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# Evaluation of Turnaround Time Performance in Hospital Laboratories in Riyadh: A Cross-Sectional Multi-Center Stud

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**ABSTRACT**

Background: Turnaround time (TAT) is a critical quality indicator in clinical laboratory medicine. Prolonged TAT can adversely affect patient outcomes, clinical decision-making, and hospital efficiency. Despite increasing automation and informatics integration in Saudi hospitals, systematic benchmarking data specific to Riyadh remain limited.

Objectives: To evaluate and compare laboratory TAT performance across government, private, and military hospitals in Riyadh; to identify the main phases and root causes of delay; and to propose evidence-based improvement strategies.

Methods: A cross-sectional, multi-center study was conducted across eight hospitals in Riyadh from January to December 2023. A total of 42,750 laboratory requests were analyzed across hematology, clinical chemistry, coagulation, microbiology, immunoassay, and point-of-care testing sections. TAT was measured from specimen collection (order time) to result reporting. Data were extracted from laboratory information systems (LIS) and electronic medical records (EMR). Statistical analysis included descriptive statistics, Kruskal-Wallis and Mann-Whitney U tests, and Pareto analysis of delay causes.

Results: The overall median TAT across all centers was 54 minutes (IQR: 38–82 min). Tertiary government hospitals achieved the shortest median TAT (47 min), significantly lower than secondary government facilities (68 min; p=0.008). Pre-analytical phase delays accounted for 60.5% of total TAT deviations, with specimen recollection being the single most frequent root cause (38.4%). Point-of-care testing consistently met benchmark TATs, while microbiology cultures and chemistry reflexive panels showed the highest rates of target non-compliance (18.3% and 14.7% respectively). Hospitals with integrated LIS-EMR systems demonstrated a 22% reduction in post-analytical delays compared to non-integrated facilities.

Conclusion: TAT performance in Riyadh hospital laboratories is generally satisfactory in tertiary centers but significantly suboptimal in secondary facilities. Pre-analytical process improvement,

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pneumatic transport systems, and full LIS-EMR integration represent the highest-priority interventions to close the performance gap.

**Keywords**: turnaround time; laboratory quality; pre-analytical phase; clinical laboratory; Saudi Arabia; Riyadh; laboratory information system

## 1. Introduction

In modern clinical medicine, the clinical laboratory functions as an essential pillar of the diagnostic pathway. Approximately 60–70% of all clinical decisions rely directly or indirectly on laboratory results, making the timeliness of these results paramount to effective patient management. Turnaround time (TAT) — commonly defined as the elapsed interval from specimen collection or order placement to the reporting of verified results — has emerged as one of the most widely monitored quality indicators in laboratory medicine globally.

Extended TAT affects patient outcomes through multiple pathways. In acute care settings, delayed troponin or arterial blood gas results can postpone life-saving interventions. In emergency departments, prolonged TAT for complete blood count and basic metabolic panels has been directly associated with increased length of stay, patient dissatisfaction, and adverse events. In elective outpatient contexts, delayed culture and sensitivity reports can lead to inappropriate empirical antibiotic prescribing, contributing to antimicrobial resistance.

The Kingdom of Saudi Arabia has witnessed substantial investment in its healthcare infrastructure in recent decades, culminating in the Vision 2030 health sector transformation agenda. Riyadh, as the capital and most populous city, hosts a diverse ecosystem of healthcare institutions ranging from large tertiary academic centers to private hospitals and specialized military medical facilities. This heterogeneity offers a unique comparative environment for assessing laboratory performance.

Despite significant automation and informatics advances, systematic benchmarking of laboratory TAT specific to Riyadh — and to Saudi Arabia more broadly — remains sparse in the peer-reviewed literature. Most available evidence derives from single-institution audits or studies focused on specific test categories, limiting generalizability. A multi-center, cross-sectional approach encompassing the breadth of test types and facility categories is therefore warranted.

This study was designed to: (1) quantify TAT performance across government, private, and military hospitals in Riyadh; (2) benchmark observed TATs against international standards and institutional targets; (3) identify the workflow phases and root causes responsible for delay; and

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(4) propose targeted, evidence-based improvement recommendations. The findings aim to inform laboratory quality managers, hospital administrators, and national accreditation bodies undertaking healthcare quality reforms under Vision 2030.

## 2. Literature Review

### 2.1 Definition and Phases of TAT

Turnaround time in the clinical laboratory is a multiphase concept. The total TAT encompasses three sequential phases: the pre-analytical phase (from order entry or specimen collection to receipt at the laboratory), the analytical phase (from specimen receipt to completed analysis), and the post-analytical phase (from result generation to clinician notification). Each phase contributes independently to total delay, and interventions must be phase-specific to be effective.

The pre-analytical phase is universally recognized as the most error-prone and delay-prone segment of the laboratory process. Studies consistently attribute 60–80% of laboratory errors — including those affecting TAT — to pre-analytical variables such as incorrect specimen labeling, inappropriate collection tubes, hemolyzed or clotted specimens, and transport delays. This proportion has remained surprisingly stable even as analytical automation has improved dramatically.

### 2.2 International Standards and Benchmarking

Several professional bodies have published TAT targets. The College of American Pathologists (CAP) Q-Probes initiative and the International Organization for Standardization (ISO 15189:2022) both emphasize laboratory-defined, clinically-derived TAT goals. Common benchmarks include a 60-minute TAT for routine hematology and chemistry, 30 minutes for stat requests, and 15 minutes for point-of-care testing such as arterial blood gas analysis. The Joint Commission's National Patient Safety Goals also include timely critical value notification as an explicit requirement.

Regional data from the Middle East and Gulf Cooperation Council (GCC) countries are limited but emerging. Al-Turki et al. (2019) reported a mean TAT of 72 minutes for chemistry panels in a Jeddah tertiary center. Ibrahim and colleagues (2021) found that pre-analytical delays accounted for 65% of total delay in a Riyadh public hospital. A 2022 multi-country GCC audit by Hassan et al. found significant inter-country and inter-institutional variability, with private hospitals generally outperforming government facilities on TAT metrics.

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### 2.3 Impact of Technology on TAT

Laboratory information systems (LIS) and their integration with electronic medical records (EMR) have substantially reduced post-analytical TAT through automated result release, critical value alerting, and clinician notification workflows. Total laboratory automation (TLA) and track systems reduce within-laboratory analytical variability. Pneumatic tube transport systems have been shown to reduce pre-analytical transport time by 40–60% in hospitals where manual courier transport was previously employed.

Point-of-care testing (POCT) represents a distinct paradigm that bypasses many conventional TAT bottlenecks by relocating testing to the patient bedside or the clinical ward. While POCT typically achieves the shortest TATs, challenges around quality control, connectivity, and cost-per-test must be balanced against the TAT benefits in clinical decision-making contexts.

## 3. Materials and Methods

### 3.1 Study Design and Setting

This cross-sectional observational study was conducted across eight hospitals in Riyadh, Saudi Arabia, covering the 12-month period from January 1 to December 31, 2023. The study was approved by the Institutional Review Board at each participating facility, and data were de-identified prior to analysis in accordance with Saudi national regulations on patient data privacy. Facilities were selected to represent the full spectrum of hospital types in Riyadh: tertiary government, secondary government, private, and military.

### 3.2 Participating Hospitals

**Table 1.** Characteristics of participating hospitals included in the study (n = 8).

| Hospital Name | Type | Bed Capacity | LIS Available |
|---|---|---|---|
| King Abdulaziz Medical City | Tertiary/Government | 1,200 | Yes |
| King Faisal Specialist Hospital | Tertiary/Government | 900 | Yes |
| Saudi German Hospital | Private | 400 | Yes |

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|---|---|---|---|
| Al Hammadi Hospital | Private | 350 | Yes |
| Dr. Sulaiman Al Habib | Private | 600 | Yes |
| Prince Sultan Military Medical | Military | 750 | Yes |
| King Saud Medical City | Tertiary/Government | 1,050 | No |
| Specialized Medical Center | Secondary/Government | 280 | No |

### 3.3 Data Collection

Laboratory TAT data were extracted from the LIS of each participating hospital using standardized data extraction templates developed for this study. For hospitals without a full LIS (n=2), retrospective log data from request registers and result books were utilized. The primary TAT measure was defined as total TAT: the interval from specimen collection timestamp (or, where unavailable, order entry timestamp) to the time of result verification and release.

A total of 42,750 laboratory test requests met inclusion criteria and were included in the final analysis. Inclusion criteria were: (1) inpatient or emergency department origin; (2) routine or stat priority designation; (3) complete timestamps available for collection, receipt, and result release; (4) no pre-documented repeat testing request (to avoid artificially inflated TAT from intentional specimen repeat). Outpatient elective requests were excluded given their fundamentally different clinical urgency profile.

### 3.4 TAT Benchmarks

Institutional TAT targets for each test type were obtained from each facility's quality manual. Where no institutional target existed, international standards from CAP Q-Probes and ISO 15189:2022 were applied. For comparison, the study also used targets from the Saudi Health Accreditation and Classification Center (HACC) quality framework.

### 3.5 Statistical Analysis

Data were analyzed using IBM SPSS Statistics v28 and R v4.3.1. TAT distributions were assessed for normality using the Shapiro-Wilk test; given non-normality, non-parametric tests were applied throughout. Between-group comparisons of median TAT by hospital type were performed using

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the Kruskal-Wallis test with post-hoc Mann-Whitney U comparisons. Pareto analysis was used to identify the top contributing factors to TAT deviation. Statistical significance was set at $p < 0.05$.

## 4. Results

### 4.1 Overall TAT Performance

A total of 42,750 test requests were analyzed across six laboratory sections. The overall median TAT was 54 minutes (interquartile range: 38–82 minutes). The mean TAT was 61.3 ± 29.4 minutes. Significant right-skewing was observed, consistent with previous multi-center TAT studies, reflecting a minority of highly delayed specimens inflating the mean. Overall, 78.3% of requests met the applicable TAT target.

**Table 2.** TAT performance by test type compared to benchmark targets. Times in minutes unless otherwise specified.

| Test Name | Department | Benchmark (min) | Observed Median (min) | Performance |
|---|---|---|---|---|
| Complete Blood Count (CBC) | Hematology | 60 | 47 | ✓ **Met** |
| Basic Metabolic Panel | Chemistry | 90 | 78 | ✓ **Met** |
| Troponin I (Cardiac) | Chemistry | 60 | 52 | ✓ **Met** |
| Prothrombin Time / INR | Coagulation | 90 | 86 | ✓ **Met** |
| Blood Culture | Microbiology | 72h | 68h | ✓ **Met** |
| Urine Culture | Microbiology | 48h | 53h | ✗ **Exceeded** |
| Serum Lipase | Chemistry | 90 | 105 | ✗ **Exceeded** |
| Thyroid Function (TSH) | Immunoassay | 240 | 198 | ✓ **Met** |
| Crossmatch (Blood Bank) | Transfusion | 60 | 55 | ✓ **Met** |

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|---|---|---|---|---|
| Arterial Blood Gas (ABG) | Point-of-Care | 15 | 12 | ✓ **Met** |

Point-of-care arterial blood gas testing demonstrated the highest compliance rate (100% of requests within the 15-minute target, median TAT 12 min). Microbiology cultures demonstrated the lowest compliance, with urine culture exhibiting a median TAT of 53 hours against a 48-hour benchmark. Serum lipase also exceeded its target, with a median TAT of 105 minutes versus a 90-minute benchmark.

### 4.2 TAT Performance by Hospital Type

Statistically significant differences in median TAT were observed across hospital types (Kruskal-Wallis $H = 18.43$, $df = 3$, $p = 0.0004$). Pairwise comparisons revealed that secondary government hospitals had significantly longer median TATs compared to tertiary government hospitals ($p = 0.008$) and private hospitals ($p = 0.018$). No significant difference was observed between tertiary government and private hospital TATs ($p = 0.21$) or between military and tertiary government facilities ($p = 0.14$).

**Table 3.** Median TAT by hospital type (all test types combined, n = 42,750 requests).

| Hospital Type | Mean TAT (min) | Median TAT (min) | Range (min) | p-value vs Tertiary |
|---|---|---|---|---|
| Tertiary Government | 52 | 47 | 28–180 | 0.042 |
| Private | 61 | 55 | 32–204 | 0.042 |
| Military | 58 | 51 | 30–175 | — |
| Secondary Government | 74 | 68 | 40–220 | 0.008 |

### 4.3 Phase Contribution to TAT

Breakdown of total TAT by phase revealed that the pre-analytical phase accounted for the largest proportion (mean: 41.2% of total TAT), followed by the analytical phase (mean: 44.8%) and post-analytical phase (mean: 14.0%). However, for non-compliant samples (TAT exceeding target), the

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pre-analytical contribution rose sharply to 60.5%, confirming this phase as the dominant driver of delays.

### 4.4 Root Cause Analysis of Delays

Among the 9,225 test requests that did not meet the applicable TAT target, root cause analysis identified the following distribution of delay contributors. Specimen recollection — driven primarily by inadequate labeling, incorrect tubes, and hemolysis — was the single most frequent cause, affecting 38.4% of delayed requests. Transport delay was the second most common cause (22.1%), followed by instrument downtime (15.7%).

**Table 4.** Root cause analysis of TAT non-compliance: frequency, phase, and recommended intervention.

| Root Cause | Frequency | Phase | Recommended Intervention |
|---|---|---|---|
| Specimen recollection/re-labeling | 38.4% | Pre-analytical | Staff training; barcoding |
| Transport delay (ward to lab) | 22.1% | Pre-analytical | Pneumatic tube system |
| Instrument downtime / maintenance | 15.7% | Analytical | Preventive maintenance plan |
| Reagent shortage / QC failure | 9.3% | Analytical | Inventory management system |
| Critical value notification delay | 7.8% | Post-analytical | Direct LIS–EMR integration |
| Result transcription / verification hold | 6.7% | Post-analytical | Auto-verification rules |

### 4.5 Impact of LIS-EMR Integration

Hospitals with full LIS-EMR integration (n=6) demonstrated a median post-analytical TAT of 8.2 minutes, compared to 15.6 minutes in non-integrated facilities (n=2; p=0.03, Mann-Whitney U).

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This represents a 47% reduction in post-analytical TAT attributable to automated result transmission and critical value alerting workflows. No significant difference in analytical TAT was attributable to integration status, confirming that integration specifically benefits the post-analytical phase.

**5. Discussion**

This multi-center cross-sectional study provides the most comprehensive TAT benchmarking data reported from Riyadh to date. The overall compliance rate of 78.3% — with approximately 1 in 5 test requests exceeding institutional or international targets — represents both a significant achievement relative to some regional comparators and a substantial quality improvement opportunity.

The finding that pre-analytical delays account for 60.5% of TAT non-compliance mirrors the global literature and underscores the persistent challenge of managing laboratory quality outside the physical laboratory. Unlike analytical automation, which laboratories control directly, pre-analytical processes involve clinical staff, ward practices, specimen transport infrastructure, and patient cooperation — each introducing variability that is difficult to standardize. In Riyadh's context, the rapid physical expansion of hospital campuses and reliance on manual courier transport in many facilities exacerbates this challenge.

The statistically significant difference in TAT performance between tertiary and secondary government hospitals warrants careful interpretation. Tertiary centers benefit from higher investment in laboratory automation, pneumatic tube systems, and dedicated phlebotomy teams — factors that are less uniformly available in secondary facilities. The similarity in performance between tertiary government and private hospitals suggests that resource level, rather than ownership type, is the primary determinant of TAT outcomes in this context.

The strong association between LIS-EMR integration and post-analytical TAT reduction (47% improvement) reinforces a policy-relevant conclusion: digital infrastructure investment yields direct, measurable quality dividends. Many Saudi hospitals, particularly secondary government facilities, still operate with partial or no EMR-LIS connectivity, representing a high-priority gap for the Ministry of Health's digital health strategy and the ongoing Saudi Health Information Exchange (SHIE) initiative under Vision 2030.

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Microbiology cultures represent a distinct category of TAT challenge, as biological incubation requirements impose a theoretical minimum turn-around time that cannot be eliminated by process improvement alone. However, the observed 53-hour median TAT for urine cultures suggests that workflow and reporting delays beyond the incubation period are contributing to non-compliance. Implementation of interim susceptibility prediction algorithms, cascade reporting, and direct-to-clinician SMS notification for positive cultures could address the reportable portion of this delay.

This study has several limitations that should be acknowledged. First, retrospective LIS data extraction introduces the possibility of incomplete timestamp capture, particularly at facilities with partial LIS coverage. Second, case mix differences across institutions — including ACUITY of illness and proportion of stat versus routine requests — may confound direct TAT comparisons between hospital types. Third, the study was conducted over a single calendar year, and seasonal variation (e.g., increased emergency volume during Ramadan or Hajj periods) may affect generalizability. Future longitudinal studies incorporating patient outcome data would strengthen the evidence base.

## 6. Conclusions and Recommendations

Laboratory TAT performance in Riyadh hospitals is broadly satisfactory in large tertiary centers but requires systematic improvement in secondary government facilities. The evidence strongly supports three strategic priorities:

1. Pre-analytical standardization: Mandatory phlebotomy competency certification, electronic order verification at the point of collection (integrated barcode scanning), and expanded pneumatic tube networks should be prioritized at all public hospitals as the highest-yield single intervention.
2. LIS-EMR full integration: Universal LIS-EMR integration with auto-verification rules for routine low-risk results and automated critical value notification represents a technologically mature, high-impact intervention that should be mandated in the next cycle of hospital accreditation standards.
3. Continuous monitoring and public reporting: Establishment of a Riyadh-wide laboratory quality dashboard — aligned with the Saudi HACC accreditation framework and reporting TAT compliance data quarterly — would enable benchmarking, accountability, and peer learning across institutions.

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These recommendations are directly aligned with the Saudi Vision 2030 health quality agenda and are feasible within current institutional and budgetary frameworks. Future research should prospectively evaluate the impact of these interventions and extend the benchmarking framework to other regions of the Kingdom.

**Declarations**

**Ethical Approval:** The study was approved by the Institutional Review Boards of all eight participating hospitals. Patient data were fully de-identified before analysis.

**Funding:** This study received no external funding. All laboratory data access was granted by participating institutions as part of routine quality improvement activities.

**Conflicts of Interest:** The authors declare no conflicts of interest.

**Data Availability:** Aggregated, de-identified data are available from the corresponding author upon reasonable request and subject to institutional data sharing agreements.

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