ISSN: 2614-6754 (print)
ISSN: 2614-3097(online)

Halaman 9406-9415
Volume 8 Nomor 1 Tahun 2024

Laboratory Information Systems and Staff Performance Optimization as a Method to Improve Laboratory Turnaround Time

Merci Monica BR Pasaribu[1], Rivaldi Febrian[2]

[1.2] Clinical Pathology Department, Faculty of Medicine, Universitas Indonesia, Jakarta, Indonesia

e-mail: rivaldi.febrian@gmail.com

Abstrak

Turnaround time (TAT) merupakan tolak ukur mutu kinerja laboratorium medik. TAT prokalsitonin tidak mampu mencapai target TAT yang ditetapkan laboratorium. Tujuan: mengkaji tahap keterlambatan TAT, melakukan upaya perbaikan, dan mengevaluasi upaya perbaikan. Metode: Penelitian prospektif ini dilakukan di Laboratorium RS Cipto Mangunkusumo pada tanggal 3 hingga 31 Januari 2022. Untuk mengukur strategi peningkatan TAT dengan tepat, penelitian ini membagi alur kerja prokalsitonin menjadi beberapa checkpoint. Hasil: Tahapan terpanjang adalah dari masuknya spesimen ke Abbott Architect c8000 hingga keluar (50 menit). Tahap terlama kedua terjadi pada alat analisa prokalsitonin (21 menit). Ketiga adalah pemindahan spesimen dari Abbott Architect c8000 ke penganalisis prokalsitonin (18 menit). Keempat, waktu dari keluarnya spesimen dari alat analisa hingga keluarnya hasil (16 menit). Contoh waktu check-in untuk masuk ke Abbott Architect c8000 (14 menit). Upaya perbaikan pun dimulai, terdiri dari optimalisasi kinerja LIS dan analis. Evaluasi menunjukkan TAT prokalsitonin <2 jam sebesar 69,6%, dengan median TAT 96 menit, menandai peningkatan TAT <2 jam sebesar 22% dan mengurangi TAT menjadi 31 menit. Kesimpulan: Sistem Informasi Laboratorium dan Optimasi Kinerja Staf efektif meningkatkan TAT laboratorium.

Kata kunci: *Laboratorium, Waktu Penyelesaian, Prokalsitonin.*

Abstract

Turnaround time (TAT) is a quality benchmark for the performance of medical laboratories. Procalcitonin TAT was unable to reach the target TAT set by the laboratory. Objective: to examine the stage where TAT is delayed, perform improvement efforts, and evaluate the improvement efforts. Methods: This prospective study was conducted at Cipto Mangunkusumo Hospital Laboratory from 3 to 31 January 2022. To properly measure strategies to improve TAT, the study divided the procalcitonin workflow into several checkpoints. Results: The longest stage was from specimen entry into Abbott Architect c8000 until exit (50 minutes). The second longest stage was within the procalcitonin analyzers (21 minutes). Third was the transfer of specimens from Abbott Architect c8000 to

the procalcitonin analyzer (18 minutes). Fourth, the time from specimens exiting the analyzer until result release (16 minutes). The time specimen check-in to entry to Abbott Architect c8000 (14 minutes). Improvement efforts were initiated, consisting of LIS and analyst performance optimization. The evaluation showed procalcitonin TAT < 2 hours at 69.6%, with a median TAT of 96 minutes, marking a 22% increase in TAT < 2 hours and reducing TAT to 31 minutes. Conclusion: Laboratory Information Systems and Staff Performance Optimization effectively improve laboratory TAT.

Keywords: *Laboratories, Turnaround Time, Procalcitonin.*

INTRODUCTION

Quality refers to a product or service's ability to meet the needs and expectations of customers. Clinicians primarily focus on factors such as availability, cost, clinical relevance, and timeliness. Among these factors, timeliness holds the highest importance for clinicians, who may prioritize quicker results over the meticulousness of the process (Hawkins, 2007). In contrast, clinical laboratories carry a heavier responsibility, considering aspects like quality, test availability, cost-effectiveness, clinical relevance, and timeliness (Kementrian Kesehatan Republik Indonesia, 2010). In assessing the timeliness of medical laboratories, the term 'turnaround time' (TAT) is employed (Hawkins, 2007).

Turnaround time (TAT), or the waiting period for laboratory results, serves as a crucial quality benchmark for evaluating the performance of medical laboratories. Delays in TAT can result in postponed diagnoses and patient care, and a prolonged TAT may necessitate redundant testing, amplifying the laboratory's workload and driving up healthcare expenses. Hence, achieving faster TAT is a universally sought-after goal to enhance the efficiency and effectiveness of patient management (Dey, 2013).

Procalcitonin, a prohormone of calcitonin, is produced by various cell types and organs in response to inflammation, particularly in cases of bacterial infections. This diagnostic test is widely employed to guide antibiotic therapy decisions and to aid in the diagnosis of sepsis. It is a routine procedure performed in laboratories. On December 22, 2020, during a management review meeting the laboratory set a quality target for 60% of procalcitonin test results to be delivered within 2 hours. However, since the announcement, the laboratory has been unable to consistently meet the quality standard throughout 2021, with performance fluctuating between 43.84% and 59.42%. The aim of the study is to examine the stage where the TAT was delayed, the improvement measures that would be implemented, and the evaluation of the outcomes resulting from these improvement efforts.

METHOD

Study Design

This prospective study was conducted at the Cipto Mangunkusumo Hospital Laboratory and comprised three distinct stages. The initial stage, conducted from January 3 to January 9, 2022, focused on data collection. The second stage, spanning January 10 to January 16, 2022, was dedicated to data analysis. The final stage, occurring from January 17 to January 31, 2022, centered on improvement and evaluation. Throughout the study, all

procalcitonin specimens were continuously included in the analysis; 24 hours a day without any interruptions. Specimens that were hemolyzed and required reanalysis were excluded from the analysis. These specimens were recorded in the Laboratory Information System. An independent project manager was a clinical pathologist who was tasked to collect data, analyze the data, and evaluate the improvement efforts. Improvement efforts were managed by the head of the laboratory. The analysts were blinded and not aware of the data collection and evaluation process. Parts of the data were already presented on the 13th Continuing Professional Development on Clinical Pathology and Laboratory Medicine 2022.

Procalcitonin workflow

The workflow of procalcitonin examination can be visualized in Figure 1. The specimen is transferred through pneumatic tubes. Laboratory analysts performed Check-In by scanning the tube's barcode. After Check-In, laboratory analysts transferred specimens to Abbott Architect c8000 directly without centrifugation and removing the cap. Tube decapping and centrifugation occur automatically within the Abbott Architect c8000 at a speed of 4000 rpm for 15 minutes. The hemolysis index was measured automatically by the Abbott Architect c8000 Analyzer. Analysts routinely inspected and rejected the hemolyzed specimens by assessing the visual and hemolysis index. Abbott Architect c8000 Analyzer analyzed the specimen for non-procalcitonin parameters first. Once it was finished, the specimens were transferred by the analyst to the procalcitonin analyzers. There were 3 procalcitonin analyzers; 2 analyzers were B.R.A.H.M.S KRYPTOR analyzers and 1 was Cobas E411. Selection is carried out by manually rescanning the tubes' barcodes. Three analyzers were consistently utilized, with specimens allocated to either analyzer based on its availability or readiness. Once the result emerged, the analyst released the result or performed reanalysis if necessary. The doctor on duty approved the result.

TAT measurement and statistical analysis

The data will be analyzed using Microsoft Excel. The data will be presented in the form of tables and figures. Categorical data will be reported in terms of frequency and percentage. For numeric data, the normality will be tested using the Kolmogorov-Smirnov test with a significance level of $p > 0.05$. If the distribution is found to be normal, the data will be presented as mean ± standard deviation (SD). If the distribution is non-normal, it will be reported as median, quartile 1, and quartile 3. Turnaround time encompasses the entire duration from when a specimen arrives at the laboratory to when doctors on duty approve the final results. To properly measure strategies to improve TAT, the study divided the procalcitonin workflow into several checkpoints (Figure 1). These checkpoints were recorded automatically and information was available for extraction in every checkpoint (Table 1). This checkpoint sub-analysis would be performed on the day that the procalcitonin request was the highest. The measurable procalcitonin TAT target is to achieve TAT in less than 2 hours for 60% of specimens.

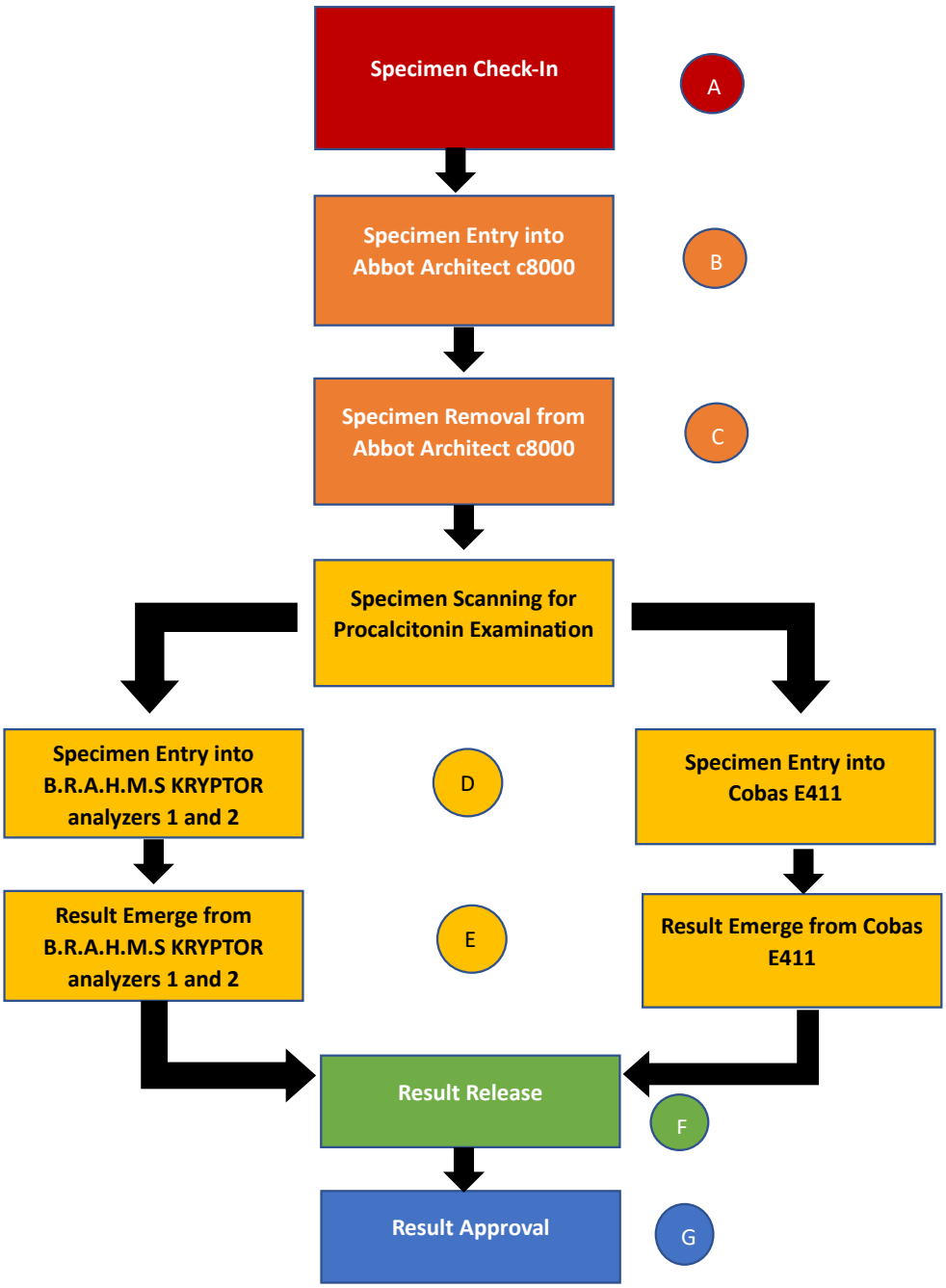

Figure 1. Schematic diagram of Procalcitonin Workflow at Cipto Mangunkusumo Hospital Laboratory

Table 1. Definition, Responsibility, Souce of Information of Each Checkpoints involved in Procalcitonin Workflow

No	Checkpoints	Definition	Responsibility	Source of Information
1	A-B	The Process from Specimen Check-In at the Laboratory to Specimen Entry into Abbot Architect	Laboratory analyst	Laboratory Information System
2	B-C	The Process from Specimen Entry to Specimen Removal from Abbot Architect	Abbott Architect c8000	Abbott Architect Analyzer Management System
3	C-D	The Process from Specimen Removal from Abbott Architect c8000 to Specimen Transfer to Procalcitonin Analyzer	Laboratory analyst	Abbott Architect, BRAHMS Kryptor, Cobas E411 Analyzer Management System
4	D-E	The Process from Specimen Entry to Results Emerging from Procalcitonin Analyzer	BRAHMS Kryptor/ Cobas E411	BRAHMS Kryptor, Cobas E411 Analyzer Management System
5	E-F	The Process of Results Emerging from the Instrument to Result Release	Laboratory analyst	Laboratory Information System
6	F-G	Process from Result Release to Result Approval	On Duty Doctor	Laboratory Information System
7	A-G	The Process from Specimen Check-In at the Laboratory to Result Approval	All of the above	Laboratory Information System

RESULT AND DISSCUSION

Pre-Optimization

A total of 862 procalcitonin specimens were examined at the Cipto Mangunkusumo Hospital Laboratory from January 3, 2022, to January 9, 2022. The procalcitonin Turnaround Time (TAT) during this period was 55.3% (n: 477/862). The highest number of procalcitonin requests came from the Emergency Department (32%), followed by Inpatient Department (30%), Outpatient Department (22%), and Executive Health Department (5%). Specimens from Cardiac Departement, Intensive Care Unit, Burn Unit, and Pediatric Departement, accounted for 11% of the procalcitonin examination requests. Procalcitonin specimens were found to be most abundant on 3 January 2022, followed by 6 January 2022, 4 January 2022,

and so forth (Figure 2). Subsequently, a sub-analysis was conducted to examine the time taken at each checkpoint from A to G (Table 2).

On January 3, 2022, a total of 1087 specimens (all specimens including procalcitonin) were processed using Abbott Architect c8000. During this day, the morning shift processed the highest number of specimens, totaling 720 (66.2%), followed by the afternoon shift with 275 specimens (25.2%), and the night shift with 92 specimens (8.6%). The majority of procalcitonin specimens were also processed during the morning shift (57.3%, n= 98/171) followed by the afternoon shift (24.6%, n= 43/171) and the night shift (18.1%, n= 30/171). Only a fraction of procalcitonin specimens (4.9%, n= 8/171) did not pass through Abbott Architect c8000. No issues were found on Monday, January 3, 2022, as reported by the on-duty staff.

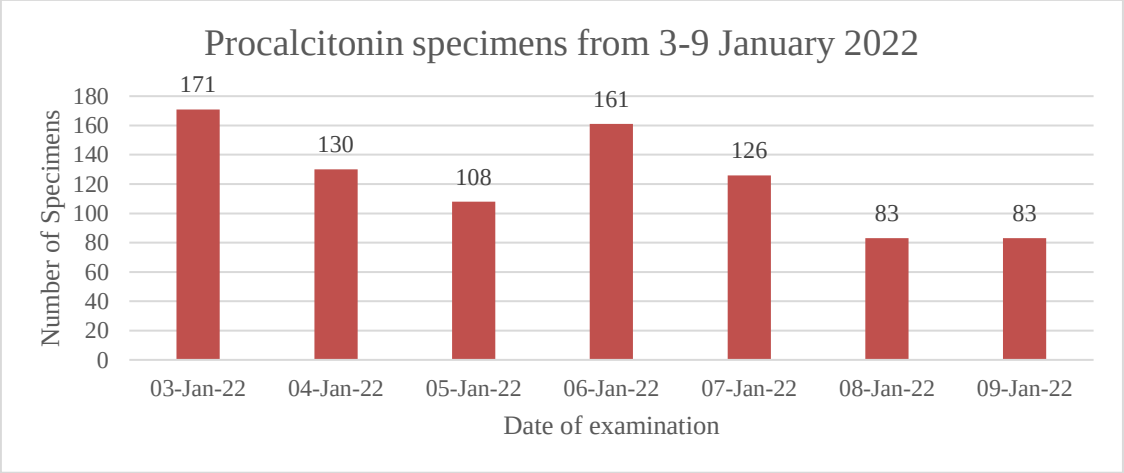

Figure 2. Procalcitonin specimens processed by Cipto Mangunkusumo Hospital Laboratory on 3-9 January 2022

Observations related to the TAT and its checkpoints are summarized in Table 2. The TAT for procalcitonin on January 3, 2022, did not meet the expected TAT target. The longest stage was found to be the period from specimen entry into Abbott Architect c8000 until the specimen's exit from Abbott Architect c8000 (B-C), with a median time of 50 minutes. During the morning shift, this stage had a longer median TAT of 54 minutes, with only 19.3% of procalcitonin TAT meeting the target. The second longest stage was observed when the specimens were within the procalcitonin analyzer instrument (D-E), with a median time of 21 minutes. The third longest stage was the transfer of procalcitonin specimens from Abbott Architect c8000 to procalcitonin analyzer (C-D), with the heaviest workload during the morning shift. The fourth longest stage was the time from specimens exiting the procalcitonin analyzer until the results were released by the analyst (E-F), especially during the morning shift, with a median time of 30 minutes.

Table 2. Procalcitonin TAT checkpoints on 3 January 2022 (pre-optimization) and 24 January 2022 (post-optimization)

Observation	A-B (min)	B-C (min)	C-D (min)	D-E (min)	E-F (min)	F-G (min)	A-G (min)	Total TAT % < 2 hour (n,%)
PRE-OPTIMIZATION								
TAT checkpoints Categorized by shift	14 (7-28)	50 (47-55)	18 (11-30)	21 (21-22)	16 (4-40)	8 (3-16)	126 (86-168)	82/171 (47,9%)
•Morning Shift	20 (11-35	54 (50-62	22 (15-41)	21 (21-23	30 (14-58	8 (4-17)	164 (127-1	19/98 (19,3%
•Afternoon Shi	7 (5-14)	48 (37-50	12 (9-18)	21 (21-24	4 (2-9)	8 (2-26)	78 (73-96)	37/43 (86%)
•Night Shift	6 (5-7)	47 (45-48	13 (7-19)	22 (21-23	10 (1-27)	10 (2-15	87 (77-108	26/30 (86,7%
POST-OPTIMIZATION								
TAT checkpoints Categorized by shift	10 (7-13)	52 (48-58)	11 (5-25)	19 (19-22)	4 (1-8)	19 (4-4	95 (72-132)	114/162 (70,4%)
•Morning Shift	11 (9-13)	54 (50-61)	10 (4-25)	19 (19-20)	3 (1-7)	26 (5-48)	99 (76-132)	75/112 (67%)
•Afternoon Shift	7 (6-8)	48 (46-50)	10 (5-19)	22 (22-30)	7 (3-20)	11 (4-63)	101 (83-142)	21/32 (65,6%)
•Night Shift	7 (6-15)	44 (37-48)	36 (8-64)	21 (19-23)	2 (1-4)	4 (1-6)	69 (55-72)	18/18 (100%)

Data in median (Q1-Q3)

Post-Optimization

Based on this data, specific improvement efforts were designed to enhance the procalcitonin examination stages, particularly in the stage from specimen check-in to specimen entry into Abbott Architect c8000 (A-B) and from the stage where results exit procalcitonin analyzer until the specimens are released by the analyst (E-F).

On January 17, 2022, improvement efforts were initiated, consisting of analyst performance optimization to raise awareness about delays in specimen check-in until entry into Abbott Architect c8000 (A-B). Additionally, optimization was also performed on the LIS to improve the faster result release process by analysts (E-F). This was achieved by segregating procalcitonin examination as a separate item in the Worklist Result Entry menu within LIS.

The optimization efforts in the stage from specimen check-in to entry into Abbott Architect c8000 (A-B) and from the release of results by analysts (E-F) were considered successful. This is supported by the reduction in time, particularly during the morning shift, where the median time from specimen check-in to entry into Abbott Architect c8000 (A-B)

was found to be 11 minutes, and from the exit of results from the instrument to analyst release (E-F) was 4 minutes (Table 2). Additionally, the percentage of procalcitonin TAT during the evaluation period showed improvement, with a total percentage of procalcitonin TAT < 2 hours reaching 69.6%, and a median TAT duration of 96 minutes (Table 3). Data for 27, 28, and 31 January 2022, showed equipment malfunctions. If these data are excluded, the total percentage of procalcitonin TAT < 2 hours becomes 72.9% (n=1089/1492), with a median TAT duration of 93 minutes (72 - 120).

Table 3. Procalcitonin TAT optimization evaluation from 17 -31 January 2022

Date of Examination	Procalcitonin TAT < 2 hour (n, %)	TAT duration (min)*	Details
17-Jan-22	96/169 (56,8%)	112 (72-144)	One analyst is on leave.
18-Jan-22	89/147 (60,5%)	102 (78-157)	-
19-Jan-22	120/137 (76,4%)	100 (82-118)	-
20-Jan-22	100/142 (70,4%)	94 (72-123)	-
21-Jan-22	111/151 (73,5%)	93 (76-123)	-
22-Jan-22	60/71 (84,5%)	85 (69-106)	-
23-Jan-22	74/87 (85,1%)	80 (65-106)	-
24-Jan-22	114/162 (70,4%)	95 (72-132)	-
25-Jan-22	108/134 (80,6%)	81 (68-103)	-
26-Jan-22	97/148 (65,5%)	107 (78-140)	-
27-Jan-22	73/131 (55,7%)	106 (75-166)	The Abbott Architect c8000 instrument experienced a malfunction, and the internal quality control did not pass, leading to its shutdown.
28-Jan-22	70/120 (58,3%)	98 (72-137)	The Abbott Architect c8000 instrument was not operational for several hours. Two procalcitonin analyzer instruments faced issues in which the instruments were not connecting to the LIS.
29-Jan-22	55/67 (82,1%)	90 (75-106)	-
30-Jan-22	66/77 (85,7%)	85(70-111)	-
31-Jan-22	114/193 (59,1%)	108 (84-149)	One analyst is on leave. Internal quality control for one procalcitonin analyzer did not pass.
Total	1346/1936 (69,6%)	96 (74-133)	-

*Data in median (Q1-Q3)

Discussion

Based on our observations, the TAT target for procalcitonin was not achieved during data collection period from 3 to 9 January 2022. An analysis of the time taken for each stage, from the longest to the shortest, revealed the following sequence: the process in Abbott Architect c8000, the process in procalcitonin analyzer, the transfer of specimens from Abbott Architect c8000 to procalcitonin analyzer, the check-in process into Abbott Architect c8000, the release of results by analysts, and approval by doctors on duty. The time spent on the examination within each instrument was relatively stable. The timing for the Abbott Architect c8000 examination was consistent with previous unpublished reports, and the timing for the procalcitonin analyzer examination aligned with the instrument's kit insert. Variability was observed in the time spent on each stage, with the longest procalcitonin examinations being analyzed by analysts during the morning shift. This may be attributed to the accumulation of many specimens, particularly those originating from the outpatient department, which extended the time required for procalcitonin examination. Furthermore, the high volume of procalcitonin specimens submitted in a single tube along with other tests contributed to an increased examination time. Based on these findings, the key focus of optimization efforts would be the check-in process to Abbott Architect c8000 and the release of results by analysts.

Improvement efforts were initiated to improve these stages. These were analyst staff performance optimization to raise awareness of such delays. The aim was to reduce the time taken during the stage check-in process to Abbott Architect c8000. Secondly, the optimization of LIS was performed. Minor modification to segregate procalcitonin examination as a separate item in the Worklist Result Entry menu was performed. The modification aimed to simplify the process of analysts releasing procalcitonin examination results that were already available in the LIS. After implementing improvement efforts, an evaluation was conducted regarding procalcitonin TAT from 17 to 31 January 2022. It revealed an increase in the percentage of TAT < 2 hours by 22% and a decrease in TAT duration to 31 minutes. If the data regarding equipment malfunction is excluded, there is an increase in the percentage of TAT < 2 hours by 25% and a decrease in TAT duration to 33 minutes.

One of the limitations of the study is there is no improvement efforts have been made to reduce the time for the transfer of specimens from Abbott Architect c8000 to procalcitonin analyzers. There are several potential approaches, such as manually or automatically aliquoting procalcitonin examination specimens for the specimens that had only one blood tube, designating procalcitonin examination as a test requiring a separate tube, and increasing the number of analysts responsible for transferring the specimen from Abbott Architect c8000 instrument to procalcitonin analyzer. Similar to Cherkaoui A et al. (2020) and Fontana C et al. (2023), we believe that adding automatic aliquoting tools on Abbott Architect c8000 to aliquot procalcitonin examination is the most cost-effective choice in the long run. However, due to budget restrained, these efforts were not conducted.

CONCLUSION

Laboratory Information System and Staff Performance Optimization can be used to improve laboratory turnaround time. Implementation of laboratory automation could be considered to improve TAT in the long term.

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