Received May 23, 2024, accepted December 19, 2024 date of publication January 20 2025.

Original Research Article

Research on Strategies for Improving Turnaround Time Efficiency through Automation Tools

Chaoping Zou*, Lifang Zhan, Fawang Li, Jiange Jiang and Zhiyong Zhang

Laboratory, Qilu Hospital of Shandong University Dezhou Hospital, Dezhou City, Shandong Province, China.

* Corresponding Author Email: 13791337482@163.com

ABSTRACT

Background: Continuously monitor monthly laboratory turnaround time (TAT) data, analyzing the reasons for the continuous increase in TAT, and applying PDCA (Plan-Do-Check- Act, and automation tools for improvement, to enhance laboratory efficiency, and provide more accurate and efficient support for clinical diagnosis and treatment.

Methods: Analyzing data from November 2022 to April 2023, identifying risk points in biochemical sample TAT, sought root causes, formulated targeted improvement plans, and continuously tracked changes before and after improvement. The analysis group consisted of data from November 2022 to April 2023, and the improvement group from May 2023 to August 2023.

Results: Despite the gradual increase in laboratory sample volumes, the overall and segmented TAT for biochemical projects decreased after improvements.

Conclusion: Continuous monitoring of quality indicators within the laboratory is essential. Using PDCA tools to identify causes and automation tools can significantly improve TAT results, effectively help identify risk points and root causes, and enhance testing efficiency. This approach can be attempted to analyze and improve other indicators.

Keywords—*Biochemistry, Laboratory turnaround time, Automation, PDCA.*

INTRODUCTION

After the onset of the COVID-19 pandemic, nucleic acid testing gradually became a focal point of the laboratory department's work. As we enter the post-pandemic period, the volume of outpatient hospital visits has surged, and the number of samples in the laboratory department has increased accordingly. Testing quality directly affects patient diagnosis and satisfaction.[1] How to utilize automated and information-based assembly lines to improve work efficiency, achieve intelligent and intensive laboratory operations, optimize personnel arrangements, and provide accurate and efficient test reports to assist clinical work in differential diagnosis, thereby enhancing patient satisfaction, is a topic that the laboratory department needs to focus on continuously.

In the context of Diagnosis Related Groups (DRGs) reform, strengthening refined management is a new challenge and opportunity for laboratory medicine.[2] In 2017, the "Clinical Laboratory Quality Indicators" (WS/T496-2017)[3] was released, clearly defining 28 indicators closely related to the quality of the clinical laboratory. It proposed that the entire testing process spans from the clinical issuance of a test request to the patient receiving the test report, including pre-analytical, analytical, and post-analytical phases. Among these, efficiency-related quality indicators are pre-analytical turnaround time (TAT) and intra-laboratory TAT. TAT refers to when the laboratory receives the specimen to when the report is sent, encompassing the total time of the analytical and post-analytical phases.

Typically, biochemical and immunological samples are the focus of intra-departmental testing work and are significant sources of influence on the total TAT of the laboratory. Continuously analyzing the operational efficiency of the production line, monitoring changes in TAT data, early warning, and applying the PDCA cycle management method to analyze causes and implement improvements are effective methods to enhance the quality of testing and operational efficiency of the department, thereby providing better services to patients.

MATERIALS AND METHODS

General Information

The Dezhou People's Hospital Laboratory (Dezhou, Shandong Province, China) is equipped with a Power Express (PE) automation line (Beckman Coulter), connected to the AU5821 and DxI800. It is equipped with Remisol middleware for data transmission and analysis.

TABLE 1. Median TAT (min) data required by the standard.

Tertiary	Hospital	Minimum	Appropriate	Best
Emergency	Biochemistry	60	**45***	30
	Immunity	88	**60**	40
Routine	Biochemistry	150	**115**	80
	Immunity	225	**149**	100

According to the "Clinical Laboratory Quality Indicators" (WS/T496-2017)[3], the acceptable range for the laboratory's TAT is established, which meets the "appropriate" requirements in the "standards" (see Table 1).

*The data in bold means the laboratory TAT requirements recommended by the state, as stated in the above text.

Study Design

Following the PDCA cycle strategy, the improvement of TAT in the laboratory biochemical project is carried out based on Plan (discovering problems and defining causes), Do (formulating improvement plans), Check (tracking effects), and Act (continuous improvement plans).

Plan: Analyze the TAT data in the laboratory for projects conducted on the PE line from September 2022 to August 2023. It was found that the biochemical TAT fluctuated and increased, and indicated that the TAT showed too long and needed improvement. An improvement team was established, and the reasons affecting TAT were identified through interviews with relevant responsible personnel. A questionnaire survey was created, and the true influencing factors were identified through voting.

Do: Discuss within the group and formulate targeted improvement plans.

Check: Check the effect after rectification, regularly count the laboratory TAT indicators, compare the execution results with the target to be achieved, and determine whether there has been any improvement, and whether the target has been reached.

Act: Continuously monitor, and plan to use for other indicators.

According to the improvement plan and timeline differentiation statistics, the period from November 2022 to April 2023 is designated as the analysis group, and the period from May 2023 to August 2023 is designated as the improvement group.

Statistics Analysis

All the data were collected and analyzed through the automation tool named Remisol of the PE assembly line, and data processing was analyzed using Excel (2019, Microsoft, USA).

RESULTS

The Fluctuation in Biochemical TAT Had Increased and Needed Improvement

The monthly specimen quantity and TAT median of the analysis group for biochemical and immunological projects are as follows (see Table 2, Figure 1, and Table 3, Figure 2):

TABLE 2. Monthly statistics of biochemical samples (before improvement).

	Nov 2022	Dec 2022	Jan 2023	Feb 2023	Mar 2023	Apr 2023
Total Samples (Number/Month)	19,269	26,313	37,022	42,045	44,326	40,462
Median TAT (min)	83.0	81.5	89.0	88.0	89.5	91.0

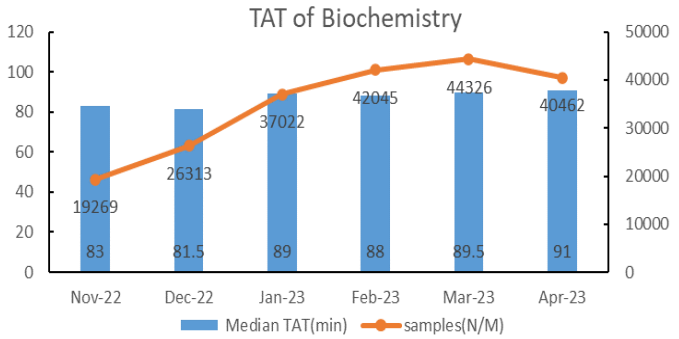

FIGURE 1. Trend of monthly median TAT of biochemical samples (before improvement).

TABLE 3. Monthly statistics of immunological samples (Nov. 2022–Apr. 2023).

	Nov 2022	Dec 2022	Jan 2023	Feb 2023	Mar 2023	Apr 2023
Total Samples (Number/Month)	1,546	2,119	2,757	2,067	2,604	2,543
Median TAT (min)	81	58	47	46	69	71.5
Median TAT (min)	81	58	47	46	69	71.5

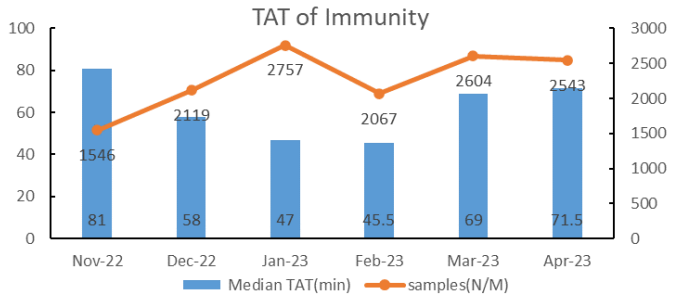

FIGURE 2. Trend of monthly median TAT of immunological samples (Nov. 2022–Apr. 2023).

The median TAT for biochemistry meets the "appropriate" requirement (< 115 min); the median TAT for immunology meets the "optimal" requirement (< 100 min). It is planned to improve the biochemical TAT, and based on the actual situation of the laboratory, taking into full consideration the increase in sample volume, the phased improvement target is set to reduce the median TAT for routine biochemical TAT to the average TAT median of the analysis group (< 84 min).

Personnel and Equipment are the Fundamental Reasons Affecting TAT

Referring to national quality management requirements, interview 20 members including laboratory members and manufacturer representatives. Review the factors affecting TAT, including personnel, equipment, management, and material. Invite participants to vote on the above factors, each selecting three items. Summarize and analyze the proportion of reasons. The data and analysis Pareto chart are shown in Table 4 and Figure 3.

TABLE 4. Reason analysis.

Categories	Entry	Quantity	Percent
Personnel	The laboratory member is limited, the sample number is large, and the result review time is lengthy.	16	26.7
	The personnel lacks a sense of timeliness, and the samples are not processed on the machine promptly.	12	20.0
Equipment	The automation level of equipment is insufficient, and the pre-treatment time is long.	16	26.7
	Instrument malfunction.	3	5.0
Material	Sample lost.	4	6.7
	The sample barcode is not clear.	2	3.3
Management	The process for handling abnormal sample results is complex.	1	1.7
	The process for handling critical values is complex.	5	8.3
Others	LIS malfunction.	1	1.7
All		**60**	**100**

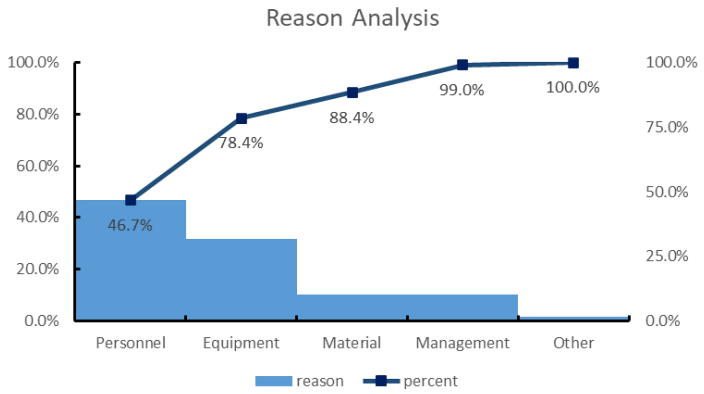

FIGURE 3. Reason analysis (Pareto principle).

According to the Pareto principle analysis, personnel and equipment are the main reasons for TAT in the laboratory. Specifically, the analysis shows: insufficient equipment automation level, long pre-processing time; personnel shortage, large sample volume, long result review time; lack of timeliness awareness among personnel, and samples not being processed promptly.

Formulate Improvement Plans

Improve the Automation Level of Equipment to Save the Quality Control Time of Pre-testing Processing

It is confirmed that the automation line meets the automatic quality control activation conditions. Prepare the necessary consumables and determine that each project will automatically start quality control testing at 6:00 AM and 4:00 PM daily. Train the responsible personnel to standardize the work content of the previous day, such as preparing reagents, instrument maintenance, project calibration, and quality control product archiving. Clearly state that the first task is to confirm that the quality control results have passed the next day, and then proceed directly to sample testing. Set the instrument parameters and conduct simulation experiments. After confirming that everything is correct, officially start.

Adjust the Automatic Review Rules to Increase the Approval Rate and Reduce the Pressure of Manual Reviews

Due to the number of department personnel cannot be increased quickly, an automated method was chosen to reduce the manual review of specimens. Data screening was conducted through the Remisol tools to analyze the specific reasons why the analysis projects did not pass the automatic review. Relevant department experts were invited to participate in discussions. Adding specialized logical rules and adjusting the review scope improved the automatic review pass rate. The sample validation confirmed a compliance rate of 100% before the official launch.

Organize Internal Departmental Training to Enhance Personnel's Attention and Reduce the Time Samples Spend on the Machine

At the departmental summary meeting, it was emphasized that the management of laboratory personnel should be standardized and gradually enhance their sense of work responsibility.

Improvement Effect Tracking

Sample Number and TAT Changes

The total volume of biochemical samples is rising, with the average sample volume for the analysis group being 34,906 units per month, and the average sample volume for the improvement group being 44,318 units per month, an increase of approximately 27.0%. The TAT has shown a fluctuating downward trend since May and meets the improvement targets. Data is shown in Table 5 and Figure 4.

TABLE 5. Monthly statistics of biochemical items (after improvement).

	May 2023	Jun 2023	Jul 2023	Aug 2023
Total Samples (Number/ Month)	43,647	42,643	43,943	47,037
Median TAT (min)	86	88.5	83.5	82

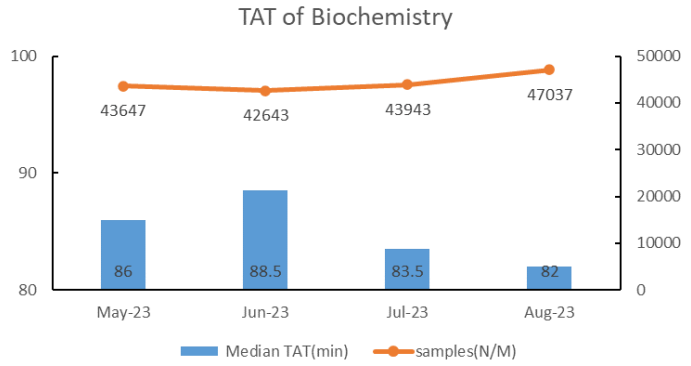

FIGURE 4. Trend of the monthly median turnaround time of biochemical samples (after improvement).

Select samples from March (before improvement) and August (after improvement), calculate the average TAT data for the time period for analysis. After improvement, the average decreased by 7 minutes compared to before improvement, with a statistically significant difference ($p < 0.01$). Data is shown in Figure 5.

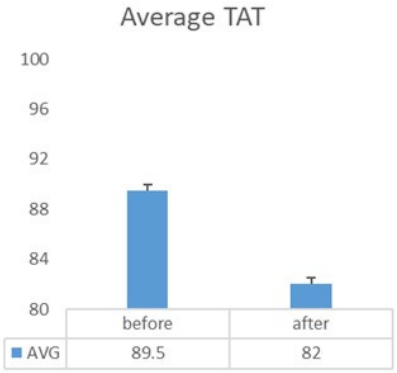

FIGURE 5. Comparison of median average TAT (turnaround time) (Control Group & Improvement Group).

Reduction in Pre-Processing Time for Biochemical Samples

Divide the overall TAT time into three segments, namely "Receive-to-Line", "Line-to-Machine", and "Machine-to-Upload". Through the analysis of pre-analytical processing using the Remisol tools, it was found that during the 7:00 AM–8:00 AM period, the "Reception-to-Line" time decreased from 24.5 minutes to 13.3 minutes, in a reduction of 45.7%, indicating that automatic quality control has a significant

effect on shortening the pre-processing time during the morning peak. During the 8:00 AM–1:00 PM period, the "Reception-to-Line" time decreased from 20 minutes to 10.8 minutes, in a reduction of approximately 46%, indicating a significant improvement in the timeliness of personnel operation. The results are shown in Figures 6 and 7.

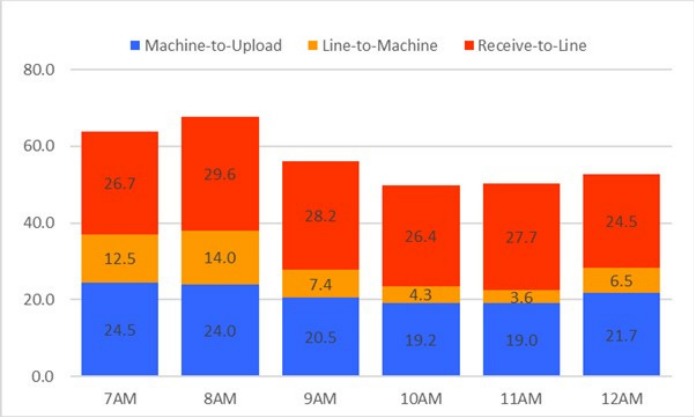

FIGURE 6. TAT data of biochemical sample segment (before improvement).

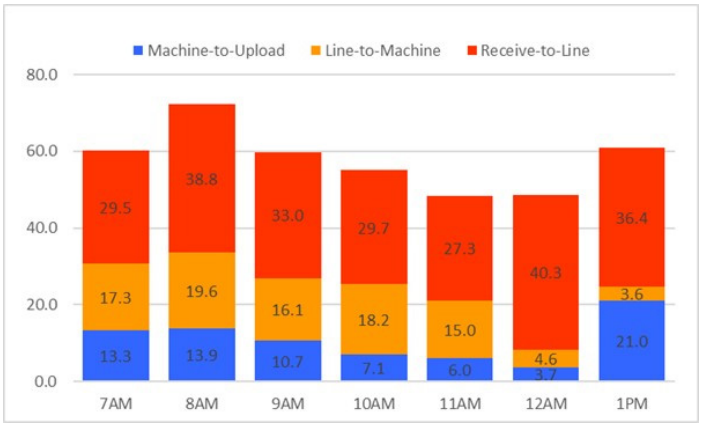

FIGURE 7. TAT data of biochemical sample segment (after improvement).

Note: The horizontal axis 7:00 AM represents the average time of all samples within the 7:00 AM–8:00 AM time interval.

Randomly select the average "Receive-to-Line" time over 30 days for two groups for comparative analysis. The average time decreased from 23.2 minutes to 11.9 minutes, showing a statistically significant difference ($p < 0.001$). The results are shown in Figure 8.

FIGURE 8. Comparison of the average "Receive-to-Line" (Control group & Improvement group).

Increase in Automatic Review Pass Rate for Biochemical Samples

Through data analysis, the average automatic review pass rate for biochemical samples increased from 48.55% in the control group to 61.03% in the improvement group, as shown in Figure 9.

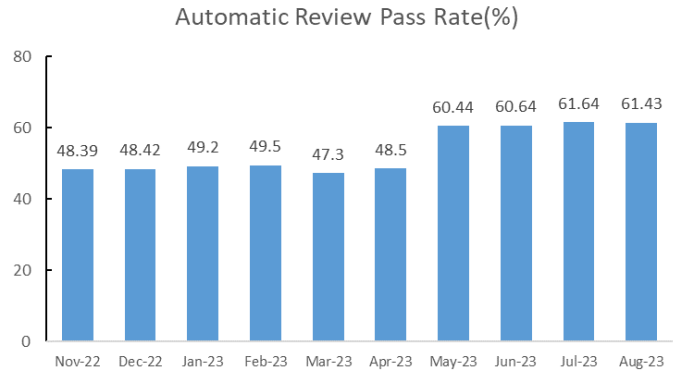

FIGURE 9. The automatic review pass rate of biochemical samples (Control group & Improvement group).

DISCUSSION AND CONCLUSION

The hospital's assembly line is connected to biochemical and immunological equipment, responsible for testing more than 90% of the laboratory's routine biochemical and immunological samples. Since its inception, it has focused on the efficiency of the assembly line and TAT. This study is based on the analysis of TAT based on the assembly line, noting the risk trend of fluctuating upward TAT for biochemical samples, and therefore decided to improve through PDCA tools. By initiating automatic quality control, the issue of prolonged waiting times for sample accumulation during peak hours was effectively solved, and the time of "Receive-to-Line" was reduced; by raising personnel awareness, samples were loaded onto the machine promptly after reception, simultaneously shortening the time of "Line-to-Machine"; by increasing the automatic review pass rate to reduce the pressure of manual review and improve review efficiency; the overall TAT returned to a better level despite the gradual increase in sample volume. The specific process is shown in Figure 10.

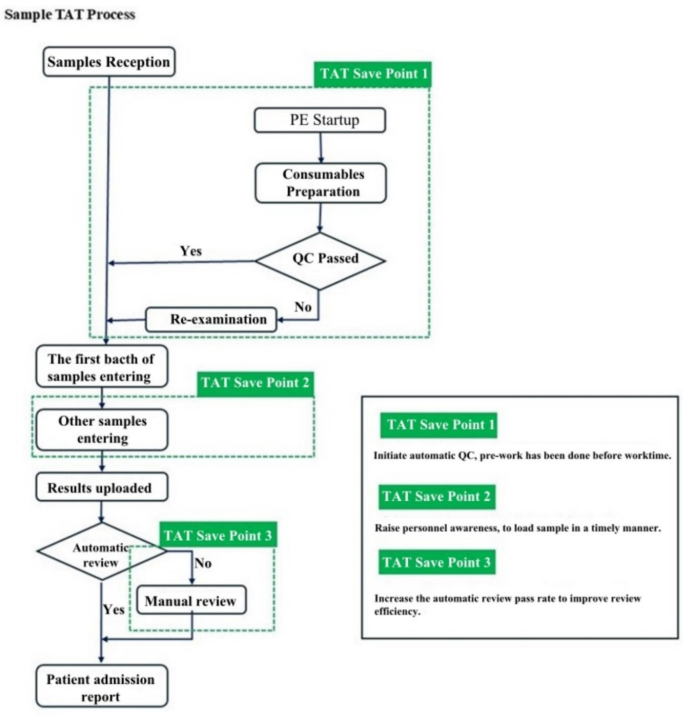

FIGURE 10. Sample of TAT process.

In 2009, the State Council began to promote the reform of public hospitals, gradually enhancing the requirements for refined management of public hospitals. In 2021, the General Office of the State Council issued the "Opinions on Promoting the High-Quality Development of Public Hospitals"[4], proposing that public hospitals should continuously improve the medical quality management system and standard system, and enhance the quality of medical services. As an important factor in measuring the management level of laboratories, the TAT of clinical laboratories is a crucial indicator affecting the quality of clinical laboratories.[5] In the ISO15189 laboratory accreditation requirement (2022)[6], the early warning role of "risk management" is mentioned multiple times and should be more widely applied in the management system of the laboratory department. The PDCA cycle is a quality management tool that helps to discover problems, find causes, and implement improvements.[7–9] In recent years, PDCA has been widely applied to managing various quality indicators in the laboratory department.[10–11] With the upward trend in the volume of samples in the laboratory department, the department needs to complete reports more efficiently and accurately, and optimize sample TAT times, to assist clinical departments in the dialectical treatment of patient conditions.

Data support is provided to improve TAT indicators through the comprehensive analysis of data information by the intelligent middleware system of the assembly line. A series of adjustments have improved the level of intelligence and efficiency of the laboratory. Therefore, strengthening data analysis is a prerequisite for improving various quality indicators in the laboratory. The laboratory can use various intelligent analysis software for regular monitoring and analysis of key quality indicators, explore the influencing factors of indicators, strengthen communication with clinical departments, determine the best improvement plans, gradually improve the quality and efficiency of laboratory work, provide efficient support for clinical departments, and provide high-quality services for patients.

AUTHOR CONTRIBUTIONS

Conceptualization, Z.Z. and J.J.; Methodology, C.Z.; Software, C.Z.; Hardware, C.Z.; Formal Analysis, F.L.; Investigation, L.Z.; Resources, L.Z.; Data Curation, L.Z.;

Writing–Original Draft Preparation, C.Z. and L.Z. and F.L.; Writing–Review & Editing, C.Z.; Visualization, L.Z.; Supervision, Z.Z.; Project Administration, J.J.

ACKNOWLEDGMENTS

We would like to thank Mr. Sun coming from Beckman Coulter for his technical assistance during the experiments.

FUNDING

This research received no external funding.

DATA AVAILABILITY STATEMENT

Not applicable.

CONFLICTS OF INTEREST

The authors declare they have no competing interests.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

CONSENT FOR PUBLICATION

Not applicable.

FURTHER DISCLOSURE

Not applicable.

REFERENCES

1. Lee, S., Yoon, S., Lee, W., et al. Strategies to shorten turnaround time in outpatient laboratory. *J Clin Lab Anal*. 2022; 36:e24665. https://doi.org/10.1002/jcla.24665.
2. Wang, Y.T. , Lu, X.Q., Peng, L.L.,et al.Analysis of the Effect of DRG Medical Insurance Payment on the Performance of Hospital Service in Hunan Province. Preprint. 2021. Available online: https://assets-eu.researchsquare.com/files/rs-428506/v1_covered.pdf?c=1631863465.
3. WS/T496-2017, Clinical Laboratory Quality Indicators. Beijing: National Health and Family Planning Commission of the People's Republic of China, 2017. Available online: http://www.nhc.gov.cn/fzs/s7852d/201702/a10a2009b9124c8a996d20d9cf70b7d5.shtml.
4. General Office of the State Council on promoting the high-quality development of public hospitals. Available online: https://www.gov.cn/xinwen/2021-06/04/content_5615551.htm.
5. Yang, Y.N., Liu, J., Hao, D.Y., et al. Correlation analysis between non-high-density lipoprotein cholesterol levels and coronary heart disease. *Chin J Arterioscler.* 2017;25(10):1031–1035. Available online: http://dmzzbjb.ijournals.cn/zgdmyhzz/article/pdf/20171011?st=article_issue.
6. ISO15189: Medical laboratories. Requirements for quality and competence (2022 edition). China National Accreditation Service for Conformity Assessment. Available online: https://www.cnas.org.cn/rkgf/sysrk/jbrkzz/art/2024/art_64e91231bd794eff9b9f37b7f3ac5cc2.html.
7. Gu, S., Zhang, A., Huo, G., et al. Application of PDCA cycle management for postgraduate medical students during the COVID-19 pandemic. *BMC Med Educ*. 2021,21(1):308. https://doi.org/10.1186/s12909-021-02740-6.
8. Joe, R., Min, X., Joanne, S. Application of the Toyota Production System Improves Core Laboratory Operations. *Am J Clin Pathol*. 2010;133(1):24–31. https://doi.org/10.1309/AJCPD1MSTIVZI0PZ.
9. Liu, C., Liu, Y., Tian, Y,et al. Application of the PDCA cycle for standardized nursing management in sepsis bundles. *BMC Anesthesiol*. 2022;22(1):1–8. https://doi.org/10.1186/s12871-022-01570-3.
10. Chen, H., Wang, P., Ji, Q. Analysis of the Application Effect of PDCA Cycle Management Combined With Risk Factor Management Nursing for Reducing Infection Rate in Operating Room. *Front Surg*. 2022;9:837014. https://doi.org/10.3389/fsurg.2022.837014.
11. Tseng, Y.W., Chen, C.C., Liao, Y.Y., et al. Optimizing Blood Culture Volumes by Implementing PDCA Cycle Management. *Clin Lab*. 2023;69(4). https://doi.org/10.7754/Clin.Lab.2022.220718.