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Original Article

Impact of Lean Strategy on Gram Staining Procedure in Microbiology Laboratory

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ABSTRACT

Background: The Gram staining procedure, a fundamental microbiological technique established in 1884, is crucial for bacterial identification and classification. Despite its significance, there is an ongoing need to enhance laboratory efficiency and reduce diagnostic turnaround times. Lean strategies, originating from Taiichi Ohno's work with Toyota, emphasize waste elimination and process improvement, offering a promising approach to optimizing laboratory operations.

Objective: This study aims to evaluate the impact of implementing Lean strategies on the efficiency of Gram staining procedures within a microbiology laboratory, focusing on reducing turnaround times and improving diagnostic precision without compromising quality.

Methods: A cross-sectional comparative study was conducted at the Department of Pathology, Combined Military Hospital, Lahore, from September to December 2022. Utilizing a non-probability convenience sampling technique, 122 samples were analyzed pre and post Lean implementation. Lean methodologies, including Just-In-Time inventory management and standardized work procedures, were applied to optimize sample transport, accessioning, processing, and staining phases. The study employed SPSS version 25 for statistical analysis, using the chi-square test to compare efficiencies, with a significance level set at $p<0.05$.

Results: Post-implementation of Lean strategies, significant reductions in non-value-added times were observed across all stages of the Gram staining process. Transport and accessioning times were reduced from 20 and 48 minutes to 15 and 30 minutes, respectively. The staining process time decreased from 121 to 104 minutes, and microscopy time was reduced from 201 to 56 minutes. Overall, the study reported a drastic decrease in non-value-added time from 825 to 56 minutes, maintaining the quality of staining results.

Conclusion: The application of Lean strategies to the Gram staining procedure significantly enhances laboratory efficiency by minimizing waste and optimizing process times. This approach not only improves diagnostic turnaround times but also maintains high-quality standards, suggesting a scalable model for broader healthcare system improvements.

Keywords: Lean strategies, Gram staining, microbiology, laboratory efficiency, process optimization, healthcare improvement.

INTRODUCTION

The integration of Lean strategies into microbiological practices, specifically within the Gram staining procedure, represents a transformative approach toward enhancing laboratory efficiency and diagnostic precision (1, 2). Initially described by Danish pathologist Christian Gram in 1884, with subsequent modifications, Gram staining has cemented its position as a cornerstone in the biological sciences, particularly in the realm of bacterial identification and classification (3). Its simplicity and effectiveness have made it a ubiquitous test in microbiology laboratories, leveraging the complexity and characteristics of bacterial cell walls to differentiate between gram-positive and gram-negative bacteria (3-5). The significance of Gram staining extends beyond mere classification; it plays a pivotal role in the timely identification of bacterial species, thereby facilitating prompt specimen processing and contributing to the reduction of overall turnaround times (5-7).

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The concept of Lean production, pioneered by Taiichi Ohno for Toyota Motor Company, has evolved significantly, finding application across various sectors, including healthcare. This methodology focuses on the elimination of waste—whether it pertains to cycle times, inventories, setup times, equipment downtime, scrap, rework, or other inefficiencies—through a relentless pursuit of process improvement and customer satisfaction (8, 9). In the context of healthcare and medical laboratories, Lean principles are employed to address the increasing demands and workloads, through continuous improvement projects centered around the SIPOC framework (Supplier, Input, Process, Output, Customer) and value stream mapping. This approach identifies and eliminates waste at each step of the process, thereby streamlining operations and enhancing service quality (10, 11).

Applying Lean principles to the Gram staining procedure within our research has demonstrated significant optimizations in the process. By identifying and eliminating waste and errors, we have been able to reduce the turnaround time for bacterial identification and classification (12, 13). This not only improves the efficiency of the laboratory processes but also enhances the overall quality of patient care by allowing for quicker and more accurate diagnoses. The adoption of Lean strategies in this fundamental laboratory technique underscores the potential for even minor adjustments to yield substantial improvements in time, resource utilization, and operational capacity. Such enhancements, in turn, free up resources that can be redirected toward the provision and improvement of other critical services, thereby underscoring the versatility and impact of Lean methodologies in healthcare settings (14, 15). Through this research, it is evident that Lean strategies, when applied thoughtfully to even the most basic laboratory procedures, can significantly contribute to the advancement of medical laboratory operations and patient care outcomes (16, 17).

MATERIAL AND METHODS

Following the acquisition of approval from the institutional review board, a cross-sectional comparative study was undertaken at the Department of Pathology, Combined Military Hospital, Lahore, over a period from September to December 2022. Employing a non-probability convenience sampling technique, the study sought to evaluate the impact of Lean strategy implementation on the efficiency of Gram staining procedures within the microbiology laboratory (18, 19). The analytical framework of the study was established through the utilization of SPSS version 25 for data analysis. This facilitated the quantitative assessment of variables such as time, presented as mean ± standard deviation, and qualitative variables such as reagents and human potential, delineated through frequency and percentages (20, 21). The inferential comparison between the conditions pre and post the application of Lean strategies was conducted using the chi-square test, with a p-value of less than 0.05 designated as the threshold for statistical significance. To achieve a confidence level of 95% and an absolute precision of 10%, with an anticipated improvement from 38% efficiency before Lean implementation to 9% thereafter, the sample size was meticulously calculated using the formula (22, 23).

$n = Z^2 1 - \alpha/2[\, P1\,(\,1 - \,P1)\, + \,P2\,(\,1 - \,P2\,)] \div d^2$ resulting in a total of 122 samples. Inclusion criteria for the study were samples submitted for culture and sensitivity analysis, while those intended for cytology and Gram Staining were excluded to maintain a focused scope. The study's methodology encompassed a Lean strategy deployment aimed at optimizing sample transport and accessioning processes. This was achieved through the introduction of a Just-In-Time (JIT) inventory management system, which ensured timely sample delivery to the laboratory, thereby reducing transport times and minimizing the risk of sample misplacement. Furthermore, the establishment of standardized work procedures for sample accessioning significantly curtailed the likelihood of errors, enhancing overall procedural efficiency. Notably, these interventions facilitated a reduction in transport and accessioning times from 20 and 48 minutes to 15 and 30 minutes, respectively (3, 24).

The procedural integrity of the study was maintained through adherence to standard microbiological practices, including a 24-hour incubation of samples at 37 degrees Celsius following inoculation onto respective culture media. Subsequent to incubation, smears from positive cultures were prepared and subjected to Gram staining for microscopic examination. A streamlined process was adopted for Gram staining, whereby multiple (six) smears were prepared on a single slide, thereby economizing on processing time. This optimization strategy successfully reduced the Gram staining process duration from 121 to 104 minutes without compromising staining quality. Additionally, the microscopy phase was expedited by having microbiologists examine up to ten smears per slide during their assigned rotation days, resulting in a further time reduction of 6 minutes (25, 26).

The study also incorporated a comprehensive evaluation of the process improvements through the development of a value stream map, which delineated the time allocated to each procedural step from sample collection to the dispatch of final reports. This visual tool was instrumental in identifying and minimizing non-value-added time, thereby enhancing the efficiency and cost-effectiveness of the laboratory process. The study adhered to the ethical principles outlined in the Declaration of Helsinki, ensuring the protection of participant rights and the integrity of the research process.

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RESULTS

The investigation into the implementation of Lean strategies in the microbiology laboratory's procedures yielded quantifiable improvements, as depicted in the comparative analysis of the process times before and after Lean application. Prior to the Lean intervention, the total time involved across various stages of the Gram staining process was notably higher, with significant non-value-added times contributing to process delays (Table 1). Transportation initially accounted for a total of 20 minutes, with 5 minutes classified as non-value added. The receiving and accessioning stage incurred 87 minutes, dominated by a non-value-added duration of 57 minutes, indicating substantial inefficiencies. Processing and staining stages showed a similar trend, with non-value added times of 66 minutes out of 103, and a striking 546 minutes out of 650, respectively. Microscopy, the final step, also reflected inefficiency with 151 minutes of non-value time out of 201.

Table 1: Time Involved Before Lean Application

Sr. No.	Steps Involved	Total Time Involved	Non-Value Added Time	Value Added Time
1.	Transportation	20 mins	5 mins	15 mins
2.	Receiving/Accessioning	87 mins	57 mins	30 mins
3.	Processing	103 mins	66 mins	37 mins
4.	Staining	650 mins	546 mins	104 mins
5.	Microscopy	201 mins	151 mins	50 mins

In stark contrast, after the application of Lean strategies, every stage experienced a reduction in non-value added time while preserving the value added time, illustrating the methodology's efficacy in waste reduction (Table 2). Post-implementation, the receiving and accessioning phase exhibited a substantial decrease in total time to 48 minutes, significantly shrinking the non-value added time to 18 minutes. The processing stage followed suit, with a drop in non-value added time to 10 minutes out of a 47-minute total. Noteworthy was the staining stage, which saw a drastic reduction in non-value added time from 546 to 17 minutes, while the value added time remained constant at 104 minutes, underscoring the potency of Lean principles in enhancing operational efficiency. The microscopy stage mirrored this improvement, with non-value time plummeting to 6 minutes from an original 151, within a condensed total time of 56 minutes.

The data underlines a transformative impact on the laboratory's throughput, with Lean strategies leading to a streamlined process that effectively minimizes waste without compromising the quality of the staining process, as the value added times remained consistent across both tables.

Table 2: Time Involved After Lean Application

Sr. No.	Steps Involved	Total Time Involved	Non-Value Added Time	Value Added Time
1.	Transportation	20 mins	5 mins	15 mins
2.	Receiving/Accessioning	48 mins	18 mins	30 mins
3.	Processing	47 mins	10 mins	37 mins
4.	Staining	121 mins	17 mins	104 mins
5.	Microscopy	56 mins	6 mins	50 mins

These enhancements are a testament to the successful application of Lean principles in optimizing laboratory operations and could serve as a benchmark for similar future endeavors in the medical field.

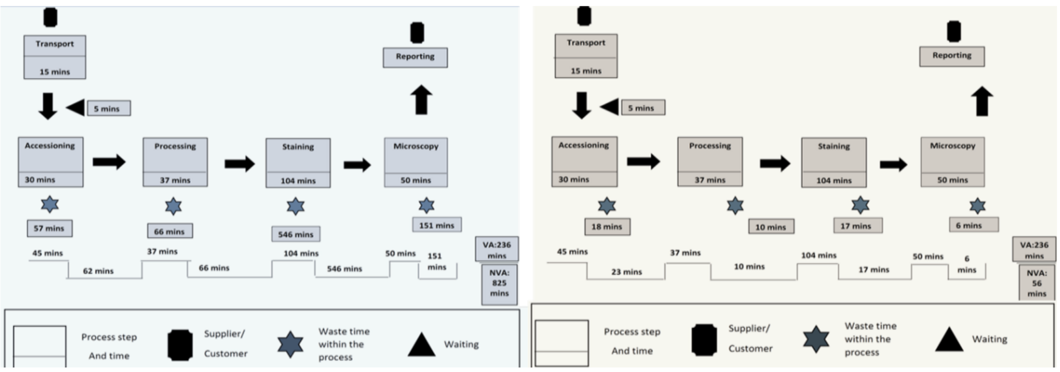

Figure 1 Comparison of Value Stream Maps for the Gram Staining Process Before and After Lean Implementation, Highlighting Value-Added (VA) and Non-Value-Added (NVA) Activities

The diagrams present a comparative value stream mapping of a microbiology laboratory's Gram staining process before and after the implementation of Lean strategies. In the initial process, transport took 15 minutes, accessioning 30 minutes, processing 37 minutes, staining 104

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minutes, and microscopy 50 minutes, accumulating to a total value-added time of 236 minutes and a high non-value-added time of 825 minutes. After Lean optimization, while transport remained the same, accessioning was reduced to 18 minutes, processing was unchanged, staining was shortened to 17 minutes, and microscopy was trimmed down to 6 minutes. This resulted in the same value-added time of 236 minutes, but a drastic reduction in non-value-added time to 56 minutes, showcasing a significant efficiency improvement in the laboratory's operations.

DISCUSSION

The incorporation of Lean principles into microbiology laboratory operations, specifically in the context of Gram staining procedures, has demonstrated a significant potential to enhance efficiency and minimize waste. This study's application of Lean methodologies was guided by Ohno's classification of the seven types of waste, which includes inefficiencies related to time, processing, production, transportation, equipment, motion, and defective products. Initially, the study identified transportation of samples as a primary source of delay, often extending up to a full day, due to irregular delivery by patients or attendants. Furthermore, the accessioning step was also identified as a bottleneck due to workload peaks causing delays (27).

By employing Lean tools such as process mapping and continuous improvement, the study successfully streamlined the Gram staining process. This led to not only a reduction in errors and turnaround times but also improved overall patient outcomes. The effective changes implemented in the laboratory procedure were a testament to the power of Lean's waste management strategies, even when applied to the most fundamental laboratory tasks. Notably, the reduction in turnaround time (TAT) from 17 minutes to a mere four minutes per sample echoed the improvements reported by Josaine S. Quetz et al., who observed a reduction in lead time from nine to five days, and by Jessica Z. Sugianto et al., who recorded a decrease from 537 minutes to 238 minutes (28, 29). These results underscore the transformative potential of Lean methodologies within healthcare systems.

Despite these successes, the study acknowledged limitations similar to those discussed by Bozena S. Poksinska in a literature review on Lean in healthcare. While three of the five Lean principles were applicable, the remaining two—supply on demand and attaining perfection—proved challenging within the complex hospital and laboratory settings where the "customers" are patients and the "products" are critical services and test results integral to human health (30). The study recognized that the implementation of Lean is an iterative, time-consuming process that requires expansion beyond a single department to fully realize its benefits across the healthcare system.

In reflecting on the study's strengths, it is evident that the Lean approach significantly improved laboratory efficiency and cost-effectiveness, maintaining or enhancing quality standards. However, the study also faced constraints inherent in the healthcare environment's unpredictability and variability in patient needs (4, 7, 10, 17, 22). Recommendations for future applications include a broader and longer-term implementation of Lean strategies across various laboratory operations to address increasing workloads and economic challenges within the healthcare sector. The study's findings advocate for a systemic adoption of Lean philosophies to foster a culture of continuous improvement and waste minimization, ultimately leading to more responsive and sustainable laboratory services (2, 10, 19).

CONCLUSION

The integration of Lean strategies into microbiological practices, particularly the Gram staining procedure, has showcased a paradigm shift in laboratory efficiency and diagnostic accuracy, underscoring the profound potential of Lean methodologies in healthcare. This study demonstrates that through meticulous application of Lean principles, significant reductions in non-value-added time and overall process times can be achieved without compromising quality, leading to faster, more accurate diagnoses and enhanced patient care. The findings illuminate the path for broader application of Lean strategies across healthcare systems, advocating for a culture of continuous improvement and efficiency. By streamlining operations and eliminating waste, healthcare facilities can better manage increasing workloads and economic pressures, ultimately contributing to a more responsive and sustainable healthcare environment.

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