Original Article

# Identifying Causes of Laboratory Turnaround Time Delay in the Emergency Department

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**Abstract**

**Background:** Laboratory turnaround time (TAT) is an important determinant of patient stay and quality of care. Our objective is to evaluate laboratory TAT in our emergency department (ED) and to generate a simple model for identifying the primary causes for delay.

**Methods:** We measured TATs of hemoglobin, potassium, and prothrombin time tests requested in the ED of a tertiary-care, metropolitan hospital during a consecutive one-week period. The time of different steps (physician order, nurse registration, blood-draw, specimen dispatch from the ED, specimen arrival at the laboratory, and result availability) in the test turnaround process were recorded and the intervals between these steps (order processing, specimen collection, ED waiting, transit, and within-laboratory time) and total TAT were calculated. Median TATs for hemoglobin and potassium were compared with those of the 1990 Q-Probes Study (25 min for hemoglobin and 36 min for potassium) and its recommended goals (45 min for 90% of tests). Intervals were compared according to the proportion of TAT they comprised.

**Results:** Median TATs (170 min for 132 hemoglobin tests, 225 min for 172 potassium tests, and 195.5 min for 128 prothrombin tests) were drastically longer than Q-Probes reported and recommended TATs. The longest intervals were ED waiting time and order processing.

**Conclusions:** Laboratory TAT varies among institutions, and data are sparse in developing countries. In our ED, actions to reduce ED waiting time and order processing are top priorities. We recommend utilization of this model by other institutions in settings with limited resources to identify their own priorities for reducing laboratory TAT.

**Keywords:** Health care quality assurance, hospital administration, hospital emergency service, hospital laboratories, length of stay

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## Introduction

The College of American Pathologists defines laboratory turnaround time (TAT) as "the period of time from test ordering to the time the results are made to the emergency department (ED).[1]" As one of the components of total patient length of stay in the ED,[2] reduction of laboratory TAT reduces ED stay,[3,4] improves ED efficiency,[5] and enhances patient safety and satisfaction.[6] On the other hand, laboratory tests have been reported as one of the causes of ED overcrowding.[7] The well-known 1990 Q-Probes Study[8] reported a median TAT (defined as the interval from blood-draw to reporting of results) of 25 min for hemoglobin and 36 min for serum potassium (these two tests had been selected as surrogates for hematology and biochemistry tests, respectively). The study suggested a median TAT (with the aforementioned definition) of 45 min for 90% of specimens as a reasonable goal for the majority of ED tests.

The strategy for reducing TAT toward a desired goal should be based on identifying the causes of delay in TAT and taking actions to eliminate them.[2,9] Nevertheless, since the resources for intervention are usually limited, it is wise to first address those steps with the greatest impact. The comparison of data from different settings worldwide may provide invaluable knowledge as to the potential causes of delay in laboratory TAT in different situations. We believe that, due to gaps in the level of technological sophistication and differences between administrative systems, models generated in one country for the assessment of TAT may not be applicable in another.

In this study, we present a simple model for identification of the causes of laboratory TAT delay that can be used in different settings and countries with different levels of resource availability. We have used this model to evaluate laboratory TAT for hemoglobin, serum potassium, and prothrombin time in a crowded tertiary care ED, and then attempted to identify those steps of the process that have the most significant role in prolonging TAT.

## Materials and Methods

In this cross-sectional study, we measured and analyzed TAT for hemoglobin, serum potassium, and prothrombin time using a modified, integrated adaptation of two previous models for studying laboratory TAT. One is the model used by Fernandes et al.,[9] which incorporated the interval between the physician's blood-draw order into the Q-Probes sequence and compared the medians with those of the Q-Probes. The other model, used by Sinreich and Marmor,[2] has a holistic approach to the entire process of patient turnaround from admission to discharge, part of which is laboratory investigation, and measures the impact of each step on the total length of stay.

The setting of our study was the ED of a tertiary-care university-affiliated teaching hospital with an annual census of more than 24000 admissions. We calculated TATs for hemoglobin and serum potassium, which were used in Q-Probes as surrogates for hema-

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tology and biochemistry investigations, respectively. In addition to the above tests, we included prothrombin time as another hematologic test that is commonly requested but not as frequently as hemoglobin. The laboratory instruments used for measuring hemoglobin, potassium, and prothrombin time were the Sysmex K-450 Hematology Analyzer (Sysmex Corp, Kobe, Japan) with a manufacturer-reported throughput of 80 specimens/h; the IL 943 Flame Photometer (Instrumentation Laboratory Co., Lexington, MA, USA) with a throughput of 90 specimens/h; and TECO Coatron M2 Coagulation Analyzer (TECO GmbH, Neufahrn, Germany) with a throughput of 70 specimens/hr. The manufacturer-reported throughputs exclude the time necessary for centrifuge of potassium specimens prior to biochemical analysis.[10–12] We performed this study over a consecutive one-week period in August of 2010, beginning at 06:00. The choice of this specific time of year was made by comparing patient flow rates in different months of the year from the hospital database, of which August appeared to approximate the average.

All tests for serum potassium, hemoglobin, and prothrombin time requested in our ED during the aforementioned period were studied. Incomplete tests (due to hemolysis, lost specimen, etc.) and those for which part or all of the data was missing were excluded. According to the ED rules of practice, all orders are stat by default.

Figure 1 depicts a flowchart of the different steps in the entire process, which includes six time points with five time intervals.

As comprehensive electronic records are not available in our hospital, the time of physician order is only manually written by the physician in patient charts. Thus we have retrospectively abstracted this information. The time of registration of the test by the nurse, specimen arrival at the laboratory, and the time of result availability are logged into the hospital computer network and therefore could be derived from that network. The time at which the specimen was ready and then dispatched from the ED were not routinely recorded. For these, a team of healthcare professionals (not employees of our institution) were hired and, after receiving appropriate training, were equipped with digital timers (synchronized every eight hours with the hospital computer system) to record the data in standard sheets at real time. This team worked in three, 8-hour shifts, beginning from 06:00 every day, to avoid coincidence with the healthcare personnel shift changes at 07:00 and 19:00. The physicians were also equipped with the same timers and charted their orders accordingly.

To avoid the Hawthorne effect, we used the strategy suggested by Campbell et al.[13]; i.e., we informed the personnel about the research nature of the operations in advance and requested them not to change their performance. Patient anonymity was secured+ through assigning numbers to patients. The collection of data did not impede or change the direction of patient management, and no risks were inflicted on the patients. The study was approved by the Ethics Committee of the Research Division of the Department of Emergency Medicine.

Statistical analysis was performed using SPSS version 13.0 (SPSS Corp., Chicago, IL). Collected data (time points) were typed into the computer by the authors and the time intervals calculated accordingly, in minutes. A problem encountered during analysis was that the times of physician order, test registration by nurse, and specimen availability did not consistently follow a linear order; e.g., in some cases, especially for more critical patients, the recorded time of registration by nurse or specimen availability was sooner than the physician order. In this case, we assumed that to save time, laboratory analyses were performed immediately following verbal orders, therefore the interval(s) were corrected to zero.

The total TAT for each test was calculated as the algebraic sum of all five time intervals. The Q-Probes Study discovered that TAT data have non-normal distribution and therefore reporting medians (instead of means) for central tendency and interquartile ranges (instead of standard deviations) for dispersion is more appropri-

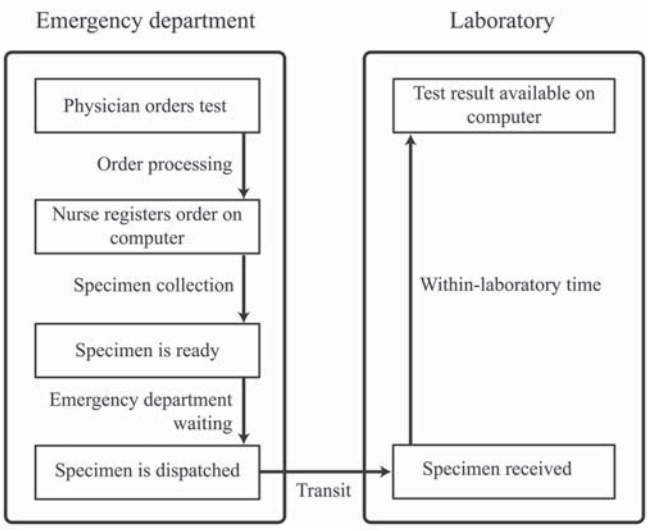


**Figure 1.** Flowchart of different steps in the laboratory turnaround process. Boxes denote time points, while arrows denote time intervals.

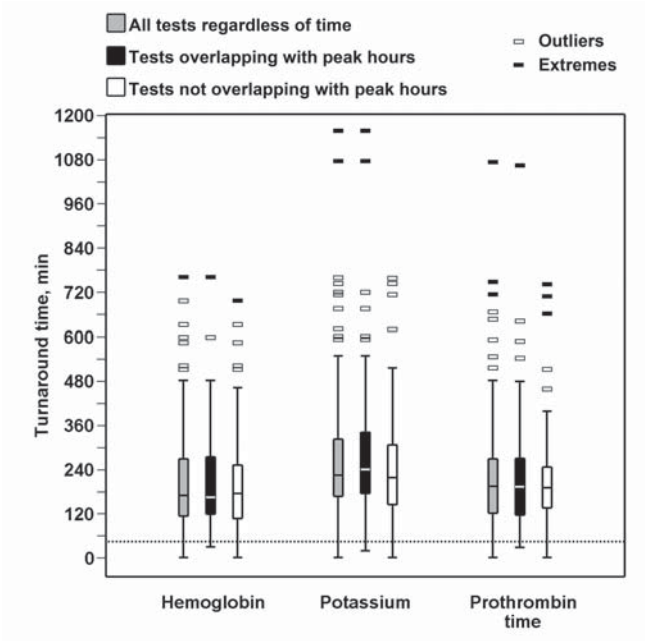


**Figure 2.** Box plots of turnaround times for different tests and different hours of the week. The dotted reference line represents the Q-Probes goal of 45 min. Key to colored boxes: grey, all tests; black, tests overlapping with peak hours; white, tests outside peak hours.

ate. The Q-Probes also recommended that institutional TATs be reported as the percentage of tests for which TATs are shorter than the Q-Probes goal (45 min). Along with reporting our TATs in the above format, we reconfirmed the presumption of non-Gaussian distribution for our data using a one-sample Kolmogorov-Smirnov test. We then performed a logarithmic transformation [ln (TAT – order processing time + 1)] to normalize data for both potassium and hemoglobin and to compare them with the same logarithmic transformation of Q-Probes medians (25 min for hemoglobin and 36 min for potassium) using a one-sample *t*-test. The order processing time was subtracted since it was not included in the 1990 Q-Probes. Since the 1990 Q-Probes did not collect data for prothrombin time, no such statistical comparison was possible for this test.

The impact of each interval on the total TAT was defined as the ratio of each time interval over total TAT (interval-to-TAT ratio). In this regard, a longer interval will have a larger ratio, which shows its greater impact on prolongation of TAT.

By reviewing patient flow rates from the hospital database, the period between 19:00 and 01:00 of the next day and the weekends (from 06:00 on Thursday to 06:00 on Saturday) were identified as peak hours, and separate analysis of tests with intervals overlapping with these periods were also performed.

## Results

Data for 551 tests were collected, of which 116 were excluded due to hemolysis (N = 14, potassium specimens), test cancellation (N = 61), lost specimens (N = 14), and incomplete data (N = 27). As seen in Figure 2, the TATs for hemoglobin (N = 132) had a median of 170 min (113–269.5), serum potassium (N = 172) had a median of 225 min (167.25–324.5), and prothrombin (N = 128) of 195.5 min (121.25–270.25). These data revealed that our medians were much higher than Q-Probes reported medians ($P < 0.001$ for both hemoglobin and potassium). The same drastic gap was noted for the percentage of tests that met the Q-Probes goal of 45 min (Figure 3).

The highest interval-to-TAT ratio belonged to ED waiting for hemoglobin and prothrombin and to the within-laboratory interval for potassium. On the other hand, specimen collection was the shortest interval and had the lowest interval-to-TAT ratio (Figure 4).

We found that slightly more than half of all tests (240 of 435, 55.17%) overlapped with peak hours. Median TAT and interval-to-TAT ratios did not change considerably in these hours compared to other periods, but the percentages of tests meeting the goal were considerably lower (Figures 2 and 3).

## Discussion

Our report shows high TATs (compared to Q-Probes goals) for our center at the time of the study. Intervals can be expressed in two ways: minutes (length of each interval) and interval-to-TAT ratios. The latter is better at explaining the impact of each interval on the total TAT compared to other intervals. This can be of benefit in identifying the intervals which should be addressed first if TAT is to be reduced.

As the within-laboratory interval depends on the laboratory instrument used and the inherent features of specimen processing, we did not compare this interval among different test types. For instance, the need to centrifuge potassium specimens prior to biochemical analysis causes the within-laboratory interval for this test to be longer than those of hemoglobin and prothrombin,[14] as was the case in our study. In contrast, using a newer automated complete blood counter with a higher throughput was probably the reason for shorter within-laboratory intervals for hemoglobin (Figure 4). With this interval ignored, the other intervals followed a similar pattern among the three test types.

The ED waiting time had the largest interval-to-TAT ratio and hence was the longest interval. This was probably due to the lack of a mechanical tube system for carrying specimens, which necessitated manual transport of specimens by personnel. Because dedicated technology or personnel for specimen transport were not available, each collected specimen was kept in the ED until an or-

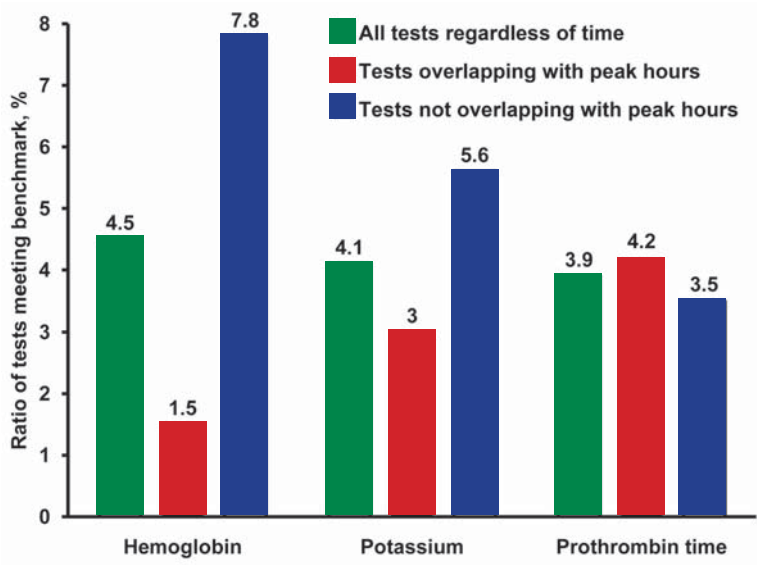


**Figure 3.** Percentage of tests meeting the Q-Probes benchmark of 45 min. Key to colored boxes: grey, all tests; black, tests overlapping with peak hours; white, tests outside peak hours.

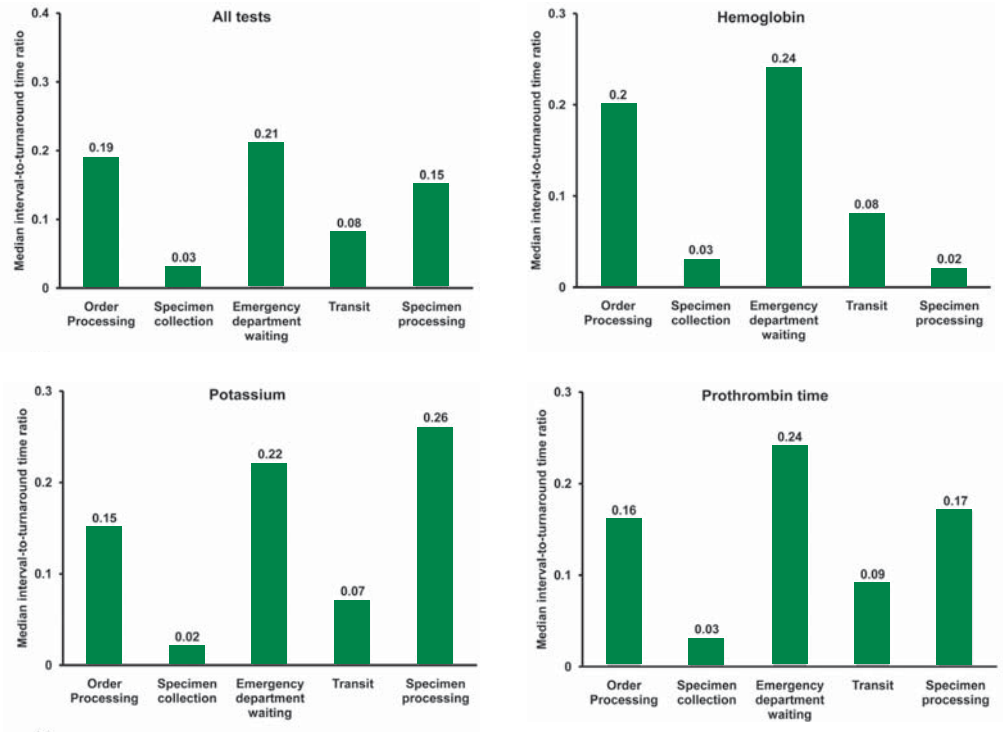


**Figure 4.** Interval-to-turnaround time ratios.

derly was able to carry the tubes to the lab. This conclusion was further supported by the 1993 Q-Probes finding, which showed that implementation of a mechanical tube system considerably reduced TAT compared to courier transport,[14] and by reports which showed that the presence of a point-of-care ED laboratory further decreased TAT.[4,15,16]

The second longest among out-of-laboratory intervals was order processing. Overcrowding is usually a challenge faced by our ED, with many patients lying on stretchers placed between licensed ED beds and in the corridors. This problem partly results from national regulations which forbid hospitals to halt admitting new patients, irrespective of the number of patients in the ED. We believe that this excessive burden may impede certain processes, such as order processing, which solely depend on the limited number of clinical ED staff. This may have contributed to the prolongation of the ED waiting interval. There are no electronic records that cover all the parts of patient care in our hospital, so nurses need to manually access patient charts to check physician orders and may be impeded by other personnel using the charts at the same time.

The specimen collection interval was the shortest interval (again with within-laboratory ignored). Fernandes et al.[9] believed that specimen collection by nurses was the reason for prolongation of this interval in their study, and suggested that assigning dedicated personnel for drawing blood would reduce this time. This conclusion was confirmed in our study, where dedicated personnel were hired for specimen collection and assisted by nurses at times of overcrowding.

The effect of overcrowding on total TAT can be seen when we look at the lower percentage of hemoglobin and potassium tests meeting the 45 min goal during peak hours.

There are several potential limitations to our study. The major limitation is that we did not measure the within-laboratory interval (including accession, queuing, and specimen processing intervals). Since revising laboratory procedures and upgrading laboratory equipment are subject to interdepartmental coordination and provision of adequate financial support, focusing on the out-of-laboratory aspects of TAT, which depend primarily on ED functioning, seems more productive. Future studies should focus on more detailed processing of different intervals.

We also had a relatively large number of excluded tests which was partly resulted from the absence of electronic records and necessitated manual recording of data by our team. Such data could have been attained readily and more precisely from electronic records. In this regard, we made every effort to train and organize our team in order for them to record as much data as possible, particularly in times of ED overcrowding. On the other hand, due to budget constraints we could not provide synchronized time stamps for our team so we had to manually synchronize all timers on a regular basis as accurately as possible.

The benchmarks we used for comparison dated back to 1990. However, to the best of our knowledge, no newer official benchmarks have been announced by the College of American Pathologists or other similar institution after the 1990 Q-Probes study, which is still being referred to in the current literature.[9]

Finally, as this study has been performed in a single institution as a pilot study in Iran, the external validity of its results is questionable. Conduction of similar studies in other centers will help to recognize differences between institutions, and larger nationwide studies will definitely provide more valid data that can be generalized to most institutions in the country.

Overall, the differences between our reported TATs and Q-Probes goals suggest that much needs to be done to improve TATs in our institution. Regional ED laboratory TAT data is sparse,[15] and to the best of our knowledge no similar study has been conducted in countries with limited resources. To improve ED TATs, we suggest that similar studies be performed on a national scale to determine achievable goals for each country and to design feasible improvement interventions. As for our institution, the introduction of a me-

chanical tube system, launching point-of-care laboratories in the ED, installing fully functional electronic records, and modification of ED throughput regulations or increasing the number of personnel are recommended.

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