ORIGINAL ARTICLE

The Frequency and Cost of Redundant Biochemistry Test in Tertiary Teaching Hospital

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ABSTRACT

Introduction: Laboratory tests account for 66% of clinical decision making and reducing inappropriate test utilisation is a step towards optimising patients' care and hospital cost savings. This study aims to identify the rate and cost of redundant test requests in our centre. **Methods:** A cross-sectional study comprising laboratory results of 14 analytes in renal function test (RFT) and liver function test (LFT) were made. Data involved blood results from adult patients admitted to Hospital Universiti Sains Malaysia from January to December 2018. The redundant test is defined as test results consecutively normal twice and requested within 26 hours for analytes in RFT and 50 hours for analytes in LFT. Cost contributions were estimated by multiplying cost-per-test with total redundant requests. The test redundancy in different wards and disease groups were also evaluated. **Results:** Equal distribution of RFT and LFT requests were observed in both genders (50% respectively), with the most requests seen in the 60 – 79 years age group. More than 20% redundancy rate was observed for seven analytes (ALT, total bilirubin, sodium, urea, potassium, AST, Chloride), and overall redundancy was 19.7%, equals to Malaysian Ringgit (MYR) 669,105.00. Oncology wards and genitourinary diseases contribute to the highest redundancy rate. **Conclusion:** This study estimated MYR 600 thousands of saving if test redundancy were to be eliminated. The finding is hoped to serve as a platform for future intervention and policymaking. Future planning to optimise the current laboratory request system and collaboration among physicians and laboratory professionals can minimise test inappropriateness.

Keywords: Inappropriate laboratory utilisation, Overutilisation, Medical order entry system, Cost-benefit analysis, Re-testing interval

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INTRODUCTION

A laboratory test is an indispensable component of healthcare service, as it contributes up to 66% of the clinical decision (1). The pledge towards its appropriate utilisation poses many challenges, especially with rapidly growing healthcare demands in limited resources (2). Overwhelming doubts on ordering appropriate tests among clinicians come from a variety of reasons. In a primary care setting, clinicians admitted to the uncertainty of requesting tests in 14.7% and interpreting 8.3% of cases, but only 6% opted for consultation with laboratory personnel (3). 75% of junior doctors also agreed not to have enough confidence in requesting the correct test, most likely attributed to the lack of exposure in the medical school curriculum (4). These, together with the practice of defensive medicine, (5) flaws in the online ordering system and difficulty to access interhospital data, create challenging barriers to the settlement of this issue (3). Nevertheless, the reduction of test inappropriateness has been proven to be achievable with various measures (6-7).

Ways of investigating the inappropriate utilisation of laboratory tests have been described. Several researchers have directly applied interventions in their studies to simultaneously compare the prevalence of unnecessary tests request both in the pre and post-interventional periods (7,8). To tackle this issue at the pre-analytical level, educational programs and guidelines on appropriate test ordering were among the interventions of choice (7). At the laboratory level, modification to the pre-existing medical online ordering system, such

as dissociating pre-existing test panels into individual requests, is an option (8). Re-testing intervals have also been adapted in many studies, taking into account previously published data (9-10) and internationally recognised guidelines (11). Other methods include assessing the proportion of re-ordered test request upon rejection of the first sample due to violation of acceptance criteria (12) and knowledge or behavioural survey to elicit the cause of inappropriate test utilisation among healthcare professionals (13-14). Despite the different methods used, the ultimate end is to elicit test inappropriateness as a possible niche to intervene.

This study aims to determine the exact proportion of test inappropriateness involving individual analytes in renal function and liver function test panels as an essential beginning to further intervention towards reducing wastage of resources. By adopting some of the methods to investigate laboratory test inappropriateness, the proportion of redundant laboratory test requests in this study is defined by a predetermined re-testing interval. Subsequently, the cost impact was estimated based on the cost-per-test request.

MATERIALS AND METHODS

Study design and setting

This study was conducted at Hospital University Sains Malaysia, located in Kubang Kerian Kelantan. It is a tertiary teaching hospital and one of the referral centres for east coast Malaysia. Hence, we received laboratory test request not just internally but externally from district hospitals and healthcare facilities. As an initial step to investigating test inappropriateness in our centre, we intend to investigate the contribution of internally received redundant test requests in a cross-sectional study involving laboratory result data from adult patients (18 years and above) admitted from 1st January 2018 till 31st December 2018.

Inclusion criteria

Data involved patients' blood investigation results of 14 analytes listed as part of the renal function test (RFT) (Sodium, Potassium, Urea, Chloride, Creatinine, Uric acid, Calcium, Phosphate) and liver function test (LFT) (Total protein, Albumin, Aspartate aminotransferase (AST), Alkaline phosphatase (ALP), Alanine aminotransferase (ALT), total bilirubin). The study employed results from patients admitted to the wards for more than 24 hours, including those seen in the emergency department and subsequently admitted to respective wards, namely, general medical wards, critical care wards, surgical wards, orthopaedic wards, obstetrics and gynaecology wards, psychiatric wards, oncology wards, ophthalmology, otorhinolaryngology wards, and executive wards. These include all stat and routine tests involving analytes that were requested as part of the RFT or LFT panels and those ordered individually through the laboratory information system (LIS).

Exclusion criteria

Paediatric patients and tests in which requests were made at all outpatient departments/clinics were excluded. Same samples that were repeated in the laboratory in were also excluded.

Study protocol

We adopted a method used by Cuda et al. 2014 with some modification; therefore, the definition of redundant laboratory test requests used in this study include all normal test results that were consecutively repeated within 26 hours apart for analytes in RFT and 50 hours apart for analytes in LFT (9). All results requested, either as part of the test panel or individually, were termed normal when they fall within our laboratory validated reference interval and abnormal when they fall outside of reference interval. Gender-specific reference intervals were used whenever applicable (Table I). To derive this, data from electronic medical records were extracted into Microsoft Excel Version 2016, and we first filtered out all abnormal results, leaving only all normal results for further scrutiny. Then, based on the documented time from which samples were first received by the laboratory, the time difference between two consecutive requests were calculated. Only repeated tests that fall within the aforesaid intervals were regarded as redundant.

Data analysis

Analysis was made using SPSS Version 24, in which categorical variables were described in frequency (n) and percentage (%). The absolute number of redundant test over the analyte's total request (as the denominator) were multiplied by 100% to achieve the proportion in

Table I: List of analytes' reference interval in RFT and LFT in Chemical Pathology Laboratory Hospital Universiti Sains Malaysia

Test panel	Analytes	Reference range	Unit
RFT	Sodium	135 – 145	mmol/L
	Potassium	3.5 – 4.5	mmol/L
	Urea	1.7 – 8.3	mmol/L
	Chloride	98 – 107	mmol/L
	Creatinine	Male : 62 -106 Female : 44 – 80	µmol/L µmol/L
	Uric acid	Male : 210 – 420 Female : 150 – 350	µmol/L µmol/L
	Calcium	2.02 – 2.60	mmol/L
	Phosphate	0.84 – 1.45	mmol/L
LFT	Total protein	64 – 83	g/L
	Albumin	38 – 44	g/L
	AST	Male : <45 Female : <34	U/L U/L
	ALP	Male: 53 – 128 Female: 42 – 98	U/L U/L
	ALT	5 – 34	U/L
	Total bilirubin	<17	µmol/L

percentage, %. Meanwhile, the time intervals of each analyte repetition representing the continuous variables were described in median [Interquartile-range (IQR)] due to their non-gaussian distributions. IQR in our study is presented in the 25th -75th percentile (hours).

Cost estimation

Calculation of cost-per-test contributed by redundancy was made using partial cost estimation considering the consumables and reagents only which was adapted from total cost recovery estimation made by Hospital Universiti Sains Malaysia bursary unit. The cost-per-test is then multiplied by each analyte's redundancy rate to obtain the estimated cost of a redundant test.

Redundancy among wards and group of diseases

Distribution of redundant test requests in 11 groups of units (emergency department, general medical wards, critical care wards, surgical wards, orthopaedic wards, obstetrics and gynaecology wards, psychiatric wards, oncology wards, ophthalmology, otorhinolaryngology wards, and executive wards (which include full-paying patient and staff wards) and 13 big groups of diseases were also obtained based on primary diagnosis coded according to International Classification of Diseases, 10th Revision codes written in patients' discharge summary. The denominator used to define redundancy contributed by each ward was derived from the total request of analytes made by each group of wards. For each group of diseases, the prevalence of redundancy was divided by the total numbers of each analyte request and multiplied by 100%.

Ethical Approval

This study has been approved by The Human Research Ethics Committee of USM (JEPeM) USM JEPeM 18120770.

RESULTS

A total of 82198 RFT and 72515 LFT requests from January 2018 to December 2018 were recorded. The summary of total requests, gender, and stratified age group distributions was listed (Table II).

Analytes in both RFT and LFT panels can also be ordered individually. Table III summarised each analyte's total requests that were requested as part of test profiles and individually. Table III also depicts the proportion of redundant test, n (%), with its estimated cost.

Overall redundancy was 19.7%, amounting to a total of MYR 669,105.00. The highest cost of redundancy mostly came from urea (MYR 71,226.00), followed by sodium (MYR 65,787.00), total bilirubin (MYR 60,729.00), and ALT (MYR 60,411.00). Four analytes had more than a 25% rate of redundancy, and the largest proportion was

Table II: Demographic data of total RFT and LFT panel request.

Variables	RFT, n (%)	LFT, n (%)
Gender		
Male	42193 (51.3)	37672 (51.9)
Female	40005 (48.7)	34843 (48.1)
Age		
18 – 39	22402 (27.3)	19557 (26.7)
40 – 59	25007 (30.4)	22143 (30.5)
60 – 79	30891 (37.6)	27336 (37.7)
>80	3898 (4.7)	3479 (4.8)

Table III: Total requests of individual analytes and proportion of redundancy with its associated cost.

Test panel	Analytes	Total request, n	Redundant test, n (%)	Cost of total test request (MYR)	Cost of the redundant test (MYR)
RFT	Sodium	85546	21929 (25.6)	256,638.00	65,787.00
	Potassium	85545	19891 (23.3)	256,635.00	59,673.00
	Urea	94426	23742 (25.1)	283,278.00	71,226.00
	Chloride	83744	19116 (22.8)	251,232.00	57,348.00
	Creatinine	101 573	14879 (14.7)	304,719.00	44,637.00
	Uric acid	85265	10738 (12.6)	255,795.00	32,214.00
	Calcium	86841	14967 (17.2)	260,523.00	44,901.00
	Phosphate	75608	13208 (17.5)	226,824.00	39,624.00
LFT	Total protein	65638	13076 (19.9)	196,914.00	39,228.00
	Albumin	72969	1150 (1.6)	218,907.00	3,450.00
	AST	72882	17004 (23.3)	218,646.00	51,012.00
	ALP	72781	12955 (17.8)	218,343.00	38,865.00
	ALT	72753	20137 (27.7)	218,259.00	60,411.00
	Total bilirubin	77657	20243 (26.1)	212,971.00	60,729.00
	Total	1 133 228	223 035 (19.7)	3,399,684.00	669,105.00

The % of each category was derived from absolute numbers of test request (n) divided with the total request (n) of each analyte (as the denominator) and multiplied by 100.

contributed by ALT (27.7%), followed by total bilirubin (26.1%), sodium (25.6%), and urea (25.1%). Albumin had the lowest percentage of redundancy (1.6%), while uric acid, creatinine, calcium, phosphate, ALP, and total protein showed redundancy ranged from 12.6% to 19.9%. The rest had redundancy within 22.8% to 23.3%.

Redundant test requests intervals for analytes in RFT (in median (IQR) was 2.18 (0.96-17.09) hours for creatinine to 20.43 (12.24-23.80) hours for uric acid (Table IV). Creatinine, urea, potassium, sodium, calcium, and chloride generally had a median of fewer than 5 hours, but uric acid and phosphate had a median of more than 20 hours. Meanwhile, redundant test requests for analytes in LFT were all more than 20 hours (for albumin, ALP, total protein, ALT, and AST) except for total bilirubin with a median of 15.30 (1.40-24.06) hours.

Table IV: Time intervals in median [IQR (25th - 75th percentile)]

Analytes	Time intervals, in median (IQR), Hours
	Redundant test
Sodium	3.32 (1.08-19.17)
Potassium	2.52 (1.06-18.81)
Urea	2.54 (1.06-17.55)
Chloride	3.40 (1.10-18.60)
Creatinine	2.18 (0.96-17.09)
Uric acid	20.43 (12.24-23.80)
Calcium	3.14 (1.07-18.47)
Phosphate	20.49 (12.39-23.82)
Total protein	23.48 (18.29-26.24)
Albumin	23.01 (14.93-25.95)
AST	23.61 (19.07-26.17)
ALP	23.43 (18.27-25.80)
ALT	23.50 (18.60-26.13)
Total bilirubin	15.30 (1.40-24.06)

The proportion of redundancy was the highest in oncology wards for 12 out of 14 analytes of study (Table V). Creatinine and total protein requests were the highest in critical wards and internal medicine wards. Meanwhile, genitourinary system conditions predominate redundancy in most analytes except for urea, creatinine, and uric acid.

Table V: Prevalence of redundant test in different wards and group of diseases

Analytes	Most prevalent ward, n (%)		Group of disease with the highest prevalence, n (%)	
Sodium	Oncology	2753 (46.3)	Genitourinary system	4574 (20.9)
Potassium	Oncology	2574 (43.3)	Genitourinary system	3877 (19.5)
Urea	Oncology	4166 (63.4)	Neoplasm	2876 (12.1)
Chloride	Oncology	2764 (47.9)	Genitourinary system	3473 (18.2)
Creatinine	Critical Care	2491 (17.3)	Infectious diseases	2624 (17.6)
Uric acid	Oncology	1623 (28.1)	Infectious diseases	2375 (22.1)
Calcium	Oncology	2329 (36.1)	Genitourinary system	2211 (14.8)
Phosphate	Oncology	1667 (32.4)	Genitourinary system	2627 (19.9)
Total protein	Internal Medicine	5536 (32.2)	Genitourinary system	2533 (19.4)
Albumin	Oncology	217 (3.8)	Genitourinary system	224 (19.5)
AST	Oncology	2595 (45.7)	Genitourinary system	3192 (18.8)
ALP	Oncology	1686 (29.7)	Genitourinary system	2209 (17.1)
ALT	Oncology	2518 (44.3)	Genitourinary system	6442 (32.0)
Total bilirubin	Oncology	2889 (48.9)	Genitourinary system	4909 (24.3)

DISCUSSION

This study revealed an almost equal distribution of RFT and LFT request in both genders (approximately 50% for both groups), with the highest prevalence in the 60 – 79 years group of age and the least in more than 80 years. The overall redundancy rate obtained was 19.7%, higher than those reported in some studies that defined repeat test ordering as part of inappropriate test utilisation (15-16). Several others demonstrated even a higher rate, 35.6% to 44.0% (17-18). This varying rate is partly contributed by inconsistencies in the definition of inappropriate test used (12,16) and diversity in analytes of study. A study in Alberta, Canada, defined inappropriate tests as those with normal initial tests repeated within 24hours (17). We take a slightly different approach by including almost the same criteria (repetition of the test within a specified interval and a normal initial result) but, the repeated test must be normal (fall within the reference interval). Overall, the redundancy rate of analytes in the RFT panel ranges from 12.6% to 25.6%, while those of LFT was 1.6% to 27.7%, with albumin being the least contributor. The low albumin redundancy rate is most likely due to the common existence of hypoalbuminemia in hospitalised patients (19).

Redundancy rate differences among the 14 analytes can be explained by the fact that, in our centre, clinicians have the option of requesting analytes as whole test panels or as individual tests. Nevertheless, there are many reasons why test ordering should not be repeated frequently when results are normal.

Redundancy in analytes in renal function test

In a stable patient with an initial normal sodium level, a repeat request should only be made after four days unless clinical deterioration occurs (17,20). But in this study, up to one-quarter of sodium requests are redundant, representing the highest redundancy rate in RFT. We also observed a redundancy rate of almost the same for four analytes, which include sodium, potassium, chloride

and urea (22.8 to 25.6%), perhaps explained by their common utility in many conditions involving volume depletion and renal diseases (22). For a stable patient with an estimated glomerular filtration rate (eGFR) of >60ml/min, urea might not give any useful information, suggesting that both urea and creatinine tandem request is not a must in all patients (23). For serum chloride, its value is rarely clinically informative when there is no underlying other electrolyte or metabolic issues (23).

Redundancy in analytes in liver function test

Requesting both AST and ALT in tandem is not necessary. Yet, our study showed a more than 20% rate of redundancy for both analytes. Due to AST non-specificity for liver injury, isolated AST elevation can be seen in heart condition, skeletal muscle injury, and haemolysis (24-26). ALT is recommended as a marker of liver injury due to its hepatocytes' concentration of 3000 times more than that of serum (24). Using ALT of >30 U/L as the cut off for AST reflex testing has demonstrated a 65% reduction in AST request, hence has the potential to avoid unnecessary AST request (23-25). Total bilirubin is the second most prevalent redundant analyte in LFT, is often thought to be indicated in all cases of liver injury. However, bilirubin is not even specific for liver disease nor needed as a routine test and is clinically observed only when serum bilirubin concentration exceeds 2-3 mg/100ml (34.2- 51.3umol/L) (10). This precludes the need for bilirubin request and repeats test in all liver injury patient.

Furthermore, after three consecutive normal tests, the probability of having an abnormal result is only less than 25%, yet Sales et al. 2016 witnessed up to more than 80% rate of repetitions (21). One factor associated with the practice of ordering an inappropriate test is requesting tests as part of routine regardless of the indication, which was agreed by 89.1% of the healthcare provider to be the leading cause for inappropriate test requests (6). Even in an intensive care setting, Oliveira et al. 2014, found a significant proportion of unnecessary routine requests and admitted to the need for guideline enforcement for requesting tests (10).

Redundancy among different wards/unit and specific diseases

Oncology wards have the rate of redundancy highest for most of the analytes, most likely explained by safety monitoring following chemo and radiotherapy. We observed no specific patterns of test repetitions among various units and departments. There is a scarcity of data available on this, except for a study which demonstrated association of surgical clinics with a high prevalence of unnecessary test request compared to internal medicine unit believed to be due to non-adherence to preoperative test guidelines (15).

Except for urea, creatinine, and uric acid, the other 11 analytes' redundancy were contributed by genitourinary diseases. It is understandable for renal conditions to require electrolytes or renal function tests ordering more frequent than other diseases. Nonetheless, for components of liver function tests, these findings are rather strange. Sales et al. 2016 had managed to prove that diagnosis and number of diagnosis at the time of discharge were not related to any pattern of repetition (21).

Time intervals of test repetition

The shortest median interval for six analytes under the category of redundancy happened to be the components of RFT in this study. They ranged from 2.18 to 3.40 hours, except for uric acid and phosphate, 20.43 hours and 20.49 hours, respectively. The rest of the LFT analytes generally were repeated within one day (median 23.01 to 23.61) except for total bilirubin with a median of 15.3 hours. The 25th percentile values of approximately 1 to 3 hours for most analytes in RFT signify the need to tackle this issue even at the pre-analytical state. Studies suggested that the reason could be due to pre-existing habits, lack of experience, unawareness of cost impacts, and litigation avoidance (3,34).

Cost burden

We estimated approximately MYR 600 thousand of cost per year contributed by test redundancy which could be saved if those tests were eliminated. Considering possible safety reasons for high redundancy in oncology wards, deducting oncology ward contributions revealed an amount of MYR 574,287 (equivalent to 16.9% of total redundancy). Studies proved that interventions could successfully reduce costs without compromising patients' safety (26,35). A 26% reduction in test requests were significantly obtained ($P<0.0001$) after a period of interventions in an intensive care unit setting (35). Elnenaei et al. 2016, had managed to achieve a 51% reduction in test requests with an annual saving of USD 60,124, while Gunel 2018 showed a saving of USD 45363.49 annually with the help of artificial intelligence (8,36).

Study limitation

Our data was retrospectively derived, and we acknowledge the possibility of the appropriateness of repeating tests earlier than the said intervals. This study was not intended to overrule any clinical decisions, but we have highlighted the potential source of overutilisation in our centre within the laboratory's capacity. Descriptive data in this study did not show the possible association of test redundancy and repetition intervals with any factors; hence this could be explored and is hoped to serve as a basis for further intervention and guidelines enforcement.

Based on some discrepancies in the total numbers of requests for each analyte of the study, it is assumed that requesters acknowledge the applicability of individual test requests, preclude the need for whole test panel

requests in every case. This pre-existing awareness is hoped to provide a promising result in the future interventional effort.

CONCLUSION

We observed a more than 20% rate of redundancy for seven analytes and more than 10% for six other analytes in our study. Overall redundancy was 19.7%, amounting up to MYR 600 thousand. This shows a sizeable proportion of test redundancy can be scrutinised in future interventions. The earliest repeat interval, a median of 2-hours, is beyond the reasonable timeframe. The contribution to the bulk of redundancy was from Oncology wards and genitourinary diseases. With this finding, we believed our data could help serve as a focus for future interventional efforts to alleviate this growing healthcare burden.

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