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Maximizing Laboratory Turnaround Time Efficiency: Workflow Optimization in Resource-Limited Settings

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Abstract

Laboratory Turnaround Time (TAT) is a critical metric in assessing the quality of laboratory services, directly impacting diagnostic speed and patient outcomes. Many laboratories in resource-constrained environments face challenges such as inefficiencies in workflow, resource limitations, and administrative redundancies, which hinder optimal TAT performance. This research aims to optimize laboratory workflow to improve TAT efficiency in a resource-constrained environment, addressing workload variability, inefficient station grouping, and administrative overlap. The research, which was conducted at the Tanah Abang Puskesmas Laboratory from May to July 2022, consisted of three stages: observation and data collection, workflow optimization, and evaluation. Interventions included task reallocation, workflow segmentation, and administrative streamlining. TAT improvement was assessed from the Complete Blood Count (CBC) and Random Blood Glucose (RBG) tests using pre- and post-intervention analysis. The results showed that after optimization, the mean TAT for the CBC test decreased significantly from 36 minutes (SD = 13.4) to 25.6 minutes (SD = 4.1), p-value <0.05. For the RBG test, the TAT increased from 88.6 minutes (SD = 4.6) to 81.1 minutes (SD = 1.4), p-value < 0.01. This intervention demonstrates the feasibility and effectiveness of lean management strategies in a resource-constrained environment. This research has implications for emphasizing the importance of systematic workflow optimization to improve laboratory efficiency. This research highlights practical and scalable solutions that can be adopted in similar settings globally, and future efforts should focus on integrating advanced technologies such as Laboratory Information Systems (LIS) to further improve accuracy, efficiency and patient outcomes.

Keywords: Turnaround Time, Laboratory, Workflow Optimization, Resource-Limited Settings.

INTRODUCTION

In a global context, healthcare systems continue to face challenges to deliver quality, efficient and timely services (Sciences et al., 2018). Clinical laboratories are an important part of the healthcare system, contributing to up to 70% of medical decisions made by physicians (Wilson et al., 2018). However, the timeliness of laboratory services is often a major issue, especially in the context of limited resources. Turnaround Time (TAT), defined by the International Organization for Standardization (ISO) 15189 as the time between two specific points in a laboratory process, is one of the main indicators of

laboratory service quality (Alain et al., 2021). The accuracy of TAT greatly affects early diagnosis, therapeutic decisions, and the efficiency of the health care system as a whole.

Global reports show that laboratories in developing countries often suffer from limited resources in terms of staff, technology and infrastructure (Schneidman et al., 2018). This exacerbates the problem of untimely TAT, which can ultimately affect patient clinical outcomes. In addition, slow TAT can lead to unnecessary repetition of tests, increase laboratory workload, and increase healthcare costs (Tsai et al., 2019). Therefore, laboratory workflow optimization is an urgent solution to improve the efficiency of laboratory services in this context.

In Indonesia, clinical laboratory services also face similar challenges. According to the Regulation of the Minister of Health of the Republic of Indonesia Number 43 of 2013, clinical laboratories play an important role in supporting efforts to diagnose, monitor treatment, and prevent disease (Wijayani, 2018). However, the implementation of laboratory services often encounters obstacles, including a lack of workflow efficiency, limited human resources, and suboptimal use of technology (Wuryaningsih et al., 2020). Data from the Ministry of Health shows that many laboratories in first-level to advanced health facilities experience longer TAT times than expected standards, which has an impact on delays in patient diagnosis and treatment (Indonesia, 2018).

Several studies have been conducted to understand the factors that influence TAT and optimization strategies. (Hawkins, 2017) showed that a systemic approach to laboratory workflow efficiency can significantly reduce TAT time. The research emphasized the importance of identifying bottlenecks in the workflow, improving communication between departments, as well as implementing automation technologies. In addition, a research by (Letelier et al., 2021) focused on a lean management approach in laboratory management in a resource-constrained country. This approach has proven effective in reducing waste of time and resources, although it requires commitment and ongoing training for laboratory staff. These studies provide an important basis for developing TAT optimization strategies in a more specific context.

The urgency of this research lies in the need to improve the efficiency of laboratory services in Indonesia, particularly in the management of TAT. The timeliness of TAT is not only an indicator of the quality of laboratory services, but also has a direct impact on patient safety and cost efficiency (Jha et al., 2021). In the context of limited resources, this challenge becomes even more complex as laboratories must operate with limited resources without compromising service quality. Thus, innovative, scalable, and evidence-based strategies are needed to address this issue.

This research offers a new approach in TAT optimization by integrating lean management principles, technology evaluation, and human resource capacity building simultaneously. In addition, this research will utilize data-driven analytical methodologies to identify critical areas in laboratory workflows that require improvement. With a focus on implementation in laboratories with limited resources, this research is expected to make a significant contribution to the development of laboratory policies and practices in Indonesia and other developing countries.

Based on the above background, this research aims to optimize Turnaround Time (TAT) efficiency through laboratory workflow improvements, especially in health facilities with limited resources. The main focus of the research is to identify the main factors that affect TAT, develop optimization strategies based on lean management

principles, and evaluate their impact on TAT efficiency and laboratory service quality. The results of this research are expected to provide practical benefits in the form of implementation guidelines to improve laboratory workflow efficiency, theoretical benefits in enriching the literature related to TAT optimization in the context of limited resources, and policy benefits to support decision making in laboratory management at the national and regional levels. Thus, this research not only contributes to the development of a more efficient laboratory system, but also supports the improvement of the overall quality of health services.

RESEARCH METHOD

Research Design

This research was conducted in Tanah Abang Community Health Center Laboratory from May to July 2022. The research was separated into three phases. The first phase was observation and data collection from 30 May to 9 June 2022. The second phase is workflow optimization, performed from 10 June to 15 June 2022. The last phase, evaluation and reporting, was completed from 16 June 2022 to 1 July 2022. During this period, we collected 1800 samples for this observation. An independent project manager was a clinical pathologist tasked to collect data, design an optimized workflow, and evaluate the workflow optimization. The head of the laboratory managed workflow optimization. The analysts and head of the laboratory were blinded and not aware of the data collection and evaluation process. Two routine parameters were chosen as the target turnaround time, the complete blood count (CBC) and random blood glucose (RBG), which were timed throughout the morning shift of the first and third phases. Hemolyzed samples required reanalysis, and clotted samples were excluded from the analysis.

Workflow Optimization

The Community Health Center Laboratory is staffed with eight certified medical laboratory analysts. Six analysts work on the morning shift from 08:00 to 16:30, and two analysts are on duty from 14:00 to 20:30 on the afternoon shift. The Laboratory processes around 60 to 80 samples a day, ranging from hematological and clinical chemistry samples.

Clinicians order laboratory tests either manually through laboratory request forms or online laboratory applications. After the patients make their payments, a phlebotomist verifies their identity, confirming their name and date of birth. Once blood is drawn into the tube, the phlebotomist records this information on the blood tubes or other containers, and laboratory results are formed. Different analysts take patient samples and laboratory result forms. They will document patient data into a ledger and perform laboratory examinations as written in the laboratory result forms. Once the results are out, analysts will write the examination results in laboratory results form. They also recorded the result into the ledger and input it into the online laboratory application. The laboratory results are given to the patient. The patient acknowledges the receipt by signing the ledger. Workflow optimization would enhance the efficiency and effectiveness of laboratory processes. This systematic approach aims to minimize waste, focus on continuous improvement, efficiently utilize resources, streamline processes, and eliminate non-value-added activities.

Data collection and analysis

Turnaround time was recorded from the start of the phlebotomy process to results written to the ledger by the analysts. Data collection was performed manually as the laboratory did not have a laboratory information system. CBC and RBG were chosen as the target routine TAT because of their high volume and clinical importance. The

measurable TAT target is to achieve mean TAT in less than 30 minutes for all CBC specimens and less than 85 minutes for all RBG specimens. The analysis will be conducted using Microsoft Excel and SPSS, and the results will be presented using tables, graphs, and figures. Normal distribution will be assessed using the Shapiro-Wilk test at a significance level of $p < 0.05$. If the data distribution is normal, it will be presented as mean ± standard deviation (SD). The unpaired t-test is used to assess the success of workflow optimization before and after implementation.

RESULT AND DISCUSSION

During observation and data collection, several issues were observed within the laboratory workflow (Figure 1). The first problem is variability in analyst workload. There was a notable disparity in analyst workload; some managed two to three workstations while others handled only one. This inconsistency in task allocation resulted in an imbalance in the division of responsibilities. Second, there is inefficient station grouping. The grouping of stations did not account for factors such as centrifugation time and patient sample types. For instance, some analysts were assigned to work across stations for immunology, microbiology, and urinalysis. This arrangement was counterintuitive as each station required distinct preparation and equipment, such as biosafety cabinets and varying personal protective equipment (PPE). As a result, workflow efficiency suffered. The final issue encountered was administrative overlaps. Administrative tasks and post-analytical duties were handled by different individuals, often involving two to three personnel for the same responsibilities. This redundancy extended to ledger entries, highlighting the need for streamlining administrative roles. Two critical interventions have been introduced to optimize the workflow effectively (Figure 1).

Task Allocation and Workflow Segmentation

The task allocation system has been revamped, focusing on streamlining workflows and optimizing station grouping based on shared characteristics such as the need for centrifugation, sample types, required PPE, and location. For example, chemistry and immunology tests, which share the same sample type, centrifugation times, and equipment, are grouped for increased efficiency. Urinalysis is paired with hematology since only urinalysis requires centrifugation equipment, allowing analysts to concentrate on urinalysis without interruption. Hematology, on the other hand, was analyzed using an automatic hematology analyzer; hence, analyses were conducted automatically, and results were readily available immediately upon completion of testing. Meanwhile, microbiology is allotted a separate workstation due to differing equipment, like biosafety cabinets and PPE. One analyst remains mobile, serving as the SARS-CoV-2 laboratory technician from 8 AM to 12 PM, and after completing this assignment, they are available to assist other workstations as needed. These changes have led to a more organized and efficient workflow, reducing delays and improving the overall process.

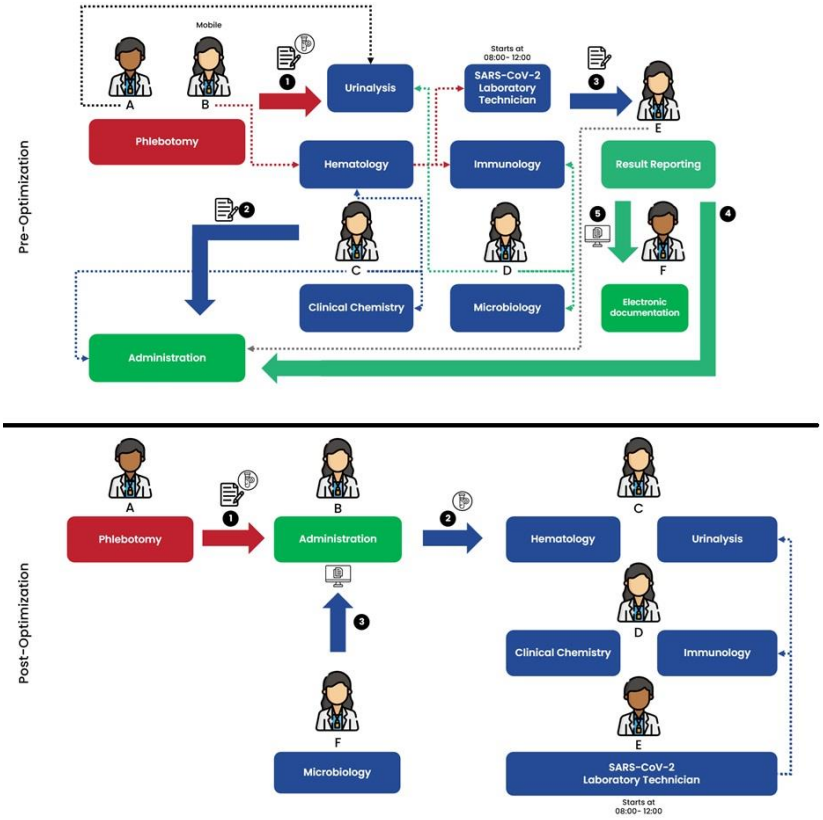

Figure 1. Workflow before and after optimization at the Community Care Center Laboratory

Pre-Optimization:

1. After the patient undergoes phlebotomy, the sample and patient request form are given to the analyst in the analytical section.
2. The analyst in the analytical section processes the sample and then records it in the ledger.
3. The resulting output is written on the patient result form.
4. The patient result form is recorded in the ledger.
5. The patient result form is typed into the online laboratory application.

Post-Optimization:

1. After the patient undergoes phlebotomy, the sample and patient request form are given to the analyst in the administrative section.
2. The analyst in the administrative section transfers the patient sample to the analyst in the analytical section.
3. The analyst in the analytical section provides the patient results to the analyst in the administrative section, who records them in the ledger and the online laboratory application.

Administration Streamlining

A dedicated role focused on administrative tasks has been implemented to optimize efficiency further. This individual is responsible for ledger entry, online data input, result reporting, and the seamless transfer of samples from phlebotomists to the corresponding test analysts. This consolidation of administrative responsibilities into a single role

eliminates redundancy and minimizes the risk of samples being overlooked or delayed. Additionally, the individual serving in this role assumes the position of a captain or head of the workspace, ensuring that all samples are diligently managed and promptly assigned to the appropriate analysts, leaving no room for oversight or delays in the workflow. These changes have significantly improved administrative efficiency and contributed to a more streamlined process.

For the evaluation, we examined TAT for two different types of routine laboratory tests: Complete Blood Count (CBC) and Random Blood Glucose (RBG) tests, before and after workflow optimization (Figure 2). For the CBC tests, the TAT before was 36 minutes with a standard deviation of 13.4 minutes; after workflow optimization, the TAT improved to 25.6 minutes and a standard deviation of 4.1 minutes, p-value < 0.05. For the RBG tests, the TAT before was 88.6 minutes with a standard deviation of 4.6 minutes. After the workflow optimization, there was a significant improvement, with a mean TAT of 81.1 minutes and a standard deviation of 1.4 minutes, p-value < 0.01.

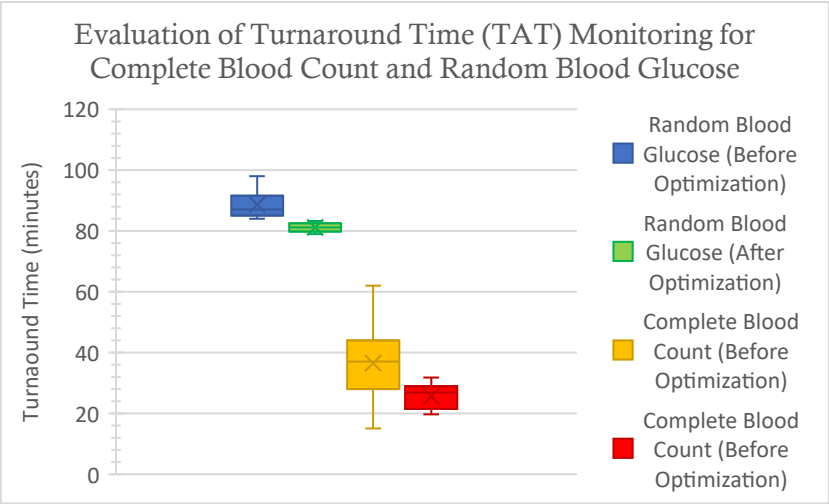

Figure 2. Turnaround Time Evaluation

The laboratory encountered persistent challenges such as variability in analyst workload, inefficient workstation grouping, and administrative overlaps, exacerbated by operating in a resource-limited setting with budget constraints. In response to these issues, a comprehensive and cost-effective approach was implemented. This approach included strategic solutions like task allocation, workflow segmentation, and administrative streamlining, all aimed at optimizing workflow and enhancing overall laboratory performance.

The outcomes of these interventions have successfully achieved the target TAT set by the project manager. In addition, optimizing workflow has significantly reduced TAT for tests such as CBC and RBG. This achievement aligns with findings from several other studies in the field, which have similarly demonstrated that implementing strategic workflow optimizations can lead to substantial TAT reductions and improvements in overall healthcare service quality (Letelier et al., 2021). These collective insights reaffirm the robustness of these strategies, regardless of resource limitations, in enhancing laboratory efficiency.

Time constraints presented limitations, as it requires continuous monitoring, regular evaluation, and further improvement could not be fully implemented within the scope of

this research. Additionally, the absence of a Laboratory Information System (LIS) required manual calculations of TAT, making complete blinding impractical. Analysts may have been aware of the project manager's timekeeping process during data collection and evaluation.

The future direction of this research involves a shift towards automation and the integration of a Laboratory Information System (LIS) to enhance workflow optimization further, aiming to achieve even greater operational efficiency (Zhang et al., 2021); (Park et al., 2023).

This research is essential as it offers a multifaceted contribution to healthcare practices. Firstly, it directly enhances laboratory efficiency by optimizing workflow and significantly reducing TAT. This expedited diagnostic process results in quicker treatment decisions and improved patient outcomes, marking a pivotal advancement in healthcare delivery. Secondly, the research provides a compelling demonstration of resource-efficient practices. It successfully introduces cost-effective interventions within a resource-limited setting, setting an exemplary standard for other healthcare organizations facing budget constraints. Lastly, this research places a profound emphasis on both efficiency and quality. By systematically addressing issues such as analyst workload variability, inefficient workstation grouping, and administrative overlaps, the research effectively streamlines laboratory operations, reduces errors, and enhances precision, ultimately elevating the overall quality of laboratory services. The laboratory can improve TAT by optimizing the workflow in a resource-limited setting.

The results of this research are in line with the findings of previous studies that highlight the importance of laboratory workflow optimization in improving TAT efficiency and service quality. A systemic approach to workflow efficiency, including the identification of bottlenecks and improved communication between departments, can significantly reduce TAT time (Burroni et al., 2021). This research supports these findings by showing that task reorganization and simplification of administrative processes can address issues such as analyst workload variation, inefficient workstation clustering, and administrative redundancy.

Furthermore, the results of this research also strengthen the conclusions of (Borges de Oliveira & de Oliveira, 2022), which showed that the application of lean management principles can reduce resource wastage and improve efficiency in resource-constrained laboratories. With the implementation of lean management-based strategies, such as task re-allocation and workflow segmentation, this research provides additional evidence that similar approaches can be effectively applied in the context of limited resources in Indonesia. These two previous studies provide a strong theoretical framework for this research, demonstrating that efficiency-focused interventions can not only reduce TAT but also improve the overall quality of laboratory services, positively impacting diagnostic decisions and patient clinical outcomes.

CONCLUSION

The conclusion in this research shows that laboratory workflow optimization can significantly improve Turnaround Time (TAT) efficiency in the context of limited resources. By implementing strategies such as task reorganization, workflow segmentation, and administrative simplification, the laboratory was able to achieve significant TAT reductions for Complete Blood Count (CBC) and Random Blood Glucose

(RBG) tests. The findings confirmed that a lean management-based approach can be an effective solution to address efficiency challenges in a resource-constrained environment. In addition, this research provides relevant practical, theoretical, and policy benefits, making it an important reference for the improvement of laboratory services at various levels of health facilities.

As a future contribution, this research opens up opportunities for further development in the field of laboratory optimization, especially by integrating modern technologies such as Laboratory Information System (LIS) and total automation. Future implementation of LIS can improve data collection accuracy, minimize human error, and speed up the analysis process. In addition, this research can inspire multidisciplinary approaches, including the use of big data analytics and artificial intelligence to identify new efficiency patterns. With these developments, this research not only supports the improvement of laboratory efficiency, but also contributes to the transformation of a healthcare system that is more integrated and responsive to patient needs.

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