# Monitoring and improvement of intralaboratory turnaround time at the university hospital Campus Bio-Medico in Rome

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## ABSTRACT

The aim of the present study was to evaluate the intralaboratory turnaround time (TAT) of the emergency samples at the laboratory of the university hospital Campus Bio-Medico. TAT for urgent tests was recorded during 7 months after the introduction of a system allowing TAT monitoring in real-time, from January to July 2012. TAT analysis was performed through five consecutive phases. At the end of each phase, TAT was evaluated and a corrective strategy, if needed, was introduced. The TAT evaluation at the end of phase I (January-March 2012) showed that all urgent tests were in extra-time. From the phase II (April 2012) to the phase IV (June 2012), three different consecutive corrective strategies, related to preanalytical and analytical phases were implemented. Each corrective action determined TAT improvement. In the last phase of the study (July 2012), no further corrective strategies were added, but a pure observation activity was decided to give time to the laboratory staff to adapt to changes introduced before. The intralaboratory TAT can improve through the introduction of TAT monitoring systems, gradual and step-by-step changes in sample management and staff adhesion to and awareness of the project.

## INTRODUCTION

Timeliness is one of the pillars of efficient laboratory service and represents a standard by which clinicians and accreditation bodies judge laboratory performance. The turnaround time (TAT) is a measure of timeliness and is often used as a key indicator of the laboratory performance (1). Clinicians depend on fast TAT to achieve early diagnosis and treatment. Furthermore, faster TAT allows early patient discharge from emergency departments or hospital in-patient services and can represent a way for cost-cutting.

In 1989, the College of American Pathologists (CAP) promoted the Q-probes program designed to establish national benchmarks of laboratory service and to identify those practices associated with better performance worldwide (2-8). Later, the CAP proposed the Q-tracks program with the aim to monitor laboratory performance continuously over long periods of time (9, 10).

TAT can be divided into three phases: preanalytic, analytic and post-analytic. The first phase begins when an order for a test is done and finishes when a specimen is delivered to the laboratory. The analytic phase includes the time needed to produce a result. The post-analytic phase is the time from the end of the analysis to the report of results. TAT is defined as “therapeutic” TAT when it includes the time from test order to the beginning of a therapeutic intervention based on the test result (11).

Many laboratories restrict their definition of TAT to intralaboratory activities, because some factors included in the definition of the therapeutic TAT are out of their control and, for this reason, considered extra-laboratory (11, 12). Many factors can influence intralaboratory TAT and among them the non-analytical issues may represent up to 96% of total TAT (13).

The aim of the present study was to evaluate the intralaboratory TAT for our emergency samples after the introduction in the laboratory of a system allowing TAT control in real-time. By this way it was possible to evaluate the contribution of analytical vs. pre- and post-analytical phases within the intralaboratory specimen processing and to promote staff awareness of TAT goals.

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## MATERIAL AND METHODS

The university hospital Campus Bio-Medico is a tertiary care 250-bed hospital. It is equipped with an integrated informatics platform (MedArchiver ) to handle patient records and to order laboratory tests and other examinations. Through this system, a barcode is generated and the nursing staff can print a sticky label containing all information about patient, tests, kind of tubes, ward and date. Laboratory data are treated through a software package, MedLis (MedArchiver). MedLis and MedArchiver are interfaced together allowing clinicians for a real-time consultation of laboratory reports.

The ward samples are received by the laboratory staff dedicated to the preanalytical phase that, after screening for any preanalytical errors, delivers samples to the technical staff in charge of the analytical process. The preanalytical area of the laboratory is equipped with two modular Olympus OLA2500 (Beckmann Coulter) for preanalytical sample processing. One of this system automatically sorts tubes and recognizes samples that need to be centrifuged. After centrifugation, the second OLA2500 decaps, aliquots and sorts tubes to any analyzer sample rack. After this first phase, samples are delivered to the open space analytical area of the laboratory, where the technical staff is resident and samples can be loaded in the specific instrumentation that, after the barcode reading, query to the host information about the test ordered. The laboratory is equipped with two Olympus AU640 platforms (Beckmann Coulter) performing clinical chemistry tests, two Dimension Vista 1500 (Siemens Healthcare Diagnostics) for performing troponin I and creatine kinase MB (CK-MB) in addition to clinical chemistry tests, an automated coagulometer (ACL TOP 700, Instrumentation Laboratory) performing prothrombin time (PT) and activated partial thromboplastin time (aPTT), and two hematology automated analysers (Sysmex Xe-2100, Dasit) to perform blood cell counts. After analysis, data are visualized by the technical staff and, if adequate, validated and made ready for clinical evaluation. The laboratory medical staff, after appropriate matching of results with clinical data of patients, produces a final report that can be visualized in real-time by ward clinicians. No automatic validation is provided.

TAT was evaluated on the basis of a sample processing time divided into the following steps: the preanalytical, the analytical and the post-analytical phase. The pre-analytical phase is from the check-in of samples (T0 time when the sample is delivered to the laboratory and taken in charge by the laboratory staff) to the instrument query host. The analytical phase corresponds to the period during which the sample is loaded onto the instruments and the analyses are running. The post-analytical phase includes both the technical validation by the technical staff (after evaluation of test results based on the quality control acceptance) and the clinical validation by the medical staff that produce the definitive report of the requested test. The software MedLis allows to trace each phase and to measure its duration in min. Data are saved in a database and made available for any further analysis including statistical evaluations. The laboratory has been equipped with a real-time system for evaluation of TAT by its staff. The system consists of a 42-inch monitor hanging in the open space area, connected with MedLis to give real-time information about the status of the sample. On the monitor, a page named “Turnaround time” is constantly opened and all urgent samples here reported. Each sample is flagged by different colours depending on its status. The green colour is given when TAT is respected (i.e., time $\leq$ established TAT), yellow colour indicates that a time corresponding to established TAT-15% has been reached but a report is not yet available, and red colour points out that established TAT has not been fulfilled and the sample is in extra-time.

In the present study, TAT for urgent tests were observed during 7 months, starting from January 2012, when the real-time system for TAT monitoring was introduced, to July 2012. For all urgent tests, intralaboratory TAT was established to be within 45 min from the sample check-in to the clinical report production. TAT was measured consecutively for each urgent sample and data stored in the database were later elaborated and evaluated. The urgent tests included in the study and their relative amounts are reported in Table 1.

The analysis of intralaboratory TAT was subdivided into 5 different phases; at the end of each phase, TAT was evaluated and a corrective strategy, if appropriate, performed as follows:

- phase I (January to March 2012): this phase was pure observational, after the introduction of monitoring system, with the aim to evidence extra-time tests and implement strategy for intralaboratory TAT improvement;
- phase II: in April 2012, the first corrective strategy was implemented a) to sensitize laboratory staff awareness of TAT respect, b) to reduce the preanalytical phase time, the dedicated staff being sensitized to provide earlier deliver of samples to the technical staff;
- phase III: in May 2012, a second corrective action was applied a) to decrease time for sample loading in the instruments, avoiding tubes to lie in wait and loading instruments continuously, b) to rerun test only if necessary, that is when the result is clearly different from the preceding or it is in contrast with the clinical picture, c) to decrease time for technical validation as soon as a result is available from the instrument to MedLis.
- phase IV: in June 2012, a third corrective strategy was performed as follows: a) earlier instrument start-up in the morning; b) alert laboratory staff to distinguish between urgent samples that arrive during the day and routine samples. Urgent samples were collected in tubes with different colour caps. Furthermore, when a test was requested as “urgent”,

**Table 1**
*Tests included in the study*

| Test | Urgent test (n) | Percentage of total laboratory tests |
|---|---|---|
| Blood cell count | 4795 | 9.6% |
| P-Sodium | 3094 | 9.7% |
| P-Potassium | 3124 | 9.6% |
| P-Calcium | 1821 | 10.2% |
| P-Glucose | 475 | 2.1% |
| Prothrombin time | 1654 | 8.3% |
| Partial tromboplastin time | 1281 | 7.0% |
| P-Aspartate transaminase | 927 | 3.3% |
| P-Alanine transaminase | 931 | 3.2% |
| P-Urea | 2651 | 8.0% |
| P-Creatinine | 2860 | 7.9% |
| P-Total bilirubin | 991 | 4.6% |
| P-Troponin I | 871 | 20.9% |
| P-Creatine kinase isoenzyme MB | 864 | 21.0% |
| D-Dimer | 388 | 24.3% |

MedLis added the information of urgency to the test flagging it by a specific symbol that appears in each phase of the sample processing. In this way, urgent tubes followed a priority path in the laboratory work. Urgent samples were treated following the same procedure independently from the time of the day and each day of the year;

- phase V: in July 2012, no further action was decided, but a pure observation after the three applied corrective strategies was considered appropriate to give time to the laboratory staff to better understand and perform requested actions.

Laboratory TAT was calculated as the difference between the established TAT and the mean TAT observed for each test during the 5 phases of the study. Furthermore, preanalytical, analytical and post-analytical steps were also examined separately to determine the reasons for TAT variability.

The Wilcoxon rank sum test was used to test whether observed differences in TAT were statistically significant. Data were analyzed with the MedCalc 11.6.1.0 statistical package (Med-Calc Software). All probabilities were two-tailed and P values ≤0.05 were regarded as significant.

## RESULTS

Table 2 shows the average TAT in the 5 phases of the study. The TAT evaluation at the end of the phase I showed that all urgent tests but one (the blood cell count) did not respect the established TAT goal of ≤45 min. After the adoption of the first corrective strategy, during the phase II, PT and D-dimer fell into the established TAT while other tests were unchanged or even worsened. In the phase III (May 2012), a second corrective strategy was implemented and TAT of urea, creatinine and calcium tests fell into the established time, while other tests were improved but not yet into the limits. In the phase IV (June 2012), a third corrective strategy was carried out and TAT analysis showed that coagulation tests and blood cells count still fulfilled established TAT; however, important tests such as troponin I, CK-MB and potassium still remained outside the established TAT. Finally, in the phase V (July 2012) TAT for all tests was fulfilled (Table 2).

The distribution of intralaboratory TAT of three important emergency tests, i.e., troponin I, creatinine and potassium, along the different phases of the study, are reported in Figure 1.

Mean intralaboratory TAT was 51 min (95% confidence interval, 47-55) during phase I; 52.7 min (47.8-57.6) in phase II; 46.5 min (42.9-50.2) in phase III; 45.6 min (41.8-49.5) in phase IV and 40.2 min (37.6-42.9) in phase V. In Table 3 the percentile distribution of the intralaboratory TAT is reported for each phase of the study. The contribution of the preanalytical, analytical and post-analytical phases to TAT was also examined and the percentile distribution is reported in Table 4.

Statistical analysis showed that the difference between TAT registered in phase I vs. phase II was not significant. Differences in TAT begin to become significant in May (P=0.003) and remain significant till the end of the study (P <0.0001). In July 2012 no further corrective strategy was performed but, in spite of this, TAT showed a marked improvement so that all emergency tests fell into the established time. This trend was confirmed by a significant difference between TAT recorded in June and July (P=0.015).

## DISCUSSION

Laboratory TAT is an important indicator of laboratory performance and its improvement is pivotal for quality management as well as for patient safety. Data reported in the present study demonstrate that TAT respect was not achieved, despite the introduction of a TAT monitoring system in the laboratory, without the application of additional, step-by-step corrective strategies. Only at the end of the phase V of the study, the TAT goal was achieved for all tests requested in emergency conditions. In phases I, II and III the mean TAT were higher than 45 min and in the phase II TAT was unchanged or even worsened despite the applied corrective strategies. These actions probably need to be assimilated and understood by the entire staff to have real benefits. In the phase IV, the mean TAT was almost within 45 min, but the full respect was achieved only for some tests, while others remained in extra-time, despite the applied corrective strategies. It is possible that the corrective strategy introduced in the phase IV, changing another time the way of working, required the staff settling into the new rules and an additional adjustment. For this reason, at the end of phase IV no further strategy

**Table 2**
*Average intralaboratory turnaround time (TAT) for each emergency test during the study period. Reported data are in min*

| Test | TAT Jan-Mar | TAT April | TAT May | TAT June | TAT July |
|---|---|---|---|---|---|
| Blood cell count | 36 | 32 | 30 | 28 | 25 |
| P-Sodium | 53 | 51 | 58 | 47 | 40 |
| P-Potassium | 53 | 55 | 48 | 46 | 40 |
| P-Calcium | 48 | 57 | 40 | 48 | 45 |
| P-Glucose | 48 | 55 | 52 | 54 | 40 |
| Prothrombin time | 64 | 43 | 46 | 40 | 36 |
| Partial tromboplastin time | 63 | 53 | 47 | 42 | 37 |
| P-Aspartate transaminase | 48 | 59 | 46 | 48 | 43 |
| P-Alanine transaminase | 47 | 58 | 48 | 51 | 43 |
| P-Urea | 50 | 51 | 42 | 48 | 41 |
| P-Creatinine | 52 | 51 | 43 | 49 | 41 |
| P-Total bilirubin | 49 | 56 | 47 | 52 | 38 |
| P-Troponin I | 57 | 56 | 58 | 49 | 45 |
| P-Creatine kinase isoenzyme MB | 57 | 55 | 57 | 49 | 45 |
| D-Dimer | 50 | 32 | 42 | 28 | 35 |

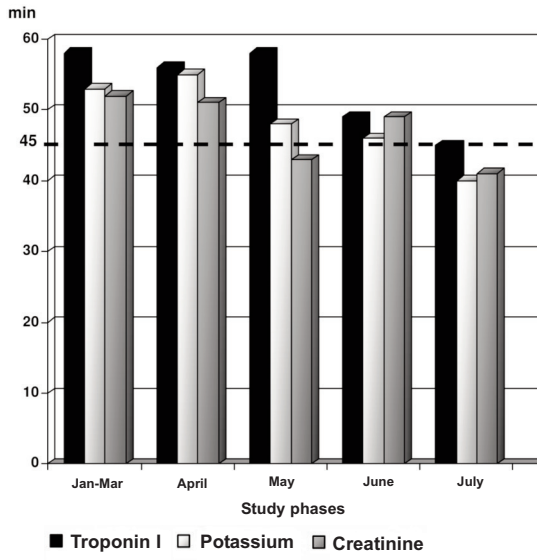


**Figure 1**
*Average intralaboratory turnaround time for troponin I, creatinine and potassium tests in different phases of the study. The dashed line indicates the goal for TAT.*

was decided with the aim to give to the laboratory staff time enough to adapt to the changes introduced before. This appears a successful key factor because at the end of the purely observational phase V the mean TAT was <45 min; furthermore, 95$^{th}$ percentile TAT value was within 45 min and the expected TAT was achieved for all tests requested in emergency.

TAT was also analyzed considering the contribution of the preanalytical, analytical and post-analytical phases. Data reported in Table 4 show that the most limiting steps for intralaboratory TAT are preanalytical and analytical phases. For this reason, the step-by-step corrective actions performed during the study were mainly related to these phases of the sample processing.

Other study have been performed to improve intralaboratory TAT. Howanitz, in his paper on errors in laboratory medicine, lists more than 20 causes (14). Within the laboratory, important steps to be considered are the sample centrifugation time, the selection of quality control rules able to minimize false rejection rates, the consolidation of analytical platforms and the optimization of the instrument interfacing (14). Our laboratory is equipped with the software package MedLis interfaced with an integrated informatics platform for laboratory data and reports management; these computerised systems can reduce both intralaboratory and extra-laboratory TAT (15). Despite this, our data showed that the informatics management of patient records is useful but not enough to assure the optimal TAT. To this aim, a process mapping to identify rate-limiting steps and to make simple improvements has to be considered and applied through step-by-step corrective actions. This approach allowed to determine which steps within the sample processing were limiting. In our setting, corrective actions were introduced first in the preanalytical phase (to provide earlier deliver of samples to the technical staff) and this strategy produced a decrease of intralaboratory TAT, but not their full respect. Afterwards, the analytical phase was improved through the decrease of the time for sample loading in the instruments, making rerun test only if necessary and decreasing time for technical validation. By this step-by-step approach, a gradual but significant improvement of TAT till its definitive respect was achieved.

**Table 3**
*Percentile distribution of the intralaboratory turnaround time (TAT) during the different phases of the study*

| | Percentile distribution, min | | | | | |
|---|---|---|---|---|---|---|
| | 10th | 25th | 50th | 75th | 90th | 95th |
| TAT Jan-Mar | 47 | 48 | 50 | 56 | 63 | 64 |
| TAT April | 43 | 51 | 55 | 56 | 58 | 59 |
| TAT May | 40 | 42 | 47 | 48 | 57 | 58 |
| TAT June | 40 | 46 | 48 | 49 | 52 | 53 |
| TAT July | 35 | 37 | 40 | 43 | 45 | 45 |

**Table 4**
*Percentile distribution of the preanalytical, analytical and post-analytical time period during the different phases of the study*

| | Percentile distribution, min | | | | | |
|---|---|---|---|---|---|---|
| | 10th | 25th | 50th | 75th | 90th | 95th |
| Preanalytical Jan-Mar | 24 | 24 | 25 | 27 | 30 | 30 |
| Analytical Jan-Mar | 14 | 16 | 18 | 22 | 28 | 29 |
| Post-analytical Jan-Mar | 6 | 6 | 8 | 9 | 9 | 10 |
| Preanalytical April | 16 | 20 | 23 | 25 | 26 | 28 |
| Analytical April | 15 | 20 | 25 | 29 | 30 | 30 |
| Post-analytical April | 5 | 5 | 6 | 6 | 8 | 8 |
| Preanalytical May | 15 | 17 | 21 | 22 | 23 | 23 |
| Analytical May | 14 | 15 | 19 | 21 | 35 | 35 |
| Post-analytical May | 6 | 6 | 7 | 7 | 8 | 9 |
| Preanalytical June | 15 | 15 | 20 | 21 | 21 | 23 |
| Analytical June | 18 | 20 | 21 | 24 | 29 | 29 |
| Post-analytical June | 5 | 6 | 7 | 7 | 8 | 9 |
| Preanalytical July | 14 | 15 | 15 | 18 | 19 | 20 |
| Analytical July | 13 | 14 | 15 | 21 | 23 | 23 |
| Post-analytical July | 6 | 6 | 7 | 8 | 8 | 9 |

In a recent study, laboratory TAT evaluation showed that pre- and post-analytical phases contributed ~75% of the total TAT and these phases need to be improved (16). In our experience, improvements can be introduced also in the analytical phase to reduce time of sample processing, when possible. Furthermore, our study highlighted some key factors influencing the intralaboratory TAT, such as the human contribution in corrective action application, laboratory staff adhesion, collaboration and awareness, which depend on the human availability to changing and not just on technical ability. Data from this study also suggest that when a change in the laboratory workflow is introduced, it should be better to give enough time to the staff to accustom to this change.

In conclusion, our study demonstrated that intralaboratory TAT can improve through the introduction of TAT monitoring systems, through gradual and step-by-step changes in samples management and through staff adhesion and awareness encouragement. Further steps to improve TAT and consequently laboratory performance should be the introduction of a full laboratory automation to ease sample management from check-in to result reports.

## CONFLICTS OF INTEREST

No authors declared any potential conflicts of interest.

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