

RESEARCH ARTICLE

Strategies to shorten turnaround time in outpatient laboratory

Seunghoo Lee  | Sangpil Yoon  | Woochang Lee  | Sail Chun  | Won-Ki Min 

Departments of Laboratory Medicine, University of Ulsan College of Medicine and Asan Medical Center, Seoul, South Korea

Correspondence

Won-Ki Min, Department of Laboratory Medicine, University of Ulsan, College of Medicine and Asan Medical Center, 88 Olympic-Ro 43-Gil, Songpa-gu, 05505, Seoul, South Korea.

Email: wkmin@amc.seoul.kr

Abstract

Background: Turnaround time (TAT) is one of the most important indicators of laboratory quality. For the outpatient routine chemistry tests whose results are checked by clinicians on the same day, we set a quality goal that >90% of these samples should be reported within 60min. As more than 20% of the samples failed to achieve this goal in 2020, we introduced an additional autoanalyzer and a real-time monitoring system to improve this rate.

Methods: As the TAT of the pre-analytical phase is the greatest contributor to TAT, we divided it into sampling, sample transport, and sample preparation times. An additional autoanalyzer was introduced, and its effect on TAT improvement was evaluated with the TAT data of June and July 2020. A real-time monitoring system was introduced to sort delayed samples, and its effect was assessed with the TAT data of June and July 2021. TAT data from December 2019 to January 2020 were set as baseline controls.

Results: The preparation time comprised the largest proportion of TAT. Although there was a slight decrease in overall TAT after the introduction of the above two strategies, the target TAT achievement rate increased significantly from 78.5% to 88.7% ($p < 0.001$).

Conclusions: We checked the cause of TAT prolongation and introduced new strategies to improve it. The addition of an autoanalyzer per se was not so effective but was better when combined with the real-time monitoring system. Such strategies would increase the quality of the laboratory services.

KEYWORDS

autoanalyzer, outpatient testing, priority, real-time monitoring, turnaround time

1 | INTRODUCTION

Turnaround time (TAT) is one of the most important indicators of laboratory performance.¹ The definition of TAT varies among different institutions and studies. Laboratories define TAT as the time from “sample reception” to “result reporting” in general, while the physicians define TAT as the time from “test ordering” to “result

reporting”.² We had previously set the starting point of TAT as the time just before phlebotomy.³

As the TAT is directly associated with the satisfaction of both patients and physicians, we have provided a “one-stop service (OSS)” for routine chemistry tests since 1998, which allows patients to visit their doctor with their test results on the same day of phlebotomy.⁴ To provide this service, we set a quality goal that more than 90% of

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OSS samples should be reported within 60 min from the sampling start time to the result reporting time.

Even though we have shortened TAT through various methods,^{3,4} the increasing number of tests every year has caused TAT prolongation, mostly the pre-analytical TAT. Because reducing pre-analytical TAT is very difficult,⁵ we further divided it into three substeps to assess the delaying effect of each step in the pre-analytical phase.

To process more samples at the same time, we installed an additional AU5800 (Beckman Coulter Inc.) autoanalyzer, expanding its maximum capacity. Despite the high throughput (2000 tests/h) of the AU5800 autoanalyzer, the TAT was not shortened as much as we expected. As more than half of the samples were collected early in the morning, the capacity was still insufficient during rush hour. Since there is a limit to increasing the capacity, we devised a real-time monitoring system to maximize the efficiency of each autoanalyzer. With this system, samples are sorted based on the elapsed time post-sampling, and the delayed samples are assigned to the autoanalyzer with the lowest workload.

The purpose of this study was to assess the effects of the introduction of an additional autoanalyzer and the real-time monitoring system on OSS TAT.

2 | MATERIALS AND METHODS

2.1 | Outpatient routine chemistry tests workflow before the implementation of TAT improvement processes

Phlebotomists called patients to draw blood. This time was recorded as the "sampling start time" in the laboratory information system (LIS). Blood was collected, and "sampling end time" was then recorded. Samples were then transferred to the laboratory through pneumatic tubes. Then, the sample sorter read the barcodes of the delivered samples and sorted the samples by laboratory divisions. This time was recorded as the "sample sorting time." To obtain serum or plasma, the samples were centrifuged for 10 min. The cap of the tube was removed manually by the laboratory personnel, and a visual inspection was done at the same time to check sample integrity. Decapped samples were then manually transferred to three AU5800 autoanalyzers. The autoanalyzers read the barcodes just before analysis, and this time was recorded as the "AU5800 scan time." Once the analysis was finished, the results were entered into the LIS; this time point was recorded as the "result entry time." The autoverification process, including a delta-check, a panic-check, and a critical value check, was implemented through LIS. If the autoverification was passed, results were reported automatically to the hospital information system (HIS). If not, the results were manually verified before being reported. The time point at which the results were reported to the HIS was recorded as the "result reporting time."

2.2 | New strategies for TAT improvement

In this study, the pre-analytical phase was further divided into sampling time (sampling start time–sampling end time), transport time (sampling end time–sample sorting time), and sample preparation time (sample sorting time–autoanalyzer scan time). The checkpoints in each phase are shown in a schematic diagram (Figure 1).

To reduce capacity overload, an additional AU5800 autoanalyzer was installed in the outpatient laboratory in March 2020. As this capacity expansion was not enough to solve the TAT prolongation issue, a new real-time monitoring system was introduced since September 2020.

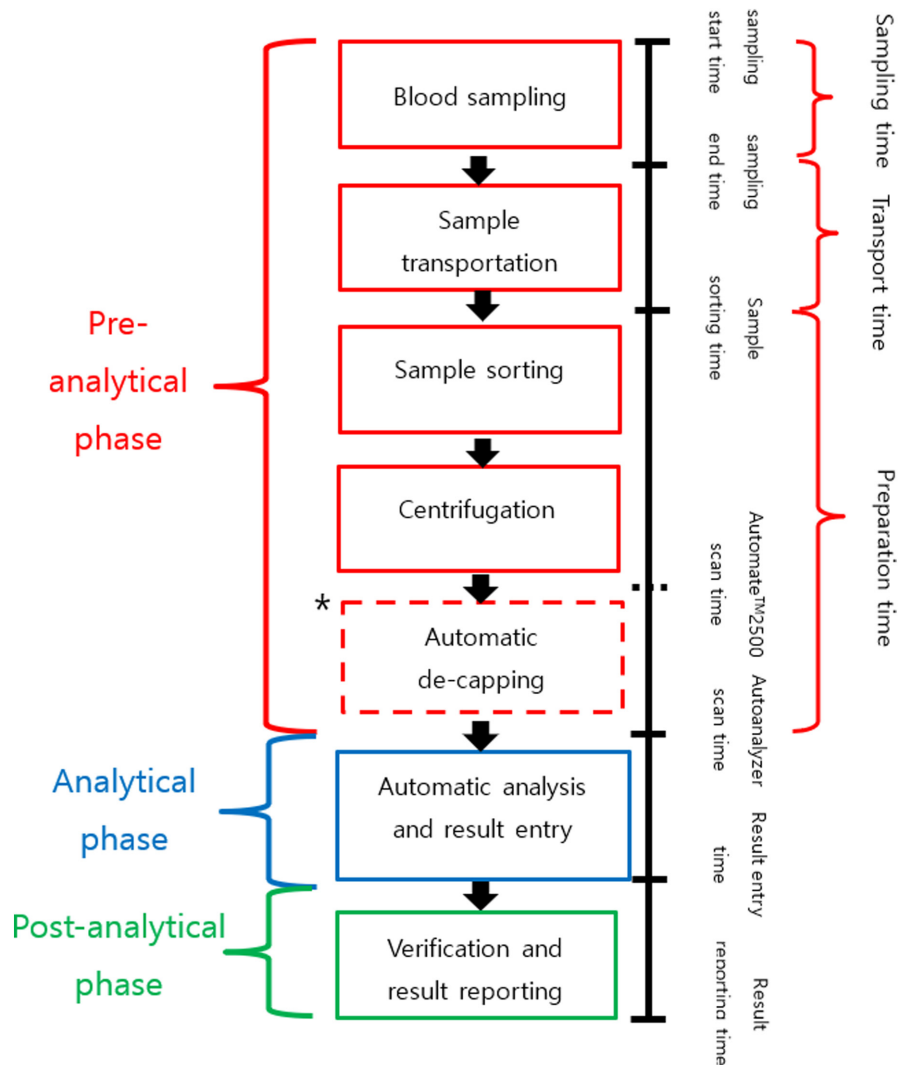
First, we introduced Automate™ 2500 (Beckman Coulter Inc.), which decaps and loads the samples onto the tray of the autoanalyzer. We installed a new sorting algorithm in this equipment. With this algorithm, Automate™ 2500 now classifies samples into groups in which the time interval between "sampling start time" and "Automate™ 2500 scan time" exceeds 45 min, is between 35 and 45 min, or is less than 35 min (Figure 2a). Second, we developed an AU5800 quota-monitoring software to equally distribute samples to the four AU5800s (Figure 2b). With this system, laboratory personnel do not need to decap samples anymore and can transfer the samples with higher priority to the AU5800 with the lowest workload. Since the samples are now decapped automatically, the integrity of the samples is not checked visually but is checked only by the autoanalyzers, using serum indices.

2.3 | Study sample inclusion and exclusion criteria

Among all samples received in the outpatient laboratory, only OSS samples collected between 8 AM and 5 PM were the subject of TAT shortening. We set OSS samples received in period 1 (December 2, 2019, to January 31, 2020) as the control group, period 2 (June 1 to July 31, 2020) as the "experimental group after the addition of one AU5800 analyzer," and period 3 (June 1 to July 31, 2021) as the "experimental group after the addition of both AU5800 and the real-time monitoring system." Since all checkpoints are automatically recorded in LIS and some steps are performed manually, TAT may be erroneously recorded due to computational or clerical errors. Therefore, the following samples were considered errors and excluded from this study: (a) samples with a sampling time of more than 30 min, (b) samples with a post-analytical phase of more than 30 min, (c) samples with a TAT of more than 2 h, and (d) retested samples.

Measurement items of AU5800 were as follows: total calcium, phosphorus, sodium, potassium, chloride, total carbon dioxide, magnesium, albumin, γ -GT, lipase, glucose, total cholesterol, total protein, AST, ALT, ALP, amylase, CK, LD, iron, total iron-binding capacity, TG, HDL, LDL, CRP, serum creatinine, uric acid, total bilirubin, direct bilirubin, and BUN.

FIGURE 1 Schematic diagram of workflow of routine chemistry laboratory for outpatients at author's institution. *Since September 2020, centrifuged samples underwent the process indicated by dotted lines.



2.4 | Statistical analysis

Microsoft Excel (Microsoft) was used for data organization. The means and SDs were calculated for each phase. To confirm the effectiveness of the two strategies, we divided the samples into those whose TAT from the sampling start time to the result reporting time is 60min or less and those that are not. A chi-square test was performed using PASW version 18.0 (SPSS Inc.) to determine the association between the new strategy and the target TAT achievement rate.

3 | RESULTS

In period 1, a total of 81,641 samples were the subject of TAT improvement, of which 64,129 (78.5%) samples fulfilled the target TAT of 60min or less. The mean value of TAT was 53.7 ± 9.3 min, and the TATs of the pre-analytical, analytical, and post-analytical phases were 33.6 ± 6.8 , 20.0 ± 6.2 , and 0.1 ± 0.8 min, respectively (Table 1).

In period 2, 87,146 samples were the subject of TAT improvement, of which 71,987 (82.6%) samples fulfilled the target TAT. The

mean value of TAT was 52.8 ± 8.3 min, and the TATs of the pre-analytical, analytical, and post-analytical phases were 34.2 ± 6.9 , 18.5 ± 4.4 , and 0.1 ± 0.9 min, respectively (Table 1).

In period 3, 75,844 samples were the subject of TAT improvement, of which 75,844 (88.8%) samples fulfilled the target TAT. The mean value of TAT was 50.9 ± 7.9 min, and the TATs of the pre-analytical, analytical, and post-analytical phases were 32.1 ± 6.5 , 18.7 ± 4.2 , and 0.1 ± 0.6 min, respectively (Table 1).

We found that the target TAT (60min or less) achievement rate had significantly improved (Table 1, $p < 0.001$) after the introduction of the two strategies.

4 | DISCUSSION

We have continuously shortened TAT through several processes of reorganizing the laboratory.^{3,4} In the 2004 study, OSS was introduced for frequently ordered laboratory items in outpatient clinics, and OSS samples were tested preferentially over other samples. As a result, 91.9% of OSS samples fulfilled the target TAT of 60min or less.⁵

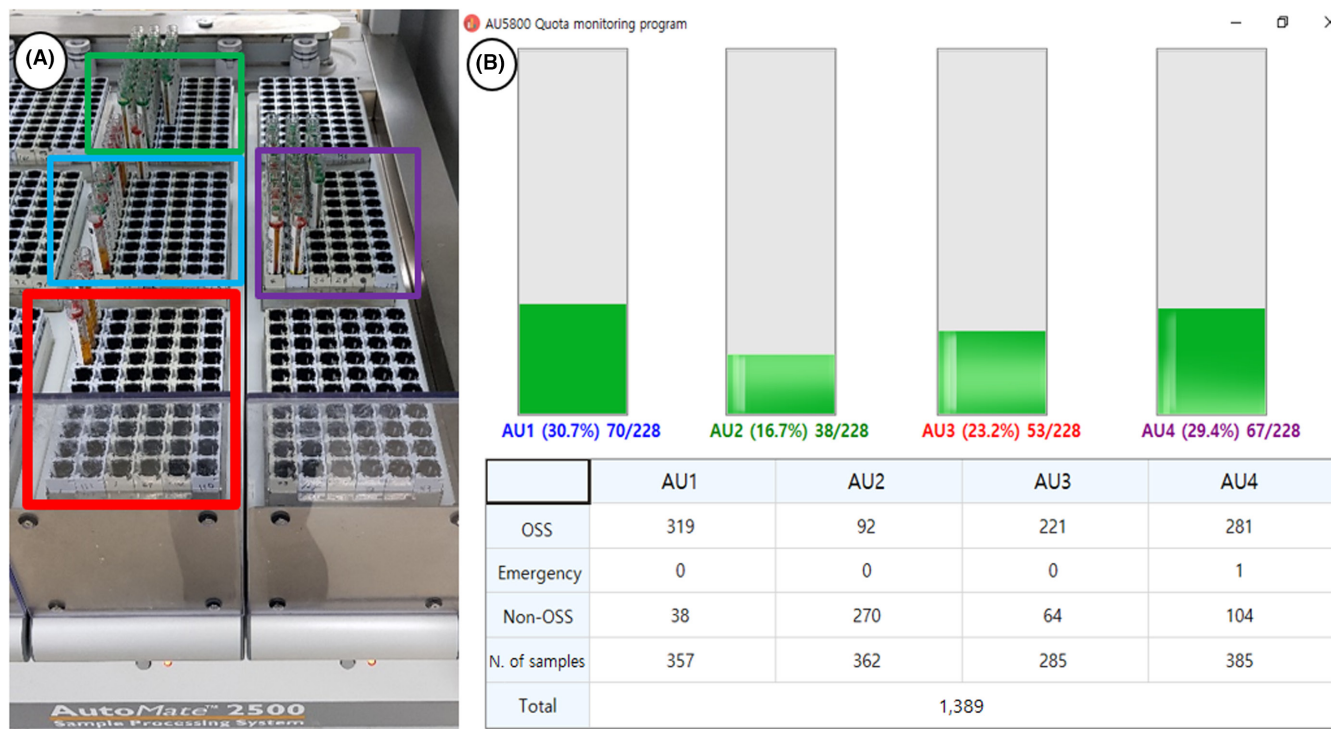


FIGURE 2 A real-time monitoring system. (A) Automate™ 2500 selectively sorts out samples of prolonged TAT. OSS samples with TAT more than 45 min are automatically placed on the red tray, those with TAT of 35 to 45 min on the blue tray, and those with TAT less than 35 min on the green tray. Non-OSS samples are placed on the purple tray. Therefore, the order of priority for analysis is as follows: red, blue, green, and purple. (B) Screen of AU5800 quota-monitoring program. Green bars represent the workload of each AU5800 autoanalyzer. Laboratory personnel transfer the tray with higher priority to the autoanalyzer with the lowest workload. Emergency row in the table designates the number of samples for which results must be reported as soon as possible. Non-OSS row designates the number of samples for which results do not need to be reported on the same day. OSS, one-stop service; TAT, turnaround time

TABLE 1 Turnaround time (TAT) of each phase and substeps, as well as the target TAT achievement rate

Phase	Period 1 (Dec 2nd, 2019–Jan 31st, 2020)	Period 2 (June 1st, 2020–July 31st, 2020)	Period 3 (June 1st, 2021–July 31st, 2021)
	Mean \pm standard deviation (min)		
Pre-analytical phase	33.6 \pm 6.8	34.2 \pm 6.9	32.1 \pm 6.5
Sampling	1.5 \pm 1.0	1.5 \pm 1.0	1.5 \pm 1.0
Transport	9.3 \pm 5.2	8.0 \pm 4.3	8.8 \pm 5.1
Preparation	22.8 \pm 4.5	24.7 \pm 5.4	21.7 \pm 4.6
Analytical phase	20.0 \pm 6.2	18.5 \pm 4.4	18.7 \pm 4.2
Post-analytical phase	0.1 \pm 0.8	0.1 \pm 0.9	0.1 \pm 0.6
Overall TAT	53.7 \pm 9.3	52.8 \pm 8.3	50.9 \pm 7.9
Sample no. (%)			
Total number of samples	81,641	87,146	75,844
Target TAT (60 min or less) achievement rate	64,129 (78.5%)	71,988 (82.6%)	67,312 (88.7%)
$\chi^2(P)$	2950.4 (<0.001 ^a)		

^a*p* values were obtained using the chi-square test.

In the 2009 study, we introduced a new LIS to divide TAT into three phases so that we could identify the phase in which delays in reporting occurred.⁴ At that time, 98.0% of OSS routine chemistry tests fulfilled the target TAT of 60 min or less.⁴ However, as the number of outpatients increased, only 78.5% of OSS routine

chemistry tests had TATs of 60 min or less under the same conditions in December 2019.

The daily average number of patients increased approximately 1.4 times from 8635 in 2007 to 11,885 in 2019 (data not shown). Because the resources and space of the laboratory are limited and

the TAT increase is directly related to patient dissatisfaction, we had to devise ways to increase the efficiency of laboratory operations.

In 1996, Valenstein reported that the main cause of increased TAT was in the pre-analytical phase,⁵ which was consistent with our results. In each study period, the pre-analytical phase accounted for 62.6%, 64.8%, and 63.1%, respectively. However, Prusa, et al. reported no or few changes in TAT despite several trials to shorten the pre-analytical phase of TAT.⁶ To identify the delayed steps in the pre-analytical phase, they subdivided the pre-analytical phase into “sampling–clot,” “clot–centrifugation,” and “centrifugation–instrument load” as they improved TAT by shortening the sample clotting time and centrifugation time. In that study, samples of 100 healthy individuals were tested, and the operator directly recorded the time of clot formation and centrifugation. However, this method could not be applied in our laboratory, because more than 2000 samples are analyzed every day. Instead, we subdivided the pre-analytical phase based on each checkpoint that is automatically recorded in LIS. We noted that the preparation time from sample sorter to autoanalyzer accounted for the largest proportion of TAT in all study periods, followed by the analytical phase. This suggests that these two steps should be the main targets of TAT improvement.

By simple calculation, an additional autoanalyzer would decrease the analytical phase of the TAT by 25%. However, it decreased by only 7.5% from 20.0 min in period 1 to 18.5 min in period 2. Further, we found that the distribution of the preparation time was wider than that of the other steps. The difference between the minimum and maximum preparation times in period 2 was ~60min (0.3–59.9 min, data not shown). This means that some samples enter the autoanalyzer as soon as the phlebotomy is done, while some samples remain idle outside the autoanalyzer. We noted that most outpatient samples are concentrated early in the morning. For 2 months in period 3, the total number of samples received in our institution was 16,000 from 8 AM to 9 AM and 2000 from 4 PM to 5 PM (data not shown). This is the reason why an additional autoanalyzer was less effective than expected, and there was a huge gap in the preparation time. To resolve this congestion, late samples should be processed first and the quota for each autoanalyzer should be equal. This is the reason why we devised the real-time monitoring system. With this system, samples are sorted based on the elapsed time post-sampling and distributed to the autoanalyzer based on the loading status of each instrument. As a result, the TAT of the preparation step decreased from 24.7 ± 5.4 min in period 2 to 21.7 ± 4.6 min in period 3, resulting in the target TAT achievement rate increment from 82.6% to 88.7%.

However, despite our efforts, we could not reach the 90% goal. We think that there is more room for improvement in the pre-analytical phase. In this study, the preparation time consists of (1) precentrifugation time, (2) centrifugation time, (3) sample decapping time, (4) sample loading time onto the autoanalyzers, and (5) standby time at the autoanalyzers. Given that the preparation time in period 3 was 21.7 ± 4.6 min, including 10 min of centrifugation time and 150s to decap 50 samples using Automate™ 2500, there was potential for improvement by shortening the preparation time to ~9 min. Considering that the real-time monitoring system was only

introduced in the interval between steps 3) and 4) mentioned above, it is possible to further shorten the TAT if the new system is expanded to the entire steps instead of to only the substeps. Anderson et al. successfully shortened total TAT dramatically by applying First-in-First-out (FIFO) workflow using both the Tempus600® pneumatic tube (Sarstedt) and the GLP Robot Reception System of Sysmex.⁷ As the samples are handled one by one in real time with this workflow, all samples are analyzed in a timely manner. Although this strategy was highly effective, that kind of system could not be applied to our laboratory because it requires a complete reorganization of the clinical laboratory. We tried to improve TAT with just minimal work process modification.

Even though our new system was effective for TAT shortening, the results of our study may not be applicable to all institutions, especially clinical laboratories not providing OSS. However, as OSS becomes more popular in Korea, our strategies could serve as a reference to other clinical laboratories.

In conclusion, an additional autoanalyzer was installed to reduce capacity overload, and a new system was introduced to sort out late samples and distribute samples equally. Both strategies were effective in shortening the preparation time and the TAT of the analytical phase, improving the target TAT achievement rate from 78.5% to 88.8%. If TAT is shortened effectively using such new strategies, patients and clinicians would be more satisfied with healthcare delivery.

AUTHOR CONTRIBUTIONS

Won-Ki Min involved in conceptualization. Sail Chun and Won-Ki Min involved in methodology. Seunghoo Lee and Sangpil Yoon involved in data curation. Seunghoo Lee involved in writing—original draft preparation. Woochang Lee involved in writing—review and editing. Woochang Lee, Sail Chun, and Won-Ki Min involved in supervision. All authors have accepted their responsibility for the entire content of this study and approved the submission.

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CONFLICT OF INTEREST

None declared.

DATA AVAILABILITY STATEMENT

The datasets that have been used and/or analyzed in this study are available from the corresponding author upon reasonable request.

ORCID

Seunghoo Lee  <https://orcid.org/0000-0002-3271-9306>

Sangpil Yoon  <https://orcid.org/0000-0002-9756-0295>

Woochang Lee  <https://orcid.org/0000-0003-3956-6397>

Sail Chun  <https://orcid.org/0000-0002-5792-973X>

Won-Ki Min  <https://orcid.org/0000-0002-5158-2130>

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