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Review Article

Biochemistry Section

A Review on Liability of Redundant Tests in Clinical Biochemistry Laboratory: A Threat to Quality Maintenance

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ABSTRACT

Clinical biochemistry laboratories support various aspects of healthcare, including routine blood tests, specialised investigations, and blood analysis for critical care monitoring. From each of these units, various tests are ordered with no consequence in diagnosis or decision-making. The proportion of repeat and redundant tests appears to be increasing in routine laboratory practice, compromising the quality and standards of laboratory work. Greater awareness among clinicians is needed regarding the time, effort, and resources wasted on unnecessary testing. The present review aimed to give an account of the impact of redundant tests on laboratory quality management. The articles available on PubMed and Google Scholar in the last ten years, that is, from 2014 onwards, on the impact of redundant laboratory tests were included in the present study. Strict inclusion and exclusion criteria were followed to induct the research material appropriate for the review. Care was taken to include quality research papers. A detailed analysis and comparative assessment of biochemical tests and their redundancy has been reported. Findings from various studies highlight that minimising repeat test requests can conserve laboratory and financial resources; however, repeat investigations are not always insignificant, particularly for critical values. Modern clinical laboratories offer a wide range of tests, enabling clinicians to select appropriate investigations at suitable intervals for patient care. Establishing standardised laboratory protocols in collaboration with clinicians can promote good laboratory practices within institutions.

Keywords: Cost of quality, Quality management, Repeat test, Routine blood test

INTRODUCTION

The introduction of Evidence-Based Medicine (EBM) into the health care sector over the last three decades has improved patient management in leaps and bounds. EBM is the scientific and rational way that uses the available and existing data systematically to formulate a healthcare decision [1]. Evidence-Based Laboratory Medicine (EBLM), is a division of EBM that deals with the evaluation and utility of laboratory tests with the intention of improving patient outcomes [2]. EBLM is defined as 'the conscientious, judicious, and explicit use of best evidence of laboratory medicine investigations for assisting in making decisions about the care of individual patients' [3]. The definition clearly states that the laboratory tests offer value only when they are clinically valid. Being clinically valid means that the laboratory investigation report should be accurate and aid the clinician in diagnosis and treatment, and the tests should be cost-effective, contributing to reduced healthcare costs for the patients [4]. With growing dependence on laboratory reports by the treating doctors in their clinical practice, the laboratories play a pivotal part in the current healthcare scenario. Medical laboratories comprising clinical pathology, microbiology, and clinical biochemistry play a major role here, as around 70% of clinical decisions are based on reports from these three disciplines [5]. The Clinical Biochemistry Laboratories cater to different modalities of healthcare services from routine blood investigations, special parameters and critical care monitoring related blood analysis. The dispatch of reliable reports by the laboratory is ensured by the incorporation of good clinical laboratory practice, which includes total quality management. Total quality management is defined as a management philosophy and approach that focuses on processes and their improvement as the means to satisfy customer needs and requirements; a quality system that is implemented to ensure quality [6]. Every laboratory quality tool is either directly or indirectly linked to a fundamental component called the 'Cost of Quality'.

Cost of quality in medical laboratories takes into account the expenses borne by the laboratory and thereby offering information that assists the laboratory to improve its services, processes and financial prospects [7]; Cost of quality includes both good and poor-quality costs. Good quality costs include preventive and appraisal costs, whereas poor-quality costs include internal and external failure costs [8]. Cost incurred in good quality practices is beneficial to the laboratory performance in contrast to the Cost of Poor Quality (COPQ), which brings bad repute to the laboratory. Poor quality costs are not easily accounted for in the laboratory budget; however, they soak up the finances beyond measure. One of the commonest causes for internal failures amounting to COPQ are reruns and redraws in the laboratory, which are silent but liable.

The menace of repeat tests is rampant across the laboratory industry and needs immediate attention. It is highly relevant in this context to define an appropriate test, which is the right of every individual undergoing a laboratory test. An appropriate test is defined by the six 'R' paradigms. It is requesting the right test with the right method, at the right time, to the right patient, to produce the right result at the right (reasonable) cost [9]. Contrary to this is a redundant test, which is defined as a re-ordered or repeated laboratory test that is ordered within an inappropriate time frame and provides no additional information [10].

Are repeat tests as rampant as it is assumed they are? What is the financial burden on the laboratory? Does re-running an abnormal test add value to reporting the result? Do repeat tests lower or improve the quality of the laboratory report? The current review aimed to seek the answers to all these intriguing queries.

MATERIALS AND METHODS

The present study was conducted as a narrative review using Google Scholar and PubMed to identify relevant literature on repeat/redundant testing in clinical biochemistry laboratories. The initial

search using the keyword "repeat/redundant test in laboratories" yielded 17,600 articles. Refining the search to "Clinical Biochemistry laboratory" reduced the results to 1,279 articles. Limiting the search to articles published from 2014 onwards resulted in 512 articles. After detailed screening based on predefined criteria, 23 articles were selected for final analysis.

Inclusion criteria:

- Prospective and retrospective studies;
- Original research articles;
- Articles published in English.

Exclusion criteria:

- Review articles;
- Studies involving molecular biology techniques;
- Research-based biochemical analyses unrelated to clinical diagnostic testing.

The final 23 studies were evaluated for quality and authenticity, and relevant data were compiled for the current review.

Redundant Tests Ordered for Inpatients of the Hospital

The tertiary care hospitals have well-equipped laboratories where most of the samples processed are of patients who get admitted there for treatment. Under this section, the current study presents a review of those articles that provide data of repeat biochemical tests in such hospitals. Rodrigues MS et al., evaluated 23 biochemical parameters processed during three months duration, and an assortment of necessary and unnecessary repeat tests from the hospital software was done. Out of 1350 samples analysed during the study period, 1429 tests were repetitions, out of which 1162 were unnecessary repetitions. This accounted for 1198 Brazilian dollars and an increase of 80.47 % of the allocated budget, with an estimated annual impact of 4,792 Brazilian dollars. Also, the study reports an increase in Turnaround Time (TAT) [11]. Repeat tests and re-ordering of tests are an uncommon phenomenon in paediatric patients owing to the difficulty of obtaining the blood sample. Fieldston ES et al., ventured into this arena by conducting a study to evaluate repeat test proportion in a paediatric emergency department at a children's hospital. They analysed laboratory tests which included Complete Blood Count (CBC), Basic Metabolic Panel (BMP) and coagulation studies of inpatients of the hospital between July 2002 and June 2010. Among 37035 tests, proportions of repeat tests for CBC, BMP and Coagulation studies were 0.9%, 1.9%, and 1.9%, respectively. The major portion (75%) of the repeats was for an abnormal value, like high potassium or low platelet and 25 % of the repeats were for a missing component [12].

A study was undertaken in Alberta, Canada, by Kandalam V et al., which included three different laboratory information systems and repeat tests for CBC and Electrolyte Panel (EP) tests processed during the year 2018. It was found that of 2020467 CBC and 1455983 EP, 67.7% and 73.5% were repeated, respectively; the proportion of inappropriate repeats was high for EP (35.6 %) compared to CBCs (5.4%). The cost to the province for inappropriately repeating CBC and EP was estimated to be $0.52 million and 1.90 million Canadian dollars, respectively [13].

Soleimani N et al., conducted a cross-sectional study in a liver transplantation centre, Shiraz, Iran, where they included twenty-six biochemical tests done on patients of the centre. The study duration was two months and was designed such that in the first month, they considered repeat tests as those tests that were done twice within the same month. Before commencing the study in the second month, they went a step ahead and chalked guideline where repeat tests were done only when the patient's report had values outside the linearity or were clinically significant, critical values and delta checks. Of the 7,714 repeat tests performed over the two consecutive months, a significant decline of 38% was found in repeat tests in the second month ($p<0.001$); however, there was no significant change in the percentage of unnecessary repeats (77% in the first month and 74% in the second month). They found that the most common cause of repeated tests was the delta check. Following the imposition of guidelines during the second month of the study, they observed that there was a decline in total cost and delay in TAT by 32% and 36%, respectively [14].

Wabe N et al., in their five-year retrospective research, conducted in six different hospitals in New South Wales, Australia, where they defined repeat test as those liver function tests which were done more than once during the hospital stay of the patient, investigators found 298567 and 205929 repeat LFTs in inpatients of the general ward and Intensive Care Unit (ICU), respectively. A median of two repeats per admission in patients of the general ward versus a median of four repeats per admission in the ICU was noted. The median repeat testing interval was 25.6 hours in the general ward and 24.1 hours in the ICU. The proportions of potential redundant repeat ordering of 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 [15]. Ab Rahim SN et al., investigated test inappropriateness among the ordered blood tests for the adult inpatient population of the hospital. The investigators have defined redundant tests here as those test results that are consecutively normal twice and requested within 26 hours for renal function test parameters and 50 hours for liver function test parameters. They report that an overall 19.7 % redundancy prevailed when the seven analytes (Chloride, sodium, potassium, alanine transaminase, aspartate transaminase, total bilirubin, and urea) were studied, and it amounted to 669105 Malaysian Ringgits [16].

The patients admitted to hospital wards suffer from various diseases and present with abnormal blood reports, which may, however, not be acutely and critically deranged. The impact of delay in TAT due to repeat tests exists, although the monetary burden is more penalising. The laboratory reports, per se, should make diagnosis and treatment hassle-free, hasten the process of recuperation; nonetheless, repeat tests add chaos to this process and prolong the road to recovery.

Repeat Tests on Critical Alerts and In Critical Care Units of Hospitals

The critical units of the hospitals, which include the emergency wards, ICUs, and postoperative wards, harbour patients whose vitals and basic biochemical parameters are monitored round the clock owing to the fluctuations these individuals are prone to and the need to correct the derangements on priority. The laboratory investigation reports of individuals in the critical care unit have a higher chance of being abnormal or critical. The laboratory authorities prioritise a sample from the critical care unit for processing as well as reporting, especially when the value is a critical alert. The clinical background of the patient's condition and a quality assurance for the tests performed in the laboratory should ensure timely release of critical values; in a laboratory unsure of its quality practices and with no access to patient health status, a critical value is all susceptible to repeat! [Table/Fig-1] compiles articles of repeated tests in critical care units and of critical values [17-20].

Every minute counts in treating an individual in a critical care or ICU, an unnecessary repeat test can delay the timely dispatch of a laboratory report further delaying patient care and could possibly cause deterioration of patient condition.

Redundant tests as part of periodic monitoring test panels

After the initial diagnosis of chronic disorders such as diabetes mellitus, renal disease, cardiovascular disease, anaemia, thyroid dysfunction, infertility, and bone disorders, laboratory investigations

Study	Study design	Tests included	Study outcome	Conclusion
Onyenekwu CP et al., [17]; 2014	Retrospective, Quarter year study	Sodium, potassium, calcium, and magnesium with critical values	2291 out of 2308 repeat tests (99.8%) were of no significant difference. There was 35 minutes delay in reporting the Magnesium test report, and 42 minutes delay for sodium test result due to repeat testing	2.9% of the laboratory running costs was spent on repeat tests
Lehman CM et al., [18]; 2014	Multicentric study involving 86 laboratories across the globe	Critical reports of two biochemical analytes: Glucose and potassium, two hematological parameters: White blood cell and platelet count were included in the study	Routine, repeat analysis of all chemistry critical values (60.8% of laboratories) was more common than for haematology critical results (52.6% of laboratories). The repeat tests of glucose, K+ and WBC remained critical 99 % of time when repeated. While repeat platelet counts appeared more variable (1.9% no longer critical and 1.7% considered significantly different)	Median repeat times were at least 17 to 21 minutes for 10% of laboratories. More importantly, 20% of the laboratories reported at least one incident in the prior calendar year where clinicians felt that a reporting delay adversely affected patient care
Baradaran Motie P et al., [19]; 2015	Retrospective cross-sectional study of one-year duration	Critical laboratory values of thirteen different haematological and Biochemical parameters were studied.	Repeat tests yielded values within CAP/CLIA guided allowable error for 2213 tests out of 2233 critical value reports.	Significant difference between first and repeat sample values was maximally observed (2.9 %) for platelet count among all the tests that were included in the study
Saffar H et al., [20]; 2020	Retrospective cross-sectional study of three months duration	Critical values and retest results of serum potassium, calcium, Haemoglobin, and prothrombin time during different work shifts was compiled and analysed	Of 178 repeat tests of potassium, 94.45 % were within the institute's acceptable tolerable limit. None of the repeat test was out of tolerance limit for calcium when they were repeated. One of the 85 repeated critical haemoglobin value was significantly different from the first value. The pro-thrombin tests had a different story altogether. 21 retest results did not meet the acceptable tolerance limit; twelve results became non-critical.	Laboratories need to develop a critical value reporting policy

[Table/Fig-1]: Outcomes of research involving repeat tests of critical values or laboratory reports from critical care units reporting articles [17-20].

are again prescribed or ordered in these patients at regular intervals to monitor disease progression and the patient's response to treatment, etc. The different test panels, such as thyroid profile, cardiac markers, and anaemia panel, are to be done only after a stipulated time interval; however, laboratories have a record of patients repeating these tests at illogically shorter and more frequent intervals, which is of no consequence. The current section reviews the literature reporting repeat tests ordered by consultants or by over-apprehensive patients at outpatient clinical settings.

In a Retrospective Cohort Study Conducted by Morgen EK et al., in Canada, Six Tests [21] (Serum total cholesterol, Glycated Haemoglobin (HbA1c), Thyroid-Stimulating Hormone (TSH), Vitamin B12, Vitamin D and ferritin) were assessed for inappropriate repeat tests using a laboratory informatics system. They found that the percentage of these tests being repeated at the intervals of three, six and twelve months were 11%, 23% and 41%, respectively. Sixteen percent of all these six tests were inappropriately repeated, costing 0.6 to 2.2 million Canadian dollars [21]. Zorbozan N and Akarken I procured data on total Prostate-Specific Antigen (tPSA) tests done in their hospital between March 2015 and 2017. According to the hospital protocol tPSA test can be repeated once every six weeks only if the first value was ≥2.5 ng/mL. The study revealed that out of 1794 tests, 198 (46.4%) values were ≥2.5 ng/mL. Among these 198 tPSA tests, 97 (49%) were unnecessary repeats. Out of these 97 tPSA results, the change between the two measurement values was less than the hospital calculated Reference Change Value (RCV) in 80 (82.5%) tests [22]. Research was conducted to gauge inappropriate test utilisation in outpatients at a tertiary care centre by Almasoud NF et al., in Riyadh, Saudi Arabia. It was a retrospective cohort study. Four tests: Lipid profile, TSH, Vitamin D and Vitamin B12 test data were retrieved from Hospital data between 2018 and 2021. In this study, they have clearly referred to and incorporated the International Societies' guidelines to define inappropriate tests for the parameters included in the research. The authors mention that the American Association of Endocrinologists advocate repeat test of TSH only after eight weeks. The Canadian cardiovascular society, Best Practice primary care pathology and Osteoporosis Canada Guidelines are against repeating lipid profile, Vitamin B12 and vitamin D tests before 13 weeks, respectively. At the end of data analysis, the researchers report that out of 109929 tests from 23280 patients, 6.1 % of all the repeat tests were inappropriate. The estimated amount wasted on these inappropriate repeats was 2364410 Saudi Riyals [23]. A recently published article from Turkey by Bozyigit C et al., with respect to inappropriate repeated laboratory testing in a clinical laboratory of a tertiary care hospital for eleven biochemical parameters which included, TSH, free Thyroxine (fT4), free Triiodothyronine (fT3), Anti-Thyroid Peroxidase Antibodies (anti-TPO), total cholesterol, HbA1c, Vitamin B12, Vitamin D3, Folic Acid (FA), iron and ferritin, is a retrospective database analysis in which test results of patients between 2015 to 2017 for the eleven parameters was retrieved from laboratory informatics management system and analysed. In the present study, inappropriate test was defined based on guidelines from different international societies, as in the previous study. If TSH, fT3, fT4 were repeated before four weeks, Vitamin D3, B12, FA, iron, ferritin, HbA1c within 12 weeks, Total cholesterol within six weeks and anti-TPO in less than a year, it was considered inappropriate. Further, the Inappropriate Repeat Rate (IRR) was calculated with formulae: IRR (%) = Number of inappropriate repeat tests/Total number of tests × 100. The three-year average IRR for eleven parameters evaluated was 10%. The IRRs for TSH, fT3, and fT4 tests were in the range of 4.2-5.3%, and those for 25(OH)D, iron, ferritin, and total cholesterol test was between 12.9-15.5%, respectively. IRRs of total cholesterol, Thyroid Stimulating Hormone, FT3, and FT4 tests were 3-4 times higher in inpatients compared to outpatients. As an exception, the IRR of anti-TPO was higher in outpatients [24].

The current-day laboratory offers multiple test panels with overlapping tests. An infertility profile and polycystic ovarian syndrome panel may have the same tests. An obesity profile and metabolic profile can be similar; anaemia and iron profile can have common tests. The test content in the profiles should be clearly disclosed for the clinicians and the patients to avoid repetition. Fancy names of test panels should not mislead and cause a burden to the consumer. There must be an option to unbundle the panel and choose an individual test. The treating doctor should choose wisely, minimally, and specifically and then request the laboratory investigation for the patient. The redundant tests can also be minimised when apprehensive patients with disorders are educated not to self-determine the need for laboratory test as they add no value clinically. The cost saved on redundant tests can be channelled for treatment and other astute expenses of the patient.

Effect of Educative Programs/Stewardship and Training of Laboratory and Healthcare Personnel on Repeat Tests

The hospitals and healthcare institutions across the world are gradually becoming aware of the resources lost on unnecessary or redundant

tests. In this direction, various interventional steps at different levels are initiated to thwart the ill-effects of repeated or inappropriate tests.

A study conducted in Canada has noticed a substantial decrease in unnecessary tests in tertiary care centre. This consisted of protocol of test requests approval from the subject expert, repatriating tests locally, distributing educational memos, introducing staged testing, laboratory assisted rule and restructuring of testing panels. Among the sixty-two targeted refer-out tests which included trace metals, vitamins, antibodies, and endocrine-related tests, there was a 33% reduction in the number of request and a 51% reduction in Number Of Completed (NoC) tests in 2022 compared to 2015. The total savings for the study period based on NoC was $807,736 [25]. In yet another article by Moyer AM et al., Clinical Decision Support (CDS) rules were used to restrict repeat measurement of serum ionised calcium, serum magnesium, and N-Terminal Pro-B-Type natriuretic Peptide (NT-proBNP) in ICU patients. In their study, Moyer AM et al., took advantage of pop-up alerts from CDS when an order of ionised Calcium (iCa) or serum magnesium was placed for the second time in a patient within 24 hours and 48 hours, respectively and an additional order for NT pro-BNP beyond one within a single hospitalisation. The pop-up alert showed the prior value of the patient and provided an opportunity to either cancel the order or to give an indication for placing the repeat request. They noted that iCa test volumes decreased by 48%, Mg by 39%, and NT-proBNP by 28% in the 90 days immediately following implementation and remained decreased by 54%, 49%, and 22%, respectively, during the following 90-day period. Adverse clinical outcomes potentially associated with hypocalcaemia or hypomagnesaemia did not increase [26]. Vrijsen BEL et al., have brought focus on another aspect of inappropriate testing in inpatients of the general medicine ward, wherein the junior doctors were more prone to order excessive tests due to lack of awareness and insecurities compared to senior consultants. After surveys and questionnaires asking for suggestions by the doctors to overcome frequent test requests, the resident doctors recommended educational training, and consultants opted for lock-out in the electronic test ordering system when the test is ordered prematurely [27]. Surgeons were found to have a higher rate of repeat test orders than the physicians; however, the request of repeats by surgeons had less waste of resources compared to the physicians, inferring that inappropriate tests were requested more by physicians [28]. In more recent times, research by Muries DMJ et al., demonstrated 154 general practitioners working in 57 general practices in the Netherlands. A statistically significant decrease in mean monthly test ordering rate after price display for the sum of all tests from 67.2 to 63.3 was seen [29]. Thurm M et al., evaluated the effect of educational training and informative poster display on the number of blood tests ordered in the hospital. There was a reduction in the number of blood tests done in the hospital by 2577 tests following educational training and informative poster display, which saved around £7006.06 [30]. As much as the concern is raised about redundant test orders from the clinician and patient end, the issue gravitates on the laboratory at equal force, where repeats occur because of poor maintenance and a misplaced system. Erdal EP et al., have done a quantitative survey of clinical chemistry laboratory stakeholders across ten international regions. The blood sample testing practices, sample quality issues, and practices to remediate poor sample quality were assessed. They found three specific issues: fibrin strands, fibrin masses, and gel globules, which clogged the probe of the analysers. The time spent on remediation, the manual removal of strands in United States laboratories, was 9 to 14 hours, on redraw or recollection of the sample was 25±32 hours and probe maintenance was 11.1±18.0 hours. The amount associated with lower sample quality and remediation was $ 100247 [31].

A positive intervention to educate and bring awareness among consultants, residents, laboratory staff and patients about redundant tests and the magnitude of resources and time lost on these tests is an investment that will pay dividends to the whole of the healthcare sector in the long run.

Minimising Repetitive Laboratory Testing Employing a Machine Learning Algorithm

Clinical chemistry laboratories are embracing artificial intelligence to appraise their role in patient care. The machine learning algorithms have found their way into laboratory medicine, where the diagnostic data can be converted into useful information to predict values that may aid a clinical decision. The study to evaluate the effectiveness of this tool was conducted by Luo Y et al., [32]. The investigators have focused on a single biochemical parameter, which is serum ferritin. They collected three months of data on patients who underwent a serum ferritin test. The demographic and other laboratory test results of these patients were used as 'predictor information'. A machine learning algorithm was developed that used predictor information of the patient to predict the current ferritin status. It was found that predicted ferritin results may sometimes better reflect underlying iron status than measured ferritin [32]. Rabbani N et al., conducted a similar study. They developed a software application that utilises a laboratory test result prediction model based on historical laboratory data. The application received a median System Usability Scale score of 75, corresponding to the 75th percentile of software tools. The researchers declare that the use of a predictive algorithm to calculate the utility of a diagnostic test is a promising model for limiting laboratory test overutilisation [33].

The periodic appraisal in terms of technology in state-of-the-art laboratories of urban areas affirms investment in good quality cost, which not only brings accolades but also returns in the form of profit.

CONCLUSION(S)

The outcome of various studies has brought focus to the fact that minimising repeat tests can result in conservation of laboratory and financial resources, the summoning of repeat laboratory investigations is not always inconsequential, especially the critical values. The new age clinical laboratories provide a battery of investigations to choose from, aiding clinicians to request the specific test at the required interval to treat patients. A standard laboratory protocol in association with clinicians can harmonise good laboratory practice in the institution.

REFERENCES

[1] Tenny S, Varacallo M. Evidence Based Medicine (EBM) [Internet]. PubMed. Treasure Island (FL): StatPearls Publishing; 2024. Available from https://www.ncbi.nlm.nih.gov/books/NBK470182/.
[2] Badrick T. Evidence-based laboratory medicine. Clin Biochem Rev. 2013;34(2):43-46.
[3] Price CP, Glenn JL, Christenson RH. Applying evidence-based laboratory medicine: a step-by-step guide. Washington DC: AACC Press. 2009: p. 1-270.
[4] Horvath AR. From evidence to best practice in laboratory medicine. Clin Biochem Rev. 2013;34(2):47-60.
[5] Sikaris KA. Enhancing the clinical value of medical laboratory testing. Clin Biochem Rev. 2017;38(3):107-14.
[6] Burtis CA, Bruns DE. Tietz fundamentals of clinical chemistry and molecular diagnostics. 7th ed. St. Louis (MO): Elsevier Saunders; 2014.
[7] Clinical and Laboratory Standards Institute (CLSI). The cost of quality in medical laboratories. 2nd ed. CLSI guideline QMS20. Wayne (PA): Clinical and Laboratory Standards Institute; 2020.
[8] Rattan A. Understanding cost of quality in the laboratory. Acta Scientific Microbiology. 2021;4(11):16-20.
[9] Plebani M, Zaninotto M, Faggian D. Utilization management: A European perspective. Clin Chim Acta. 2014;427:137-41.
[10] van Walraven C, Naylor CD. Do we know what inappropriate laboratory utilization is? A systematic review of laboratory clinical audits. JAMA. 1998;280(6):550-58.
[11] Rodrigues MS, Souza CL, Oliveira MV. Repetition of biochemistry tests in a laboratory of public hospital in southwest of Bahia, Brazil, and associated cost. J Bras Patol Med Lab. 2017;53(4): 233-39.
[12] Fieldston ES, Fakeye OA, Friedman DF. Repeat laboratory testing in the pediatric emergency department: how often and how important? Pediatr Emerg Care. 2019;35(3):190-93.

[13] Kandalam V, Lau CK, Guo M, Ma I, Naugler C. Inappropriate repeat testing of complete blood count (CBC) and electrolyte panels in inpatients from Alberta, Canada. Clin Biochem. 2020;77:32-35.
[14] Soleimani N, Azadi A, Esmaeili MJ, Ghodsi F, Ghahramani R, Hafezi A, et al. Termination of Repeat Testing in Chemical Laboratories Based on Practice Guidelines: Examining the effect of rule-based repeat testing in a transplantation center. Journal of Analytical Methods in Chemistry. 2021;2021(1):9955990.
[15] Wabe N, Hardie RA, Lindeman R, Scowen C, Eigenstetter A, Georgiou A. Potentially redundant repeat liver function test ordering practices in Australian hospitals: A 5-year multicentre retrospective observational study. Int J Clin Pract. 2021;75(5): e14004.
[16] Ab Rahim SN, Omar J, Jelani AM, Yaacob NM, Wan Azman WN. The Frequency and cost of redundant biochemistry test in tertiary teaching hospital. Malaysian Journal of Medicine & Health Sciences. 2022;18(1):114-120.
[17] Onyenekwu CP, Hudson CL, Zemlin AE, Erasmus RT. The impact of repeat-testing of common chemistry analytes at critical concentrations. Clinical Chemistry and Laboratory Medicine. 2014;52(12):1739-45.
[18] Lehman CM, Howanitz PJ, Souers R, Karcher DS. Utility of repeat testing of critical values: A Q-probes analysis of 86 clinical laboratories. Archives of Pathology and Laboratory Medicine. 2014;138(6):788-93.
[19] Baradaran Motie P, Zare-Mirzaie A, Shayanfar N, Kadivar M. Does routine repeat testing of critical laboratory values improve their accuracy? Med J Islam Repub Iran. 2015;29:176.
[20] Saffar H, Abdollahi A, Hosseini AS, Torabi Farsani M, Hajinasrollah G, Mohaghegh P. Necessity of routine repeat testing of critical values in various working shifts. Iran J Pathol. 2020;15(3):161-66.
[21] Morgen EK, Naugler C. Inappropriate repeats of six common tests in a Canadian city: a population cohort study within a laboratory informatics framework. American journal of clinical pathology. 2015;144(5):704-12.
[22] Zorbozan N, Akarken I.Unnecessary Repeated Total PSA Tests and Evaluation with Minimum Retest Interval and Reference Change Value. J Clin Chem Lab Med.2019;2:119.
[23] Almasoud NF, Aldosari MA, Mahmoud AS, Alendijani YA, Alkhenizan AH. Inappropriate laboratory test utilization in outpatient tertiary care: implications for value-based healthcare. Saudi Medical Journal. 2024;45(4):356-361.
[24] Bozyigit C, Odabasi MS, Dirican M. Analysis of inappropriate repeated laboratory testing. Turkish Journal of Biochemistry. 2023;48(2):145-51.
[25] Lou A, Thoni A, Shandi N, Yang Z, Nassar BA, Elnenaei M. Effective stewardship strategies to enhance appropriateness of refer-out test requests in a Canadian tertiary centre laboratory. Clinical Biochemistry. 2024;2024:110777.
[26] Moyer AM, Saenger AK, Willrich M, Donato LJ, Baumann NA, Block DR, et al. Implementation of clinical decision support rules to reduce repeat measurement of serum ionized calcium, serum magnesium, and N-Terminal Pro-B-Type natriuretic peptide in intensive care unit inpatients. Clin Chem. 2016;62(6):824-30.
[27] Vrijsen BEL, Naaktgeboren CA, Vos LM, van Solinge WW, Kaasjager HAH, Ten Berg MJ. Inappropriate laboratory testing in internal medicine inpatients: prevalence, causes and interventions. Annals of Medicine and Surgery. 2020;51:48-53.
[28] Kilinçarslan MG, Şahi N EM. Who repeats more laboratory tests inappropriately? Surgeons versus physicians. Int J Risk Saf Med. 2021;32(3):219-27.
[29] Muris DMJ, Molenaers M, Nguyen T, Bergmans PWMP, van Acker BAC, Krekels MME, et al. Effect of a price display intervention on laboratory test ordering behavior of general practitioners. BMC Family Practice. 2021;22(1):242.
[30] Thurm M, Craggs H, Watts M, Brooks A. Reducing the number of unnecessary laboratory tests within hospital through the use of educational interventions. Ann Clin Biochem. 2021;58(6):632-37.
[31] Erdal EP, Mitra D, Khangulov VS, Church S, Plokhoy E. The economic impact of poor sample quality in clinical chemistry laboratories: results from a global survey. Ann Clin Biochem. 2017;54(2):230-39.
[32] Luo Y, Szolovits P, Dighe AS, Baron JM. Using machine learning to predict laboratory test results. American Journal of Clinical Pathology. 2016;145(6):778-88.
[33] Rabbani N, Ma SP, Li RC, Winget M, Weber S, Boosi S, et al. Targeting repetitive laboratory testing with electronic health records-embedded predictive decision support: A pre-implementation study. Clinical Biochemistry. 2023;113:70-77.

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