LFT ordering in hospital settings, which can be used to benchmark any potential interventions or quality control exercises within these institutions. For example, the principles of the Sensible Test Ordering Practice (STOP) program which was implemented to varying degrees at some hospitals at the end of 2013[44] or Choosing Wisely can be tailored based on the subgroups who experienced the highest levels of unnecessary repeat testing. While aim of the STOP initiative was to promote consistent and rational diagnostic test ordering practices in acute care settings (emergency department [ED] and ICU) several other hospital areas have adopted its principles for clinician education. This study also uncovers possible test ordering practices that are misaligned with the recommendations of the few published guidelines we could uncover. Unwarranted testing, which includes tests repeated too soon, may have some negative consequences, including downstream tests, interventions and medications, that may cause more harm than good as well as draw on resources unnecessarily,[45,46] therefore, it is important that testing is done according to evidence-based practice. In that regard though, we have identified a lack of targeted information in guidelines about LFT in ICU and critically ill patients, which will be an important area of study to generate outcome-based guidelines for this particularly vulnerable patient population.

4.4 | Strengths and limitations of the study

To the best of our knowledge, this is the first large-scale study about the prevalence and factors associated with potentially redundant repeat LFT ordering in hospitals. The inclusion of multiple sites including six public hospitals and the large sample size over several years can be considered as the key strength of this study. However, this study has some limitations. One of the main limitations was the absence of test results data. Because of this, we were unable to determine whether the frequency and timing of repeat LFT requesting depended on the results of the first LFT test. Similarly, whilst we attempted to determine the associations of certain demographic and clinical factors with PRRT ordering, we were unable to investigate the effects of illness severity indicators such as the Acute Physiologic and Chronic Health Evaluation (APACHE) and Sequential Organ Failure Assessment (SOFA) scores particularly for ICU patients because of the absence of these data. Another limitation was that as we utilised data from general public hospitals only, the testing patterns observed in the current study may not be generalisable to private hospitals or specialised public (eg children's or women's) hospital settings.

5 | CONCLUSION

The findings of this study reveal that repeat LFT testing is still common practice in Australian hospitals, often within 24 hours, despite guidelines not supporting repeat testing for at least 48-72 hours. These results suggest the existence of potential "routine testing" practices, despite a lack of any evidence suggesting that testing more often than guidelines recommend has any impact on patient outcomes. Further efforts should be made to better understand whether better adherence to existing guidelines is required, or if there is any case for guidelines to be updated based on certain patient subpopulations. For example, evaluations used in this study can be further used to guide qualitative study into reasons why tests are repeated too soon, and to inform interventions to improve the quality of test ordering practices in hospitals. Finally, during the literature search for this study, we also uncovered that current guidelines do not adequately address LFT testing for acutely ill patients in ICU, an issue which should be supported by undertaking further outcome-based study.

DISCLOSURES
None declared.

DATA AVAILABILITY STATEMENT
Conditional and restricted access to relevant Local Health District data used and analysed during this study was granted under ethical approval. Local Health District data are not publicly available.

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SUPPORTING INFORMATION

Additional Supporting Information may be found online in the Supporting Information section.