ORIGINAL ARTICLE

Improvement of Urgent Tests Laboratory Turnaround Time Through Laboratory Lean Management

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ABSTRACT

Introduction: Laboratory turnaround time (LTAT) is considered a reliable indicator of the quality and efficiency of a laboratory's service. LTAT achievement, particularly of urgent tests, remains unsatisfactory and challenging in many clinical laboratories especially in tertiary health care centres with high workload and restricted resources. The unresolved issue of unsatisfactory urgent renal profile (RP) LTAT below the standard performance goal prompted our interest to improve laboratory's handling of urgent test request. We thus implemented the Lean principle in the management of urgent test requests using urgent RP as the test model. **Methods:** The implementation of laboratory Lean involved 4 steps process; (1) Development of burning platform for change (2) Identification of waste (3) Planning and implementation of control measures (4) Measuring, monitoring, and sustaining the improvement. Urgent RP LTAT and the percentage of the request met the time requirement determined based on the data extracted from laboratory information system (LIS) before and after the implementation of Lean was compared to assess the effectiveness. **Results:** Urgent RP LTAT after the implementation of Lean was reduced i.e 35 min (before) vs 31 min (after), with the percentage of LTAT met the time requirement was significantly increased above the set target i.e 82.8% (before) to 93.5% (after) with P-value = 0.001. **Conclusion:** Implementation of innovation using Lean management has significantly improved urgent RP LTAT achievement, thus optimised urgent test management in our Chemical Pathology laboratory. Lean is a strongly recommended strategy to improve urgent test LTAT especially in laboratories with restricted resources.

Keywords: Laboratory turnaround time (LTAT), Urgent RP, Lean, Renal profile, Turnaround time

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INTRODUCTION

Urgent test is defined as the test of which the result is likely to influent clinical decision and management of a patient before the result would be routinely reported (1). It is considered as an important component in acute and critical care setting management such as in emergency department and operating room.

The increasing pressure from clinicians who need to deliver quick clinical management to the patients especially in acute and critical care settings has led to the requirement of providing a fast turnaround time test (TAT) results by clinical laboratory. Turnaround time is perceived by clinician as the time interval between their order of test until the result is received or also called as 'total testing cycle' time (2). It is often employed by many clinicians to benchmark the quality, efficiency and performance of a laboratory service (3) (4). Thereupon, dissatisfaction on test TAT by clinicians has become a major source of complaints to the laboratory's service. Consequently this led to consumption of much time and effort by the laboratory in order to resolve the complaint and improve the service (5).

There are many factors influence test TAT. About 75% of the total test TAT is contributed by pre- and post-analytical phases activities (3). Most of them are beyond the laboratory's control and authority. In view of the influence of the non-analytical variables on the TAT, most clinical laboratories determine TAT as the time interval from specimen receipt until the result is reported or referred to as laboratory TAT (LTAT) (6).

LTAT is often included in the laboratory's client charter and regarded as a laboratory quality indicator in alignment with ISO 15189 requirements (7). Indeed, LTAT of urgent

test has been recommended by international body as one of the key performance indicator (KPI) for Pathology service (8). The general benchmark is 90% of the urgent test to be completed within 60 minutes (5). However, the goal tends to vary between laboratories, depending on the defined tests, workload, instrument, work processes and management requirement. In Malaysia, as the most common urgent test requested is renal profile (RP), the timeliness of urgent RP LTAT was adopted as KPI for Chemical Pathology laboratory, which required that, at least 90% of urgent RP is released within 45 minutes.

Despite of using advanced analytical technology, transport systems and computerisation, LTAT of urgent test remains unsatisfactory in many laboratories (9) (10) (11) especially those with large volume of sample such as in tertiary hospital setting. The same problem was encountered in our Chemical Pathology laboratory. Our laboratory support 1198-bed hospital with a busy emergency and accident department, multiple intensive care units, numerus general and specialty wards and outpatient clinics. We received the highest workload among all other laboratories in Northern part of Malaysia i.e average of 2500 specimens per day, with 8000 to 10000 test analysis were performed daily. In the background of inadequate financial and human resource, limited physical space and unavailability of hospital information system (HIS), management of urgent request was apparently a challenging task. Assessment and monitoring of urgent test LTAT, particularly Renal Profile (RP) in our laboratory showed the achievement was below the standard set target.

The substandard achievement of urgent RP LTAT performance, demand from clinician and complaint from the laboratory's staff about their fatigue on chasing urgent tests have prompted our interest to improve the laboratory's TAT of urgent test. The improvement measure proposed was Lean management strategy.

Lean is a impelling tool in identifying and eliminating waste or non-value-added activities from the work process (12). This principle was first introduced and invented during the half of 20th century by the Toyota Motor Corporation (13). In 1990s, Lean has stepped far beyond the scope of manufacturing industry into the healthcare sector. Just recently, this principle also has been disseminated into medical laboratories as service improvement method, with few reports are available in the literature (14) (15) (12). To increase our understanding on the implementation of Lean and its key role in the improvement to the delivery of care, we explore the concept in our chemical pathology laboratory, highlighting on the management of urgent RP LTAT. The aim was to reduce urgent RP LTAT and increase the percentage of request meeting the time requirement in Chemical Pathology laboratory.

MATERIALS AND METHODS

This study involved determination and comparison of urgent RP LTAT before (baseline) and after (post-intervention) the implementation of Lean in Chemical Pathology Unit, Pathology Department Hospital Pulau Pinang.

Implementation of Lean

The Lean implementation in our laboratory was conducted within 2 months period from September to October 2015. The implementation was adapted from the method outlined by Coons et al (12). In our current study, the implementation was summarized into 4 steps;

1. Define the need for improvement
2. Analysis of waste
3. Planning and implementation of control measures for improvement
4. Measuring, monitoring, and sustaining the improvement

1. Define the need for improvement

Failure of the laboratory to achieve satisfactory urgent RP LTAT achievement not only affect the efficiency of patient's management especially in acute care setting, but it also is a signal of laboratory incapability to accommodate a good quality service to the customers. Based on the baseline urgent RP LTAT determined prior to commencement of Lean, improvement was apparently needed. Our aim of improvement was defined as to reduce urgent RP LTAT and to increase the percentage of request meeting the time requirement to more than 90%.

2. Analysis of waste

This process helped us to locate where was the target for improvement. Literally, waste is defined as anything that provide no added value (16). The process of waste analysis began by mapping out the current work process and activities involved in the management of urgent RP request. Wastes were identified through direct observation of all the work processes and interview with staffs (Table I). Any unnecessary and inappropriate process step or activity was considered as a waste. After waste identification, an ideal (future) work process lay out was created and served as the waste elimination planning guide.

Current processes lay out of urgent RP

Current work processes involved in the handling of urgent RP was laid out in Fig. 1. The work processes were sectioned into pre-analytical, analytical and post-analytical. There was no separate workflow for urgent test nor dedicated laboratory personnel assigned for daily monitoring of urgent test handling. All staffs in all sections were required to prioritize urgent specimen than the others.

Table I: Waste, control measures and Lean tool used during period of intervention

Unnecessary or inappropriate work process (waste)	Plans (control measures)	Type of Lean's tool used
a. Pre-analytical phase		
• Unnecessary request of urgent tests	• Revision of 'urgent test' list	Batch reduction
• Checking and sorting urgent request using 7 digits barcode	• Specimen triage using green form and orange barcode label	Visual control
• Registration and Test entry for urgent test by two MLTs	• Assign only one dedicated MLT for registration and test entry	Standardized work
• Demography of request	• Demography done by the same MLT who perform the registration and tests entry	Standardized work
• Marking the top of urgent specimen's tube cap with marker pen	• Dedicated bucket is used for urgent specimen	Standardized work
• Ensure bucket rack need to completely filled-up before proceeding to centrifugation	• Proceed centrifugation without need to wait the bucket is completely filled-up.	Flow
b. Post-analytical		
• Serial tracing of result in LIS by MLT for result verification using request form	• Use of a large LED monitor screen for real time result tracking	Kanban, visual control
• Science officer verify the result	• Result verified by MLT	Standardized work
• One common printer is used for result printing causing mixed of urgent and routine result	• Use of a dedicated printer for urgent RP result printing in the laboratory	5S, standardised work
•	• Placement of one network printer in the Emergency and Trauma Department	Flow, standardised work
• Use of white coloured A4 paper for all results	• Use of pink paper print-out for urgent RP for easier identification	Visual control

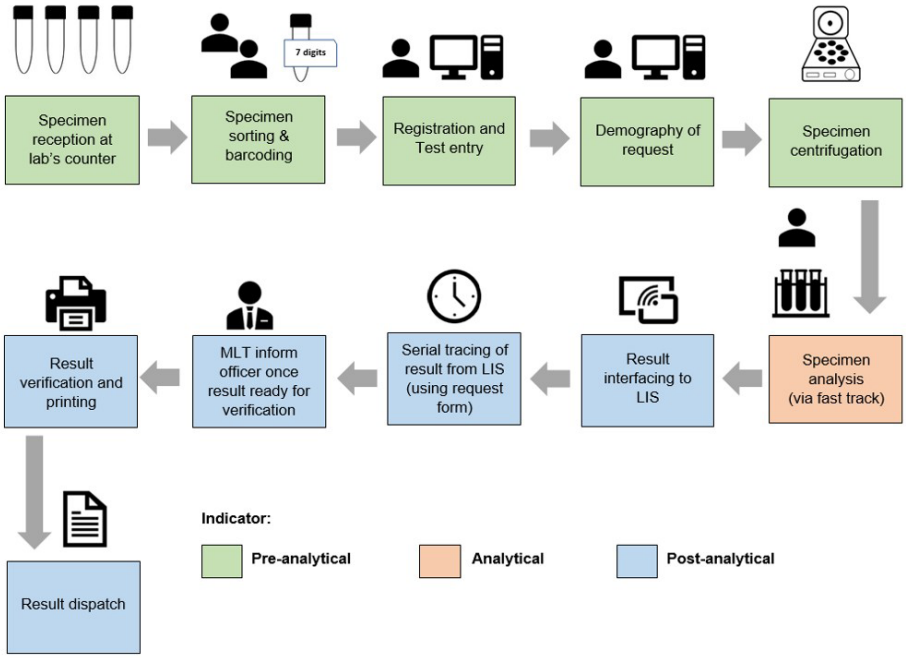

Figure 1: Current process lay out (Pre-intervention process map)

In pre-analytical section, the staffs usually identified the urgent specimen through poor visual cues i.e the "urgent" stamp on the request form and 7 digits white coloured barcode label on the specimen and the request form. Some of the urgent specimens were unnecessarily requested and labelled as urgent. This has consumed staff's time and effort to segregate between true and unnecessary urgent request for further intervention.

The urgent request form subsequently passed for test entry (and registration) and demography. These tasks were performed by 2 different medical laboratory technologists (MLTs) sitting at the pre-analytical section. The specimen will be marked with marker pen on the tube cap for easier recognition of urgent specimen. Centrifugation was proceeded only when the specimen rack full. Analysis of RP was performed on two integrated Roche Cobas 8000 (ISE and C702) with throughput capacity of 2000 test per hours for each. During analysis, STAT track was used, and the analysis time was approximately 10 minutes.

In post-analytical section, since the time elapsed for each test was unknown, a dedicated MLT sitting at the test entry workstation (in pre-analytical section) performed result tracing serially from LIS using the barcode on the request form to check the readiness of results. Once the results ready, the MLT informed science officer in charge to verify the results.

The ideal (future) Process lay out

An ideal process lay out was created with the input from all staffs and instrument vendors (Fig. 2). The ideal workflow process was shorten as compared to pre-intervention workflow process i.e. reduced from 11 to 8 steps. It was used as a guide in the planning of waste

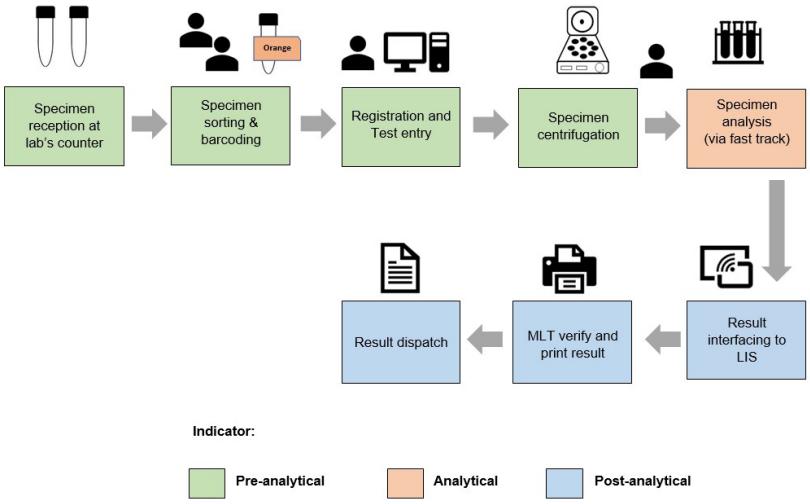

Figure 2: Future (ideal) work process map

elimination and implementation of control measure.

3. Planning and implementation of control measures for improvement

Specific plans or control measures for improvement were determined in each laboratory testing phase. The control measures were determined using selected Lean tools. The tools used include batch reduction, standardized work, flow and 5S. Kanban concept and visual control were also has incorporated into some of the work processes (Fig 3 and Table I). The implementation of the plan was completed within 2 months, from September until October 2015.

In pre-analytical section, considerable effort spent on searching for urgent specimen due to poor visual cues was eliminated with the implementation of specimen triage using visual control. Green coloured request form and orange barcode label were used to improve the urgent specimen identification and prioritization (Fig 3a). Anyone in the lab can easily distinguished the urgent RP request from other routine specimens thus, helped the urgent specimens to "leap-frog" others. Overuse of urgent requests may cause the truly urgent tests not managed as fast as necessary, hence delaying the LTAT of the true urgent tests (17). Large number of unnecessary urgent test request and burden related to its handling was eliminated through batch reduction tool. The existing urgent test list has been revised and after final discussion with clinicians, a new urgent test list has been established. Reducing the staff's burden of chasing for "unnecessary" urgent test has allowed them to focus only on the true urgent specimen. Lastly, staff's task in pre-analytical section, test entry, registration and demography activity of urgent test were condensed to only one staff to eliminate redundancy of work.

In post-analytical section, serial manual tracing of result readiness in LIS was also eliminated through incorporation of Kanban's system using visual signal. A large light-emitting diode (LED) monitor screen linked to the LIS mounted on the wall is used to display the 'flow' of urgent test request (Fig 3d). This system allowed real time tracking of sample processing according to the time elapsed. Each of the urgent test is highlighted in different graded colour according to time elapsed. To ease the staff, only 2 colours were used. Yellow colour indicates time intervals of more than 20 minutes after the specimen registration, and red if the time has elapsed for more than 30 minutes. This system allowed the tracking of the result be done in real time and effortlessly in one glance, hence enable each of the urgent RP was verified in time not exceeding the pre-determined LTAT. Revised workflow, which required that MLT to verify the urgent RP has helped to reduce waiting time for result verification by science officer. The science officer (STAT team leader) monitored the process through LIS which has been added with new configuration that separated urgent test into separate inbox (Fig 3b).

Considering that fast and timely result dispatch is the crucial parts in the management of urgent test, another innovation utilizing visual management concept was established in post-analytical section. A pink coloured A4 paper was used to eliminate the difficulty in searching for the report thus allowed easier identification and faster

Figure 3: (a) coloured form and barcode for urgent request (b) configuration of urgent RP profile in LIS (c) dedicated printer and use of coloured paper for printing of urgent test results (d) real time TAT monitoring of urgent test

reports dispatch (Fig 3c). To enhance the efficiency of the urgent result printing, a dedicated printer labelled with the words "for urgent result only" was used. A network printer also has been installed in emergency department since most of the urgent RP request came from there. This intervention has reduced the time for report delivery and eliminate the need of human resource for result dispatching.

4. Measurement and monitoring of the intervention's effectiveness

After the implementation of the control measures, the urgent RP LTAT and the percentage meeting the time requirement were determined (post-intervention). The improvement of Lean will be measured by comparing the baseline (pre-intervention) and post-intervention urgent RP LTAT achievement. The trend of achievement within 6 months after Lean i.e from November 2015 until April 2016 was displayed using histogram to inspect for sustainability.

Determination of urgent RP LTAT before and after Lean

Data for determination of urgent RP LTAT were obtained from laboratory information system (LIS). Baseline (pre-intervention) urgent RP LTAT was determined from 5 months data prior to implementation of Lean, from April to August 2015. While post-intervention RP LTAT was determined from 6 months data after the implementation of Lean i.e from November 2015 until April 2016. Monthly and the average urgent RP LTAT of baseline and post-intervention were calculated using Excel office 365, and the results were expressed in minutes. The monthly percentage of request met the time requirement before and after intervention were also determined as numbers of urgent RP result released within 45 minutes divided by the total number of urgent RP requested in a month x 100%.

Statistical analysis of data

The effectiveness of urgent RP management was measured by comparing the mean LTAT and the percentage mean of request meeting the time requirements during pre- and post-intervention using independent samples T-test. P value of <0.05 was considered as significant. The statistical analysis was performed using SPSS version 24.0.

Ethical clearance

Ethical approval was obtained from the Medical Research and Ethics Committee (MREC), Ministry of Health Malaysia.

RESULTS

Pre-intervention (baseline) urgent RP LTAT

Analysis of previous 5 months pre-intervention data showed that, the monthly average of urgent RP was 1384, which account about 1.5% of the total urgent test request. The mean LTAT was 34.5 minutes (Table II). The highest percentage meeting the time requirement was 86%, while the lowest was 81%, thus the discrepancy between the highest and the lowest was 5% (Fig. 4).

Table II: Urgent RP LTAT during pre- and post-intervention

	LTAT, mean (SD)*	% of request released within 45 minutes
Pre-intervention	35 (34)	82.8
Post- intervention	31 (38)	93.5
P-value**	P=0.001	P=0.001

*Mean (SD) in minute
**P-value < 0.05 is considered as significant

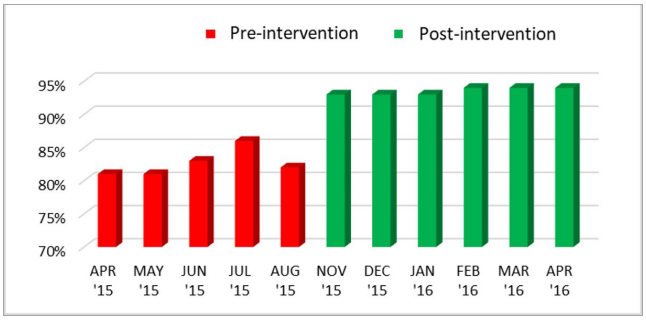

Figure 4: Monthly achievement of urgent RP LTAT during pre- and post-intervention (in percentage, %)

Post-intervention (baseline) urgent RP LTAT

During the 6 months post-intervention period, there was a monthly average of 1394 urgent RP requested, which account about 20% of all urgent request. The mean LTAT was 31 minutes (Table II). The highest percentage meeting the time requirement was 94%, while the lowest was 93%, thus discrepancy between the highest and the lowest was 1% (Fig. 4).

Effectiveness of Lean intervention

The number of urgent RP remained the same during pre- and post-intervention, however the number of total urgent test request reduced from 23% to 14.7%. The mean LTAT before and after the intervention was significantly reduced (P=0.001), and the mean percentage of request met the time requirement showed a significant incre4sed (p=0.001) (Table I). Monthly percentage of urgent RP LTAT met the time requirement is displayed in Fig. 4.

DISCUSSION

Retrospective data analysis of 5 months pre-intervention showed that our laboratory's baseline of urgent RP LTAT achievement was below the target set by the management. Monthly urgent RP LTAT met the time requirement was also inconsistent, as indicated by high fluctuation and wide discrepancy between the lowest and the highest percentage of urgent RP LTAT achievement (Fig. 4).

The issue of unsatisfactory urgent test LTAT has been addressed by many studies (3) (9) (17) (18). Various strategies to improve urgent test LTAT have been proposed and implemented in the literature, depending on the studies and laboratory settings. In this study, we demonstrated that Lean management with incorporation of Kanban using visual signals in the work processes has significantly improved urgent RP LTAT in our Chemical Pathology laboratory. This was evidenced by significantly shorter LTAT and increase of percentage of urgent RP achieved the time requirement within 6 months period post-intervention. The achievement was also more consistent, as indicated by a narrower discrepancy between the highest and the lowest percentage of achievement within the post-intervention period. The percentage of requests met the time requirement was noted to be constantly above set target during the observed period, which showed that the achievement is sustained over time.

Lean is defined as an organized and efficient approach to lessen the time interval between customer's request and delivery of service through identification and elimination of waste (12). In medical laboratory context, Lean is generally focus on the strategy to reduce the time interval between the order of the tests by clinician and delivery of laboratory results back to clinician. Table III lists out types of waste or non-value-added activities commonly identified in work processes. In our laboratory, among the identified waste was the large number of unnecessary urgent test requests, which was looked as the cause for extra processing or additional effort to the staffs. Repetition of task during test entry and demography was also recognised as a waste since the employee's ability and capacity was not fully utilized. Serial tracing of results by MLTs was another waste related to extra processing and increased waiting. All the identified wastes were eliminated using selected Lean tools such as incorporation of Kanban using batch reduction, visual signal, work process standardization and workflow modification. As a result, the number of process steps involved in the handling of urgent RP was reduced i.e from 11 to 8 steps, and this consequently shortened the urgent RP LTAT in our laboratory.

Table III: Eight types of waste in a work process

Type of waste		Explanation
1.	Defects	Work that contains errors, rework, mistakes, or lacks something necessary
2.	Overproduction	Making more, earlier, and/or faster than is required by the next process
3.	Waiting	Idle time created when material, information, people, or equipment are not ready
4.	Not utilizing employee's knowledge, skills, and abilities	The waste of not leveraging peoples' full talents and capabilities
5.	Transportation	Movement of patients and materials that adds no value
6.	Inventory	Any supply in excess of what is required
7.	Motion	Movement of people that does not add value to the product or service
8.	Extra Processing	Additional effort that adds no value to the product or service from the customers' viewpoint

Driving Lean improvements within our chemical laboratory was challenging initially, but with the use of suitable approach, tools, and support from staffs, top management and instrument vendors, it has resulted in significant improvements to our management or urgent test, and more importantly to our patient's care. During the implementation of Lean, the most difficult part encountered in our laboratory was to sustain the improvement. Any implementation of intervention strategy though it is minimal and simple, will require continuous monitoring and supervision as the key elements for sustained success. Convincing laboratory's staffs to adhere and maintain to the changes was the major effort and the most challenging task. Beside continuous education on the importance of Lean management to the staffs, appointment of STAT team which consisting of 3 MLTs in-charged in laboratory pre-analytical area and one science officer as team leader has ensured the urgent RP request handling in our laboratory continuously supervised and monitored. The appointment of the STAT team members was rotated on monthly basis. Periodic achievement of urgent RP LTAT was displayed on the notice board in the laboratory so that it will be noticeable by all laboratory staffs. Appreciation was addressed to the team for achievement above the performance goal. This has indirectly increased the motivation of subsequent team to adhere to the improvement as much as possible to ensure the urgent RP LTAT during their assigned period is achieved.

In the newly introduced health care system model, every patient is anticipated to have critical disease, therefore would require immediate intervention. In this situation, laboratories must treat every test as urgent, and this will abolish the distinction between routine and urgent sample handling process. To address this need, many laboratories are considering the installation of total laboratory automation system. The total laboratory automation is regards as the most appropriate tool which able to accommodate the growing demand of the crucial need and contribute to the improvement of patient's outcome (19). However, not all laboratories are financially affordable to acquire total or pre-analytical laboratory automation. In laboratories with financial constraint, implementing intervention using lean management principle was shown to be practical and more realistic. It was shown to be helpful in eliminating wasteful, unnecessary and inappropriate activities that contribute to the delay in urgent RP LTAT in our laboratory. Incorporation of Kanban and visual signal approach to the existing processes without need for additional automation system, human resource or major changes to the existing workflow has made the revised processes more convenience for implementation. It is

recommended that this strategy can be implemented in laboratories which plan to move to the new health care model with only one-pieces flow process but doesn't afford to install pre-analytical automation system or perform major changes to the existing laboratory's workflow.

CONCLUSION

Appropriate management of urgent tests is important to ensure the results can be produced in a timely manner, hence able to serve its intended purpose. The current state of the laboratory's unsatisfactory urgent RP LTAT achievement triggered improvement opportunities through a simple yet effective work process innovation. Implementation of Lean management with waste elimination and incorporation of control measure using Lean tools such as digital Kanban and visual signal has significantly improved urgent RP LTAT achievement, thus optimised urgent test management in our laboratory.

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