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عنوان البحث

Assessing Factors Affecting Laboratory Turnaround Time (TAT) in Hospital Laboratories: A Descriptive Cross-Sectional Study

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## Introduction

Clinical laboratories are a cornerstone of today's healthcare systems. They support diagnosis, guide treatment choices, and help monitor disease progression across almost every medical specialty. A large share of clinical decisions rely on laboratory test results, and in acute areas such as emergency and critical care, having results **quickly and accurately** can be lifesaving.

One of the most widely used indicators of laboratory performance is **Turnaround Time (TAT)**. In simple terms, TAT is the period between a test being requested and the moment the confirmed result is available to the clinician. This interval reflects how well the whole testing process is functioning, across the **pre-analytical, analytical, and post-analytical** phases.

Over recent years, hospital care has become more complex: test menus have expanded, patient volumes have increased, and there is growing pressure to reduce the length of stay and improve flow. All of this places additional demands on laboratories to produce results both rapidly and reliably. When TAT is prolonged, clinicians may face uncertainty, treatment decisions can be delayed, and patients may remain longer in emergency or inpatient units. This can also lead to frustration among both patients and healthcare staff. In contrast, when TAT is well controlled, it helps streamline clinical workflows, reduce crowding in emergency and outpatient areas, and support more efficient use of hospital resources.

Despite major investments in **automation, laboratory information systems (LIS), and sample transport solutions**, many hospitals still struggle to consistently meet their TAT targets. Research has shown that delays may occur at any point in the testing pathway. The pre-analytical phase—including ordering, patient preparation, sample collection, labeling, and transport—is particularly prone to mistakes and inefficiencies. The analytical phase can be affected by instrument breakdowns, quality control failures, batch testing practices, and workload peaks. In the post-analytical phase, slow result review, LIS issues, and communication problems between the laboratory and clinical units can all add extra time.

Another important aspect is that TAT is not uniform. It can vary depending on the type of test, the clinical area requesting it, and even the time of day. For example, turnaround for urgent tests requested from the emergency department may differ from that of routine inpatient tests, depending on staffing patterns, triage rules, and how instruments are allocated. Studies in emergency departments have linked prolonged TAT for key tests—such as hemoglobin, electrolytes, and coagulation profiles—with longer ED stays and delays in clinical decisions.

To address these challenges, many laboratories have turned to **quality improvement approaches**, especially Lean and Six Sigma. These methods focus on mapping processes, removing waste, standardizing work, and reducing unnecessary variation. Evidence from multiple projects shows that when laboratories systematically examine what is causing delays and then design targeted interventions, they can substantially shorten TAT and improve overall efficiency.

However, the factors influencing TAT are not identical across institutions. Differences in infrastructure, staffing levels, test complexity, equipment, information systems, and clinical demand mean that each laboratory faces a unique combination of challenges. For this reason, **local, context-specific studies** are needed to clarify which structural and process-related factors are most important in each setting.

This research proposal describes a **descriptive cross-sectional study** that will examine the determinants of laboratory TAT in hospital laboratories, quantify the extent of delays, and identify priority areas for improvement. The ultimate goal is to generate practical, evidence-based recommendations to support better performance.

## Statement of the Problem

TAT is widely recognized as a critical quality indicator in laboratory medicine, yet many hospitals still struggle to provide results within the expected time frame. Complaints from clinicians about delayed laboratory reports are frequent, particularly in emergency departments where quick decisions are essential. Internal quality reports often show that agreed TAT targets are regularly missed for tests that are considered high priority.

The literature repeatedly suggests that a large share of TAT problems arise **outside** the analytical phase. Instead, they are often linked to pre-analytical and post-analytical steps. Factors such as poor communication, inconsistent sampling practices, delays in transporting specimens, lack of clear rules for prioritizing urgent tests, staffing shortages, analyzer downtime, manual result verification, and LIS disruptions can all contribute to extended turnaround times.

Even though these issues are broadly understood, many laboratories **do not have a systematic, data-driven analysis** of which factors matter most in their own environment. Data on performance may be collected but not deeply explored. Where analysis is performed, it often focuses on overall average TAT and does not break the process down into individual phases or look at root causes. Staff perspectives—on where bottlenecks occur, how work is distributed, and where communication fails—are also not always captured or incorporated into planning.

Without a comprehensive evaluation, it is difficult for laboratory managers and hospital leaders to design **targeted interventions**. Investments in additional automation, more staff, or changes in workflow may not be directed to the most influential problems. As a result, delays and complaints can persist despite significant effort and cost.

This study addresses this gap by conducting a structured, empirical assessment of the main factors influencing laboratory TAT in hospital laboratories. By doing so, it aims to support more effective quality improvement efforts and help ensure that laboratory results are available in a timely manner, particularly for conditions where rapid decisions are essential.

## Significance of the Study

This study is important on several levels: clinical, operational, managerial, and academic.

### Clinical Significance

Timely laboratory results are closely linked to **safe and effective patient care**. When TAT is short, clinicians can confirm diagnoses earlier, start or adjust treatment sooner, and avoid unnecessary delays in discharge or transfer. Shorter TAT has been associated with reduced length of stay in emergency departments and smoother patient flow throughout the hospital.

### Operational Significance

From an operational viewpoint, TAT reflects how efficiently internal laboratory processes are functioning. Identifying where delays occur makes it possible to streamline workflows, reduce rework, and lower stress on laboratory personnel. When TAT improves, coordination between the laboratory and clinical departments usually becomes easier, with fewer follow-up calls, fewer complaints, and less need to repeat urgent requests.

### Managerial and Strategic Significance

At the managerial level, this study will provide **evidence** to inform decisions about staffing, investment in automation, transport systems, and LIS upgrades. It will also support compliance with accreditation standards. Many national and international bodies—including ISO 15189 and the College of American Pathologists (CAP)—require that TAT be monitored, analyzed, and improved as part of a broader quality management program.

### Academic Significance

Academically, the study will add to the body of work on laboratory performance and quality improvement. By using frameworks such as **Lean management** and **Donabedian's structure–process–outcome model**, it offers a structured way of understanding how resources and processes influence TAT. The findings can be compared with those from other institutions and may serve as a basis for designing future intervention studies.

Ultimately, the results of this research have the potential to guide practical changes that improve TAT, enhance patient care, and strengthen laboratory quality systems.

## **Objectives of the Study**

### **General Objective**

To evaluate the factors that influence laboratory Turnaround Time (TAT) in hospital laboratories using a descriptive cross-sectional design.

### **Specific Objectives**

1. To describe the current TAT performance for selected laboratory tests in hospital laboratories using retrospective data.
2. To identify and classify the factors affecting TAT across the pre-analytical, analytical, and post-analytical phases.
3. To assess the relationship between staffing levels and TAT performance.
4. To examine how workload and sample volume impact TAT.
5. To explore the role of equipment performance and LIS-related issues in prolonging TAT.
6. To capture laboratory staff views regarding workflow bottlenecks and causes of delays.
7. To develop evidence-based recommendations to optimize TAT and improve laboratory efficiency.

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## Research Questions

1. What is the current TAT performance for selected laboratory tests in hospital laboratories?
2. Which factors in the pre-analytical, analytical, and post-analytical phases most strongly affect TAT?
3. How are staffing levels and the distribution of workload associated with TAT performance?
4. To what extent do equipment availability, instrument downtime, and LIS performance contribute to prolonged TAT?
5. From the perspective of laboratory staff, what are the main workflow bottlenecks and operational challenges affecting TAT?
6. Based on the findings, what practical strategies can be proposed to improve TAT?

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## Research Hypotheses

1. **H1:** Pre-analytical factors (such as delays in collection and transport of specimens) are significantly associated with prolonged TAT.
2. **H2:** Lower staffing levels and unfavorable staff-to-workload ratios are significantly associated with longer TAT.
3. **H3:** Higher sample volumes and workload peaks are significantly related to delayed TAT.
4. **H4:** Equipment downtime, maintenance problems, and LIS malfunctions significantly contribute to extended TAT.
5. **H5:** Laboratories with more standardized and streamlined workflow processes show shorter TAT compared with laboratories that have less structured processes.

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## **Literature Review**

### **1. Definition and Importance of Turnaround Time**

Turnaround Time (TAT) is one of the most frequently used indicators to assess laboratory performance. While definitions vary slightly between institutions, TAT generally refers to the time from a test being requested until the result is reported. Some laboratories measure from specimen receipt to result verification; others measure from collection to result availability. Regardless of definition, TAT reflects the responsiveness of the laboratory and is a major driver of clinician satisfaction (Steindel & Howanitz, 2001). TAT is especially critical in high-acuity settings such as emergency departments, intensive care units, and operating rooms: delays in receiving laboratory results can extend emergency department length of stay, postpone admissions or discharges, and in some cases contribute to poorer clinical outcomes (Fernandes et al., 2004).

### **2. Phases of the Total Testing Process**

The total testing process is commonly divided into three phases: pre-analytical, analytical, and post-analytical. Each phase comprises several steps and may influence TAT differently.

#### **2.1 Pre-Analytical Phase**

The pre-analytical phase covers all activities from test ordering until the sample is ready for analysis: order entry and verification, patient preparation and identification, sample collection and labeling, handling and transport of specimens to the laboratory, and reception/registration in the laboratory information system (LIS). Many studies show that the pre-analytical phase is the major source of laboratory errors and delays (Howanitz et al., 1992; Steindel & Howanitz, 2001). Sources of delay include incomplete or incorrect test orders, difficulties in venous access, mislabeling, lack of clear rules for urgent tests, manual transport of specimens over long distances, and batching of samples for collection or transport. In settings without pneumatic tube systems or dedicated couriers, samples may spend considerable time in transit especially during busy periods or night shifts (Fernandes et al., 1997).

#### **2.2 Analytical Phase**

The analytical phase is the actual testing of specimens using automated analyzers or manual methods. With modern automation, analytical times for many routine tests are relatively short and predictable. However, delays may still occur owing to instrument breakdowns or technical failures, quality control failures requiring repeat runs, inadequate maintenance or calibration, reagent shortages or use of expired reagents, and analyzer overload during peak workload periods (Inal et al., 2017). Lean Six Sigma laboratory improvement projects have demonstrated that better maintenance scheduling, improved instrument utilization, and more balanced distribution of tests across analyzers can reduce analytical-phase delays and contribute to overall TAT improvement.

### **2.3 Post-Analytical Phase**

The post-analytical phase includes activities after the test result is generated: technical and clinical review of results, authorization and release of reports, transmission of results via LIS or electronic health record, and communication of critical values to treating clinicians. Delays at this stage often stem from manual verification processes, lack of auto-verification rules, LIS downtime, printing or report-distribution problems, or unclear responsibilities for notifying clinical units about urgent or critical findings. Data entry errors or sending results to the wrong location may further contribute (Fernandes et al., 2004).

### **3. Factors Affecting TAT in Emergency and Inpatient Settings**

Multiple studies have focused specifically on TAT in emergency departments (EDs). Investigations using time-motion or root-cause approaches have shown that order-processing time, sample queue time at the analyzer, and transport time are major contributors to delays (Jalili et al., 2012). Other root-cause investigations identified laboratory assistant availability, specimen recollection rates, and number of patients awaiting beds as significant issues (Fernandes et al., 1997; 2004). High workload and ED overcrowding repeatedly surface as key issues: when staffing and infrastructure do not keep pace with demand, even well-designed processes may fail, leading to missed TAT targets. Beyond the ED, inpatient and outpatient services also show TAT variability associated with test priority (routine vs stat), staffing patterns, and dedicated instrumentation (Dawande et al., 2022).

Point-of-care testing (POCT) has been proposed to shorten TAT and thereby reduce ED stays by bringing testing closer to the patient; however, evidence is mixed, and POCT carries its own challenges (quality control, staff competency, integration with LIS) (Huq et al., 2020).

#### **4. Staffing, Workload, and Organisational Factors**

Staffing levels, skill mix and organisational culture are repeatedly identified as important determinants of TAT. Under-staffed laboratories — particularly during nights and weekends — often struggle to keep pace with incoming requests. Over-worked staff may deviate from ideal workflow practice, increasing the risk of errors and delays (Khalifa, 2019). Self-assessment studies across testing phases report that many pre-analytical incidents are linked to human and organisational factors: inadequate training, limited supervision, and poor adherence to standard operating procedures (Meena et al., 2019). Communication between the laboratory and clinical units also plays a role: clear guidelines to distinguish urgent from routine tests, agreed TAT targets for different test categories, and regular feedback loops help reduce confusion and limit unnecessary stat requests (Bhatt et al., 2019).

#### **5. Quality Improvement Approaches: Lean and Six Sigma**

In response to ongoing TAT challenges, many laboratories have adopted Lean and Six Sigma methodologies. Lean focuses on removing “waste” and improving flow; Six Sigma aims to reduce variation and defects. In one example, a Lean Six Sigma initiative reorganised laboratory workflows, removed non-value-adding steps and redesigned the specimen reception process; measurable TAT improvements were achieved (Inal et al., 2017). Common improvement initiatives include redesigning specimen reception and triage areas, implementing barcoding for better tracking, balancing workload across instruments, using auto-verification rules where appropriate, and standardising communication of critical results (Fernandes et al., 2004). These projects show that systematic analysis and structured change management can deliver meaningful TAT reductions.

#### **6. Conceptual and Theoretical Models**

Avedis Donabedian’s Structure–Process–Outcome (SPO) model is one of the most influential frameworks in healthcare quality. It proposes that quality results from the interplay of structure (resources, infrastructure, organisational characteristics), process (what is done) and outcome (the

results). Applied to laboratory TAT, structural factors include staffing, instrument capacity and LIS/EHR systems; process factors cover how samples move through the testing phases and how results are communicated; outcomes include TAT metrics, clinician satisfaction and potentially, patient outcomes (Donabedian, 1988). This study draws on the SPO model along with Lean concepts to guide the analysis of how structural and process elements interact to influence TAT.

## Theoretical Framework of the Study

The theoretical foundation of this study combines:

1. **Donabedian's Structure–Process–Outcome (SPO) Model**
2. **Lean Management Principles**

### Donabedian's SPO Model

In the context of laboratory services:

- **Structure** refers to the human resources (numbers and qualifications of staff), physical space, analyzers and equipment, LIS/EHR systems, and policies for ordering and prioritizing tests.
- **Process** covers all steps in the testing cycle:
  - *Pre-analytical*: ordering, sample collection, labeling, and transport;
  - *Analytical*: performing tests, running QC, and maintaining instruments;
  - *Post-analytical*: verifying, releasing, and communicating results.
- **Outcomes** include TAT measures, clinician satisfaction, rates of complaints about delays, and indirectly, patient outcomes such as time to treatment.

Using this model helps structure the analysis by linking specific structural factors and process features to TAT outcomes. It also highlights that improvements in structure (for example, staffing levels or LIS capabilities) and

process (for example, standardizing specimen transport) should translate into better turnaround performance.

### **Lean Management Principles**

Lean management is centered on **maximizing value and minimizing waste**. In a laboratory setting, waste can take many forms: unnecessary movement of samples, repeated handling, waiting time, manual steps that could be automated, or batching that causes avoidable delays.

Tools such as value stream mapping can be used to visualize the journey of a specimen from the moment it arrives in the lab to the release of the result. This makes it easier to pinpoint where time is being lost and which activities do not add value.

By combining Donabedian's model with Lean thinking, this study views TAT problems as the outcome of misalignment between structure and process. The analysis will therefore consider how staffing, equipment, LIS capacity, workflow design, communication patterns, and triage rules interact to shape TAT.

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## **Methodology and Research Methods**

### **Study Design**

The study will adopt a **descriptive cross-sectional design**, using both quantitative and descriptive data. It will assess TAT and its associated factors at a single point in time by analyzing retrospective laboratory data and administering a structured questionnaire to laboratory staff.

### **Study Setting**

The research will be conducted in hospital-based clinical laboratories that provide both routine and urgent testing in areas such as clinical chemistry, hematology, coagulation, and basic microbiology. These laboratories typically support emergency, inpatient, and outpatient services and operate around the clock.

## **Study Population**

The study will focus on:

1. **Laboratory tests and records** – selected routine and stat tests for which TAT is routinely monitored (e.g., CBC, electrolytes, coagulation tests).
2. **Laboratory staff** – medical technologists, technicians, supervisors, and quality officers involved in pre-analytical, analytical, or post-analytical activities.

## **Inclusion and Exclusion Criteria**

- **Inclusion (records):**
  - Tests performed during a defined study period (for example, three to six months).
  - Tests with complete electronic TAT data (documented time of order or collection and time of result release).
- **Exclusion (records):**
  - Tests that were canceled or rejected due to pre-analytical issues with no valid result produced.
  - Records missing key timestamps.
- **Inclusion (staff):**
  - Laboratory personnel with at least six months of experience in the current laboratory.
- **Exclusion (staff):**
  - Staff on short-term rotation or training who are not regularly involved in routine workflows.

## **Sample Size and Sampling Technique**

A sample of laboratory test records will be selected using **systematic or stratified sampling**, ensuring representation of different shifts (morning, evening, night), types of tests (routine versus stat), and clinical sources (emergency, inpatient, outpatient). The final sample size will depend on the total number of tests performed during the study period and available resources.

For the staff component, a **census** approach may be used if the laboratory team is relatively small. Otherwise, all eligible staff who consent to participate and meet the inclusion criteria will be invited (convenience sampling).

## **Data Sources and Variables**

### **1. Retrospective LIS Data**

- Variables will include: test type, ordering location (ED, inpatient, outpatient), timestamps (order, collection, receipt in the lab, verification, release), test priority (routine/stat), instrument used, and shift.
- Derived variables will include: total TAT and, where timestamps allow, phase-specific intervals (e.g., collection-to-receipt, receipt-to-verification, verification-to-release).

### **2. Structured Staff Questionnaire**

- Sections will cover:
  - Demographic information (role, years of experience, shift)
  - Perceived workload and adequacy of staffing
  - Perception of pre-analytical delays (e.g., issues with transport, labeling, ordering)
  - Perception of analytical delays (e.g., instrument capacity, maintenance, QC problems)

- Perception of post-analytical delays (e.g., verification steps, LIS performance)
- Suggestions for improving TAT.

### **3. Observation or Process Mapping (optional)**

- Qualitative assessment of workflow to highlight clear bottlenecks, waiting points, and instances of rework.

## **Data Collection Procedure**

### **1. Approvals and Ethics**

- Obtain authorization from hospital and laboratory leadership.
- Seek ethical approval from the appropriate institutional review board or ethics committee.

### **2. Extraction of LIS Data**

- Collaborate with IT/LIS staff to export anonymized TAT data for the defined study period.
- Check the extracted data for completeness and accuracy.

### **3. Questionnaire Administration**

- Distribute printed or electronic questionnaires to eligible laboratory staff during their shifts.
- Provide clear instructions and emphasize that responses are confidential and voluntary.
- Collect completed questionnaires within a specified time window.

### **4. Data Entry and Cleaning**

- Enter LIS and questionnaire data into statistical software such as SPSS or R.
- Perform data cleaning, checking for missing values, outliers, and inconsistencies.

## **Data Analysis**

### **Quantitative Analysis**

- **Descriptive statistics:**
  - Calculate mean and median TAT for different tests, locations, and priorities.
  - Describe frequencies and percentages for key variables such as shift, workload, and staff perceptions of bottlenecks.
- **Analytical statistics:**
  - Compare TAT across shifts, test types, and locations using suitable tests (e.g., t-tests, ANOVA, or non-parametric equivalents).
  - Explore relationships between TAT and factors such as workload (tests per hour), staffing levels, and instrument downtime using correlation or regression analyses, depending on data quality.

### **Qualitative / Descriptive Analysis**

- Summarize open-ended responses and staff suggestions.
- Identify common themes related to workflow problems, communication issues, and ideas for improvement.

### **Ethical Considerations**

- Patient identifiers will **not** be collected; all TAT data will be anonymized and used only for quality improvement and research.
- Participation of staff in the questionnaire will be entirely voluntary, and responses will be kept confidential.
- Data will be stored securely, with restricted access for the research team only.
- Study results will be reported in aggregate form, without identifying individual staff members or patients.

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## **Study Instruments**

### **1. Data Extraction Form / Template**

- Designed to capture key timestamps and variables from the LIS, including requested tests, location, order time, collection time, receipt time, verification time, and release time.
- May be implemented as a standard query or export format with the help of IT personnel.

### **2. Structured Questionnaire for Laboratory Staff**

- Consists mainly of closed-ended items using Likert scales to assess:
  - Perceived staffing adequacy (e.g., “There are enough staff on my shift to manage the workload.”)
  - Workload intensity
  - Frequency of pre-analytical issues (e.g., “Specimens from certain units often arrive late or incorrectly labeled.”)
  - Frequency of analytical problems (e.g., analyzer downtime, QC delays)
  - Frequency of post-analytical delays (e.g., verification or LIS issues).
- Includes open-ended questions to solicit detailed comments and improvement ideas.

### **3. Optional Observation Checklist / Workflow Map**

- Used by the researcher to observe and document:
  - The sequence of steps from specimen arrival to result release
  - Waiting times between steps

- Any rework, backtracking, or manual transfers
- Physical constraints within the laboratory layout.

Together, these instruments are intended to provide a **comprehensive picture** of TAT: objective data, staff perspectives, and direct observations of how work actually flows.

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## Study Limitations

### 1. Retrospective Data Constraints

The study relies on existing LIS data, which may not capture every relevant detail. Missing or inaccurate timestamps can affect the precision of calculated TAT values.

### 2. Single-Setting and Generalizability

The findings may reflect the specific organizational structure, processes, and patient population of the hospital laboratories included in the study and may not be directly generalizable to all other settings.

### 3. Self-Reported Staff Perceptions

Questionnaire responses are based on staff perceptions and may be influenced by recall bias, personal experiences, or concerns about how their answers might be interpreted.

### 4. Cross-Sectional Design

Because the study takes a snapshot at a particular point in time, it cannot fully capture seasonal changes, long-term trends, or the impact of future interventions.

### 5. Unmeasured Confounding Factors

Some relevant influences—such as clinicians' test-ordering behavior or external policy changes—may not be fully captured in the available data.

Despite these limitations, the study is expected to provide **valuable insights** into the main determinants of TAT and to offer a strong foundation for future quality improvement activities.

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