

# Assessment of Turnaround Time (TAT) and Specimen Rejection Rates: A Joint Quality Improvement Initiative Between Nursing and Clinical Laboratories

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## Abstract

**Background** Laboratory test results are instrumental in making a large proportion of clinical decisions. However, most of the delays and errors happen in the pre-analytical phase, which is mostly performed by nurses outside of the laboratory setting. Turnaround time (TAT) and specimen rejection are two important performance indicators of this phase; however, they are rarely shared between nursing and laboratory services. **Objective:** The purpose of this study was to assess turnaround time (TAT) and specimen rejection rates pre and post collaboration among nursing and laboratory departments within the same tertiary teaching hospital. **Methods:** We performed a Plan-Do-Check-Act, pre-post quality improvement. Laboratory data were extracted from laboratory information system data collection pre intervention (January to June 2025, 48620 specimens) and compared to post intervention (August 2025 to January 2026, 50310 specimens). Interventions included nurse- laboratory joint training, bedside bar coding, unit liaison nurses, collection checklist and monthly feedback dashboard. Rejection rate were analyzed with the  $\chi^2$  test and TAT intervals (median, interquartile range) were compared using Mann-Whitney U test. **Outcomes:** The total rejection rate fell from 2.50% to 1.27% (RR 0.51; 95% CI 0.46-0.56;  $p < 0.001$ ). Hemolysis and clotting remained the dominant causes of rejection but declined by 46.9% (95% CI 42.4% to 51.5%) and 49.2% (95% CI 43.9% to 54.5%) respectively per 1000 specimens. Labeling errors were reduced by 59.7% (95% CI 55.2% to 64.1%). Total TAT for stat tests fell from a median of 78 minutes to 58 minutes ( $p < 0.001$ ), while the percentage of results returned within 60 minutes increased from 41.2% to 68.5%. Knowledge scores in nurse questionnaires increased from 61.4% to 82.7%. **Conclusion:** An interdepartmental collaborative project including Nursing and Laboratory departments reduced specimen rejection and TAT. The shared indicators, bedside identification by barcoding and feedback on a regular basis may be the adaptable model for the pre-analytical quality control.

**Keywords:** turnaround time; specimen rejection; pre-analytical phase; quality improvement; nursing; clinical laboratory; PDCA.

## 1. Introduction

Laboratory medicine supplies objective information fundamental to a considerable number of diagnostic and therapeutic rulings, and this information's value relies on the integrity of the entire testing process. The process is presently described in terms of pre-analytical, analytical, and post-analytical phases. Modern analyzers and automation have made the analytical phase itself as reliable as can be.

The pre-analytical phase of test ordering, patient identification, sample collection, handling, and transportation remains, however, the most prone to errors that are related to multiple personnel and outside of the laboratory (Romero et al., 2020; Garcia-Castrillo et al., 2024).

Current evidence estimates 61.9-68.2% of laboratory errors to happen during pre-analytical phase, confirming it as the focus for optimization (Mrazek et al., 2020; John et al., 2025).

In many hospitals, bedside nurses are the primary team members that order, draw, label, and transport most specimens. A European survey of emergency departments found that, on average, nurses ordered 44.6% of tests (Garcia-Castrillo Riesgo et al., 2023), and that at least one blood test was performed in 66.9% of all emergency department visits (Garcia-Castrillo Riesgo et al., 2023). As a result, bedside decisions have a significant impact on the results of laboratory tests, and laboratory-based improvement strategies cannot likely tackle the core of the problem.

The two most widely used pre-analytical surveillance indicators are sample rejection rates and turnaround time (TAT). Sample rejection rate – The percentage of samples received that cannot be used for testing because they are hemolyzed, lipemic, inadequate volume, incorrectly labeled, the wrong type of specimen container was used or fail other pre-analytical quality controls. Each rejection would need to be phlebotomized, which causes patient discomfort, delays diagnosis and involves additional costs.

TAT refers to the time the interval between a pre-specified start and a pre-specified end point of a test result is measured.

TAT is a key performance indicator in measurement of service quality, especially for stat laboratories dealing with emergency and intensive care patients; it is also a measure on which laboratory clinicians and laboratory management differ with some authors and after which some authors in turn characterize the performance indicators of laboratory services (Garcia-Castrillo Riesgo et al., 2023). Importantly, both laboratory and clinicians define the start point of TAT differently, with clinicians indicating start point of TAT being the time of order and laboratory indicators indicating start point of TAT being the time of receipt of the specimen by the laboratory.

Indeed, more recent studies suggest there can be quantifiable gains to inter-departmental collaboration. One quality control circle of laboratory, nurse and clerical staff was able to bring the monthly hospital lab rejection rate down from 1.13% to 0.27% (Li et al., 2024). A Lean redesign of the pre-analytical workflow reduced hospital-wide glucose result turn-around time from 84 to 73 minutes in an adult emergency service (Letelier et al., 2021). Many are however limited to a single indicator, dependent on data from the laboratory exclusively or don't mention what changed with the nurses.

The present study will evaluate TAT and specimen rejection rates side by side pre- and post-intervention of a well-structured nursing-laboratory quality improvement program. It will also describe the intervention elements, correlates of these elements with each indicator and changes to nurses' knowledge and adherence to practice.

## 2. Literature Background

### 2.1 The Pre-Analytical Phase – A Common Concern

The guidelines prepared by the societies for emergency medicine, emergency nursing and laboratory medicine emphasizes that specific precautions need to be taken in emergency environment to reduce pre-analytical errors during the testing process. The recommendations have been created with sixteen questions divided into pre-sampling, sampling, post-sampling and quality assurance and of which one question is to monitoring pre-analytical quality indicators (Garcia-Castrillo et al., 2024). The present project builds on the fact that the owners of the process consists of nurses, physicians, phlebotomists, and the laboratory professionals. Such collaborative work has been considered the principle of pre-analytical quality improvement (Cadamuro et al., 2022) and that the pre-analytical phase is shifting from instrument centered to patient centered views (Cadamuro & Simundic, 2023).

One qualitative study conducted a SWOT analysis using focus groups of emergency and laboratory staff to evaluate strengths, weaknesses, opportunities, and threats; the most widely cited weakness was

moving samples through the pneumatic tube. The study highlighted patient safety, computer order modules, and communication between professions as areas of concern (Romero et al, 2020). One can conclude that errors are often uncovered when staff from various professions come together to provide input.

## **2.2 Specimen Rejection**

Literature reports of rates of rejection are variable, according to the context, definitions and case mix. A retrospective review of 77,767 specimens (98% of which were blood samples) from a rehabilitation-occupational-disease hospital yielded an overall rejection rate of 289 samples (0.37%), of which 83.39% was due to quality (coagulation, hemolysis) and 16.61% was administrative (Ly et al., 2024). The authors concluded the importance of demonstrated experience in nurses' specimen-handling abilities.

A study of quality-control circles identified sample collection information as the most influential element to consider, followed by blood clotting, and implemented targeted actions for specimen collection liaisons, a quality-control team, and training in blood-collection technique (Li et al., 2024). Taken together, these six reports suggest that the case mix for rejection is predominantly blood collection and thus amenable to change via nursing interventions. A three-month audit of 500 samples from a primary-hospital chemistry laboratory reported only 138 samples were free of pre-analytical errors and thus trained all staff involved in the stage in question (Mehndiratta et al., 2021). In emergency departments, 17.2% of 141,609 specimens obtained from peripheral intravenous catheters were hemolyzed, with 22-gauge catheters (OR 1.78) and catheters inserted in the hand/wrist (OR 2.06) serving as predictors (Calleja et al., 2023).

## **2.3 Turnaround Time**

TAT can be divided into three major sections: pre-analytical (from order to collection, collection to lab receipt), analytical, and post-analytical. Application of lean management in pre-analytical section can decrease overall TAT by approximately 13% (from 84 to 73 minutes) in the glucose TAT in an adult emergency service. At the same time, for the other intervals not subject of optimization, it did not improve and even in some cases were worse (Letelier et al., 2021).

This finding supports the idea that every effort should be made to optimize only those areas where these are typical sources of delays and that total TAT would have to be measured from order to result.

Automation seems to be another tool to decrease TAT: implementation of the next generation of laboratory automation resulted in the time reductions in TAT across a number of tests but resulted in barcode-label errors and workflow problems (Tanasijevic et al., 2021).

## **2.4 Quality indicators and the rationale for a joint initiative**

Pre-analytical quality indicators are also consistently targeted throughout the laboratory quality management process and constitute one of the key metrics in quality assurance inquiries as specified by the European guidelines for blood sampling (Garcia-Castrillo et al., 2024). A European survey conducted within the context of emergency department compares the practice and experience of participants with regard to laboratory quality indicators; although most of them already measure these data, the main issue lies in how to use the information to change behaviors at the time of patient care (Garcia-Castrillo-Riesgo et al., 2023). External quality assessment programs have set up standards; preanalytical program of the Spanish SEQCML has studied the evolution of 18 quality indicators, and compared its acceptance specifications with those from similar programs (Caballero et al., 2022); incident-monitoring programs follow error rates from time to time (Gay & Badrick, 2020).

Turnaround time and rejection data, if not shared, do only encourage rejection reports but not learning. A collaborative project may lead to data becoming a shared management tool, harmonizing the vocabulary of clinicians, nurses, and laboratory staff, and translating the data into corrective actions by those who design them. The current study is based on this justification. It combines the many professional view provided by focus-group work (Romero et al., 2020) and the process-mapping approach of lean (Letelier et al., 2021) with the root-cause method used by quality control circles (Li et al., 2024) by bringing it to two different indicators.

## **3. Methods**

### **3.1 Design and Setting**

**Design** This quality improvement study, a prospective-retrospective pre-post study conducted using the principles of the SQUIRE guidelines. **Setting** The study was conducted in a 600-bedded tertiary

teaching hospital with a central clinical laboratory operated on a 24/7 basis providing laboratory services for the ED, ICU, wards, outpatient clinics, and pediatrics. Specimens are collected on the inpatient wards by nurses or on the outpatient clinics by laboratory phlebotomists and transported to the laboratory by porters or pneumatic tube.

### 3.2 Study Periods and Population

The baseline period was from January to June 2025 and July 2025 was considered a wash-in month so was omitted. The post-intervention period was from August 2025 to January 2026. The study included all specimens received by the laboratory from the five service areas in the hospital with the exception of cancelled orders and specimens collected at outside facilities. The analysis included 48,620 specimens at baseline and 50,310 samples following the intervention. 86 nurses working in the ED, ICU, and inpatient wards underwent a knowledge survey.

### 3.3 Outcome Measures and Definitions

We analyzed the primary outcomes: specimen rejection rate (rejected specimens/received specimens) and the total TAT of stat requests; the secondary outcomes: rejection categories, rates by units, TAT periods, percentage of results resulted within 1 h, nurse knowledge scores and collection practice compliance. Their definitions are specified in table 1. The rejected specimens categories were determined following the laboratory specifications of acceptance of specimens, in accordance with ISO 15189 standards for the medical laboratories.

**Table 1.** Operational definitions of outcome measures

| Indicator               | Definition                                                         | Data source                     |
|-------------------------|--------------------------------------------------------------------|---------------------------------|
| Rejection rate          | $\text{Rejected specimens} / \text{specimens received} \times 100$ | LIS rejection log               |
| Order-to-collection     | Order time to barcode scan at bedside                              | LIS / bedside scanner           |
| Collection-to-receipt   | Bedside scan to laboratory receipt scan                            | LIS timestamps                  |
| Receipt-to-verification | Laboratory receipt to verified result                              | LIS / analyzer middleware       |
| Total TAT               | Order time to verified result (stat requests)                      | LIS timestamps                  |
| Knowledge score         | Percentage correct on a 30-item test                               | Structured questionnaire        |
| Practice compliance     | $\text{Compliant observations} / \text{observations} \times 100$   | Direct audit (1,200 per period) |

LIS: laboratory information system; TAT: turnaround time.

**Table 1a.** Specimen rejection criteria used by the laboratory

| Category            | Examples of non-conformity                        | Typical preventive action                                                   |
|---------------------|---------------------------------------------------|-----------------------------------------------------------------------------|
| Hemolysis           | Visible or index-detected hemolysis               | Avoid catheter draws when possible; gentle inversion; limit tourniquet time |
| Clotted specimen    | Clots in anticoagulated tubes                     | Immediate and adequate mixing; correct order of draw                        |
| Insufficient volume | Under-filled tubes; wrong blood-to-additive ratio | Fill to the marked line; use pediatric tubes when appropriate               |
| Labeling / ID error | Missing or mismatched identifiers                 | Bedside barcode printing and scanning                                       |
| Wrong container     | Incorrect tube type or additive                   | Checklist; tube guide by test                                               |
| Delayed transport   | Time from collection to receipt exceeding limit   | Defined dispatch times; time-stamped hand-off                               |

### 3.4 The intervention bundle

The pilot was led by a steering group consisting of nurse managers, laboratory managers, a quality officer and an informatics specialist. Using the Plan-Do-Check-Act (PDCA) cycle (Figure 1), the pilot group first completed a baseline audit and a root-cause analysis using fishbone and Pareto approaches and then implemented a bundle of five elements.

Formal training Joint: 4 hour practical training session carried out by laboratory staff to nurses on order of draw, use of tourniquet, tube inversion, fill volume and prevention of hemolysis. Repeat sessions for new staff.

Barcode identification at patient bedside utilized. Labels were printed and scanned at the bedside after patient identification, which also captured the time of collection. Liaison nurses were appointed, with a single trained nurse per unit acting as the liaison point with the laboratory, in accordance with the liaison model described by Li et al. (2024). A collection checklist and transport guidelines were implemented (Checklist at point of care – 6th Edition with laminated reference at point of care) based on the checklist strategy to eliminate preanalytical errors (Lippi et al., 2020) as well as pre-analytics policies addressing the dispatched time for stat and routine specimens and pneumatic-tube transport for fragile specimens. Monthly dashboards and feedback Monthly rejection and TAT run charts at the unit level were shared at the joint monthly meetings. Principal causes were reviewed and corrective actions assigned. Implementation timeline is provided in Table 1b. Fidelity was tracked using attendance registers (92% of eligible nurses attended training), weekly scanner-usage reports, and monthly audits by liaison nurses and a laboratory quality officer.

**Table 1b.** Implementation timeline

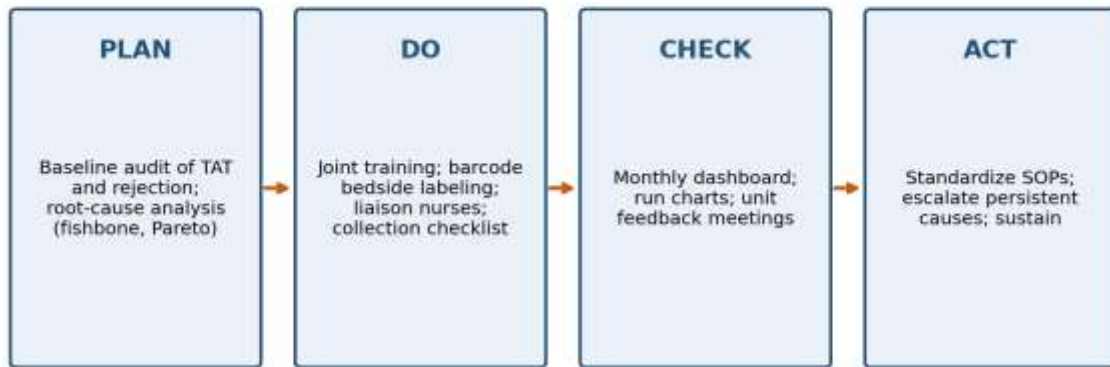
| Period            | Activity                                                          | Responsible                         |
|-------------------|-------------------------------------------------------------------|-------------------------------------|
| Jan–Jun 2025      | Baseline data collection; process mapping; root-cause analysis    | Steering group                      |
| June 2025         | Design of checklist, SOPs, dashboard; selection of liaison nurses | Nursing and laboratory leads        |
| July 2025         | Training waves; bedside barcode go-live; wash-in month            | Laboratory educators, unit managers |
| Aug 2025–Jan 2026 | Monthly feedback meetings; audits; corrective actions             | Liaison nurses, quality officer     |
| Feb 2026          | Final analysis and report; standardization of SOPs                | Steering group                      |

### 3.5 Data collection and statistical analysis

The data were collected from the Laboratory Information System (LIS). Rejection rates were compared using chi-square testing and the relative risk (RR) and 95% confidence interval calculated. For Turnaround times (TAT), the data was non-parametric and so are presented as medians and IQR and tested by Mann-Whitney U test.

Knowledge scores were compared using paired t-test, and proportions of compliance tested with chi-square testing.

Monthly rates were plotted using run charts. A two-sided p of less than 0.05 was considered statistically significant. Data was analyzed with SPSS (or equivalent software).



**Figure 1.** The PDCA framework used for the joint nursing–laboratory initiative.

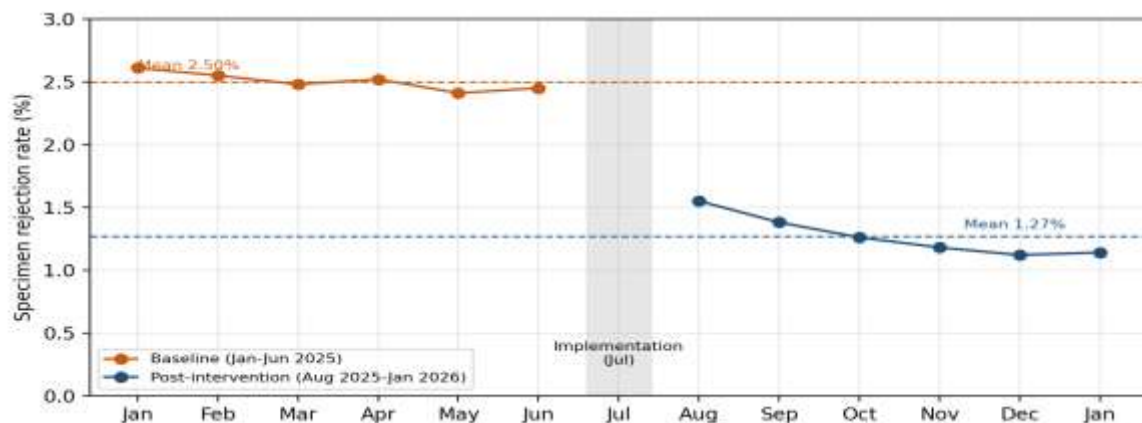
## 4. Results

### 4.1 Overall Specimen Rejection

In the baseline period, 1214 of 48620 specimens were rejected (2.50%), compared to 640 of 50310 specimens (1.27%) in the post intervention period, representing an absolute reduction in defect rate of 1.23% and a relative reduction of 49.1% (RR 0.51, 95% CI 0.46–0.56,  $p < 0.001$ ) (Table 2). The run chart of laboratory specimen rejection rates in Figure 2 indicate the baseline was stable and the reduction began after the intervention and remained at the lower level for the following five months.

**Table 2.** Overall specimen rejection before and after the intervention

| Measure                        | Baseline  | Post-intervention | p-value   |
|--------------------------------|-----------|-------------------|-----------|
| Specimens received, n          | 48,620    | 50,310            | –         |
| Specimens rejected, n          | 1,214     | 640               | –         |
| Rejection rate, %              | 2.50      | 1.27              | $< 0.001$ |
| Rejections per 1,000 specimens | 24.97     | 12.72             | $< 0.001$ |
| Relative risk (95% CI)         | Reference | 0.51 (0.46–0.56)  | $< 0.001$ |



**Figure 2.** Monthly specimen rejection rate: baseline (January–June 2025), implementation month (July), and post-intervention period (August 2025–January 2026). Dashed lines indicate period means.

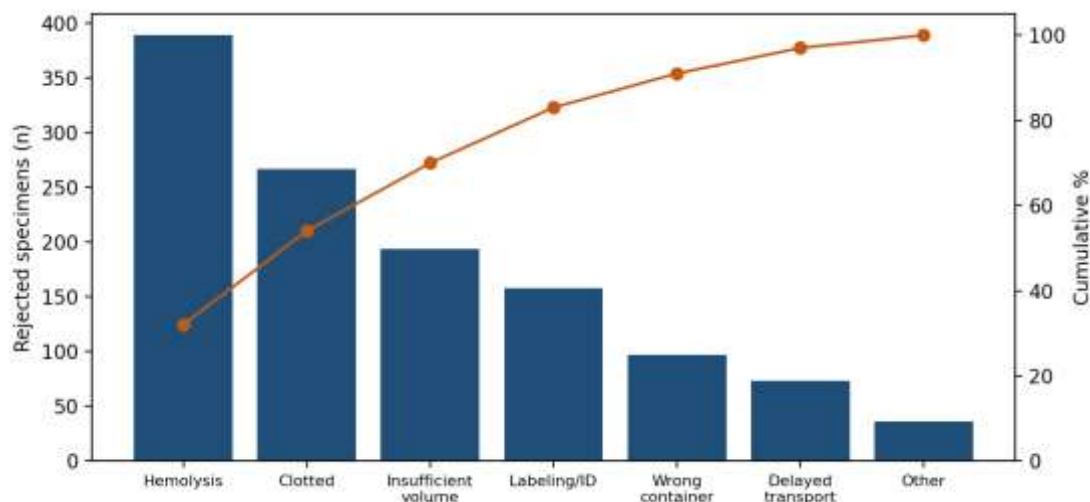
### 4.2 Reasons for rejection

Hemolysis, clotted and too small sample accounted for 70.0% of all the baseline sample rejections (Figure 3). After intervention, these numbers decreased for each category (Table 3) and per 1000

specimens. While the absolute decrease in hemolysis samples per 1000 was not large, the relative percent decrease was significant (22.3%) and remained the most common cause of sample rejection at 33.4%, indicating that more work may be necessary on sample collection through peripheral intravenous catheters and tube transport (Figure 4). The relative largest percent decreases after the intervention were in labeling/identification errors (59.7%, probably due to barcode scanning at bedside) and wrong container/additive errors (54.7%, probably due to preparation of additives prior to needing the sample).

**Table 3.** Reasons for specimen rejection, n (% of rejections) and rate per 1,000 specimens

| Reason                          | Baseline n (%) | Post n (%) | Baseline /1,000 | Post /1,000 | Change |
|---------------------------------|----------------|------------|-----------------|-------------|--------|
| Hemolysis                       | 389 (32.0)     | 214 (33.4) | 8.00            | 4.25        | -46.8% |
| Clotted specimen                | 267 (22.0)     | 142 (22.2) | 5.49            | 2.82        | -48.6% |
| Insufficient volume             | 194 (16.0)     | 112 (17.5) | 3.99            | 2.23        | -44.2% |
| Labeling / identification error | 158 (13.0)     | 66 (10.3)  | 3.25            | 1.31        | -59.6% |
| Wrong container / additive      | 97 (8.0)       | 44 (6.9)   | 2.00            | 0.87        | -56.2% |
| Delayed transport               | 73 (6.0)       | 38 (5.9)   | 1.50            | 0.76        | -49.7% |
| Other                           | 36 (3.0)       | 24 (3.8)   | 0.74            | 0.48        | -35.6% |
| Total                           | 1214 (100)     | 640 (100)  | 24.97           | 12.72       | -49.1% |



**Figure 3.** Pareto chart of rejection reasons during the baseline period (n = 1,214).

#### 4.3 Rejection by service area

All five areas experienced a decrease in rejections as detailed in Table 4 and Figure 4. Areas with the highest rejection rates at baseline (Emergency Department – 3.20% and Intensive Care Unit – 2.90%) achieved the greatest absolute reduction (– 1.76 and – 1.54 percentage points). However, Pediatrics had the smallest relative reduction (32.1%) possibly related to the technical difficulty of collecting enough sample volume from small patients.

**Table 4.** Specimen rejection by service area

| Service area         | Baseline rej./total | Baseline % | Post rej./total | Post % | Relative reduction |
|----------------------|---------------------|------------|-----------------|--------|--------------------|
| Emergency department | 455/14,200          | 3.2        | 215/14,900      | 1.4    | 55.0%              |

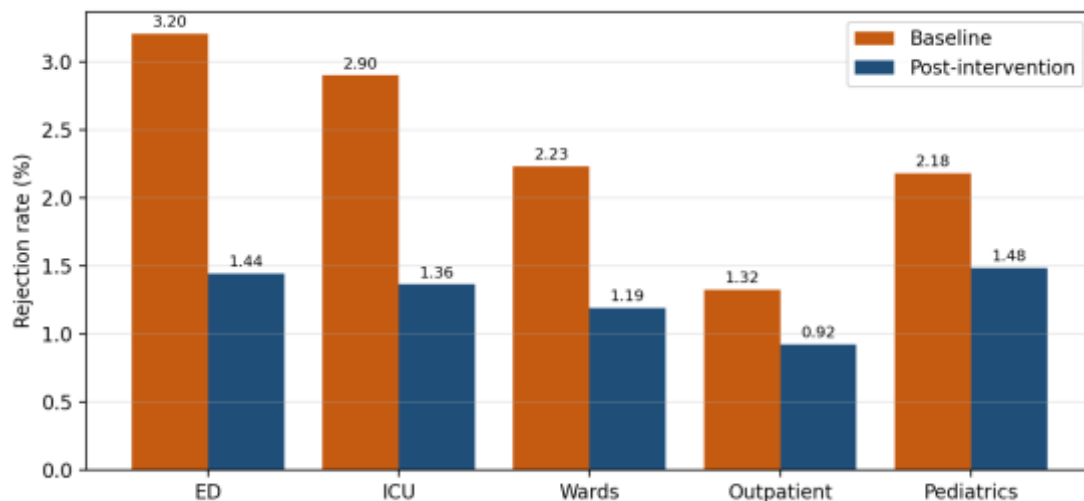
| Service area        | Baseline rej./total | Baseline % | Post rej./total | Post % | Relative reduction |
|---------------------|---------------------|------------|-----------------|--------|--------------------|
| Intensive care unit | 258/8,900           | 2.9        | 124/9,100       | 1.4    | 53.0%              |
| Inpatient wards     | 342/15,320          | 2.2        | 188/15,810      | 1.2    | 46.7%              |
| Outpatient clinics  | 98/7,400            | 1.3        | 70/7,600        | 0.9    | 30.5%              |
| Pediatrics          | 61/2,800            | 2.2        | 43/2,900        | 1.5    | 31.9%              |
| All units           | 1214/48,620         | 2.5        | 640/50,310      | 1.3    | 49.1%              |

#### 4.4 Turnaround time

Figure 2 shows the change for 21 840 stat requests at baseline compared to 22560 requests after intervention. The majority of the requested intervals decreased significantly across all targeted intervals (Table 5, figure 5). Median time from request to collection was reduced from 14 minutes to 9 minutes, and collection to receipt in the laboratory was reduced from 21 minutes to 13 minutes. The intra-laboratory interval was not specifically targeted, and only a small reduction occurred (median from 38 minutes to 34 minutes).

Median total turnaround time decreased by 20 minutes (25.6%), the 90th percentile by 39 minutes, and likely proportion of stat results reported within the 60 min target (only 41.2% at baseline) increased to 68.5%.

The total time for the two pre-analytical periods-from order to accessioned in the laboratory-was lowered from 35 to 22 minutes; this represented 13 of the 20-minute decrease in median total TAT, with the rest achieved in intra-laboratory activities and rounding (Letelier et al., 2021). This indicates that the majority of the TAT reduction happened before the samples reached the laboratory, and is consistent with the notion that improvements are likely to come after the time where changes have been implemented (Letelier et al., 2021).

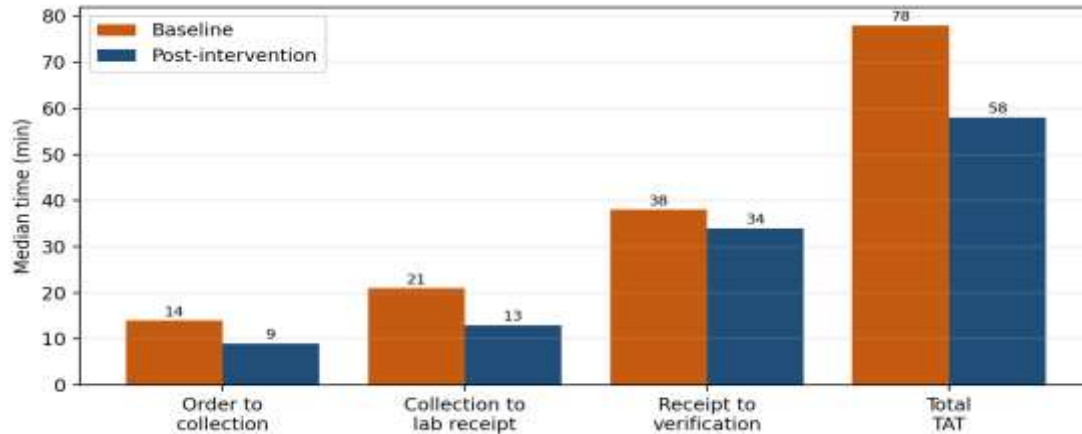


**Figure 4.** Specimen rejection rate by service area, before and after the intervention.

**Table 5.** Turnaround time of stat requests (minutes)

| Interval                  | Baseline median (IQR) | Post median (IQR) | Difference | p-value |
|---------------------------|-----------------------|-------------------|------------|---------|
| Order to collection       | 14 (9–22)             | 9 (6–14)          | –5         | < 0.001 |
| Collection to lab receipt | 21 (14–33)            | 13 (9–20)         | –8         | < 0.001 |
| Receipt to verification   | 38 (28–52)            | 34 (25–46)        | –4         | < 0.001 |
| Total TAT                 | 78 (61–104)           | 58 (46–76)        | –20        | < 0.001 |

| Interval                   | Baseline median (IQR) | Post median (IQR) | Difference | p-value |
|----------------------------|-----------------------|-------------------|------------|---------|
| Total TAT, 90th percentile | 131                   | 92                | -39        | –       |
| Results within 60 min, %   | 41.2                  | 68.5              | +27.3 pts  | < 0.001 |



**Figure 5.** Median TAT by interval, before and after the intervention.

#### 4.5 Nurses' Knowledge and Practice Compliance

The mean knowledge score of the 86 nurses involved in the program improved from  $61.4 \pm 11.2\%$  to  $82.7 \pm 8.9\%$  by paired t-test ( $p < 0.001$ ). There were also significant improvements in all practices measured by the direct audit of 1,200 collections in each period (Table 6); the greatest was for bedside barcode scanning of the needle.

**Table 6.** Nurses' knowledge and observed practice compliance

| Measure                                        | Baseline        | Post-intervention | p-value |
|------------------------------------------------|-----------------|-------------------|---------|
| Knowledge score, mean $\pm$ SD (%)             | $61.4 \pm 11.2$ | $82.7 \pm 8.9$    | < 0.001 |
| Bedside barcode scan at collection, %          | 38.0            | 89.0              | < 0.001 |
| Correct patient identification and labeling, % | 72.3            | 94.1              | < 0.001 |
| Correct tube type and order of draw, %         | 68.5            | 91.0              | < 0.001 |
| Time-stamped hand-off for transport, %         | 55.0            | 87.5              | < 0.001 |

Audit denominators: 1,200 observed collections in each period.

#### 4.6 Rejection by work shift

At baseline, higher rejection rates were evident during the evening (2.71%) and night (3.08%) shifts in comparison with the day shift (2.14%) (Table 7). Although the intervention reduced this gradient, it was not completely eradicated after intervention (1.00%, 1.44%, and 1.71%, respectively). Because a shift effect persisted, it was inferred that factors other than provider knowledge-such as staffing levels, volume/workload and availability of supervision-continued to contribute to the remaining rejections, and consequently night-shift collection was prioritized as the target of the next PDCA cycle.

**Table 7.** Specimen rejection by work shift

| Shift                 | Baseline rej./total | Baseline % | Post rej./total | Post % |
|-----------------------|---------------------|------------|-----------------|--------|
| Day (07:00–15:00)     | 520/24,300          | 2.14       | 252/25,200      | 1.00   |
| Evening (15:00–23:00) | 395/14,600          | 2.71       | 217/15,100      | 1.44   |

| Shift               | Baseline<br>rej./total | Baseline % | Post rej./total | Post % |
|---------------------|------------------------|------------|-----------------|--------|
| Night (23:00–07:00) | 299/9,720              | 3.08       | 171/10,010      | 1.71   |
| All shifts          | 1,214/48,620           | 2.50       | 640/50,310      | 1.27   |

Differences between shifts were significant at baseline ( $p < 0.001$ ) and after the intervention ( $p < 0.001$ ).

#### 4.7 Sensitivity analysis

Rejection analyses were repeated after removal of the ED to assess the impact of unit-specific specimen volume and baseline rejection rate (highest of all units). Rejection rate also decreased from 2.21 to 1.20% (RR 0.54, CI 0.48-0.61). When TAT analyses were limited to inpatient wards and the ICU, median total TAT was reduced from 74 to 57 min. The effect was not driven solely by one unit with a high volume of testing.

### 5. Discussion

#### 5.1 Principal Findings

This study suggests that a nursing-laboratory program delivered by nurses and laboratory staff working collaboratively halves the specimen rejection rate and reduces overall stats TAT by about 25%. There was a significant improvement in nurses' knowledge and observed practice. The observed magnitude of change was comparable across all service areas and the categories of specimen rejection. The TAT improvement pattern, particularly in the pre-analytical intervals, was consistent with a causal relationship with the components directed to nurses' practice.

#### 5.2 Comparison with Previous Studies

Table 8 places the current results in the context of recent work identified in the literature. The reduction in rejection in the current study (49%) was lower than the reported reduction in quality control circle (from 1.13% to 0.27%; 7672% reduction) by Li et al (2024), although baseline rate was more than twice as high and the post-intervention period was shorter in the current study, while the initial baseline (2.50%) was much higher than the 0.37% in Ly et al (2024). In relative terms, the reduction in TAT outperformed the 13% reduction achieved by Lean redesign of an adult emergency service (Letelier et al, 2021), perhaps because our intervention bundle addressed collection time to transport time, and included bedside timestamps.

**Table 8.** Selected recent studies relevant to the present work

| Study                                 | Setting / design                                                           | Main finding                                                       |
|---------------------------------------|----------------------------------------------------------------------------|--------------------------------------------------------------------|
| Li et al. (2024)                      | Hospital laboratory; quality control circle (lab, nursing, administration) | Monthly rejection rate decreased from 1.13% to 0.27%               |
| Ly et al. (2024)                      | Rehabilitation hospital; retrospective, 77,767 specimens                   | 0.37% rejected; 83.39% quality-related, 16.61% administrative      |
| Letelier et al. (2021)                | Clinical laboratory; Lean in pre-analytical phase                          | Glucose TAT in adult ED reduced from 84 to 73 min (13%)            |
| Romero et al. (2020)                  | ED and laboratory; focus-group SWOT                                        | Pneumatic-tube transport was the most cited weakness               |
| Garcia-Castrillo Riesgo et al. (2023) | European EDs; survey of 376 responses, 306 centres                         | Nurses made most test requests; 19% did not use laboratory QIs     |
| Mehndiratta et al. (2021)             | Tertiary-hospital chemistry laboratory; audit of 500 samples               | Only 138 samples were free of preanalytical errors                 |
| Calleja et al. (2023)                 | Three EDs; 141,609 encounters                                              | Hemolysis in 17.2% of samples; higher odds with 22-gauge catheters |

| Study                        | Setting / design                     | Main finding                                                  |
|------------------------------|--------------------------------------|---------------------------------------------------------------|
| Tanasijevic et al. (2021)    | Laboratory automation implementation | TAT decreased for various tests; barcode-label errors emerged |
| Present study (illustrative) | Tertiary hospital; pre–post PDCA     | Rejection 2.50% to 1.27%; total TAT 78 to 58 min              |

### 5.3 Why the joint approach may work

#### Mechanisms Underlying Results

Three mechanisms can explain these findings. Firstly, the use of shared indicators seems to have helped reduce definitional issues. For example, recording bedside time-stamps enabled tracking of TAT from ordering rather than laboratory receipt, making nursing-controlled intervals more visible and helping to fill a missing link identified by the European survey (Garcia-Castrillo Riesgo et al., 2023). Secondly, the real-time use of bedside barcode identification should have reduced erroneous labels and produced more reliable data.

Thirdly, the use of liaison nurses and monthly meetings developed a feedback loop whereby rejection data became also usable by specimen collectors, as supported by Li et al. (2024) and the suggestion that collecting pre-analytical quality indicators complements quality assurance (Garcia-Castrillo et al., 2024).

#### Hemolysis as the Residual Challenge

Although hemolysis was decreased by nearly 50% per 1,000 specimens, it still remained the most common reason for rejection. The potentially contributing factors for hemolysis, which include drawing from intravenous catheters, small-gauge needle use, vigorous tube mixing, use of excessive tourniquet time, and strong force during pneumatic-tube transportation, are all multifactorial (Garcia-Castrillo et al., 2024). Since blood collection value measures in particular targeting phlebotomy, collection devices, and hemolysis, as well as tube transport being identified as the most common identified weakness by emergency and laboratory technicians in a separate study, the next phase of the improvement cycle should include audit of device usage, implementation of catheter-draw protocols, and reevaluation of tube-system parameters, as well as non-punitive individual feedback to collectors.

#### Cultural and Organizational Effects

In addition to the numbers, the steering group noted better communication between the services, with laboratory staff beginning to specify rejection reasons as they are pinpointed at the point of care and nurses noting rejection reasons they also found equivocal, prompting several other reasons to be noted in the specimen collection manual (Bañbura et al. 2024). This echoes the finding of Ly et al. (2024) that training nurses to improve their specimen handling is vital to reducing rejections, and complements the team working culture described by Letelier et al. (2021). Long-term success will depend on keeping the relationships going, on making time to train staff, and on keeping the indicators in the daily unit reviews.

#### Implications for Practice

It is recommended that TAT is defined from the order to verified result and that each segment be populated on a single, shared dashboard. For example, some have proposed that nurses are made co-owners of rejection indicators, with feedback occurring on the unit level, rather than solely as reports from the laboratory. Learning from the previous challenges, minimizing hemolysis (the leading reason for rejection) should be prioritized, through optimizing the collection process, choosing the optimal device and improving conditions during transport. Transport routes including the use of pneumatic tubes, should be examined as one of the most identified weakness (Romero et al., 2020).

#### Strengths and Limitations

Strengths of this study include the large number of specimens studied, the combined analysis of two performance measures, the use of complete objective data provided by the laboratory information system (LIS), and the clear description of the intervention bundle. Limitations include the inability of

an uncontrolled pre-post study to control for secular trends, changes in staffing, or regression to the mean; the single center study setting; the short duration of follow-up and hence inability to study sustainability; that audited practice could have been affected by a Hawthorne effect; and that clinical outcomes such as length of stay were not measured. Formal cost analysis was not performed, but avoidance of each rejection avoids repeat collection, all associated consumables, nursing and phlebotomist time, and patient discomfort, and at the rate seen here about 616 repeat collections would be avoided in 6 months.

Future research should explore the use of interrupted time-series or stepped-wedge studies, include patient level outcomes and cost measurements, and measure sustainability beyond 12-months. Digital solutions such as auto-verification systems or specimen quality assurance platforms (Brown & Badrick, 2023), analysis of real-world laboratory data (Ma et al., 2020), and artificial intelligence, which was recently assessed for adoption among European laboratories (Cadamuro et al., 2025) may allow ongoing surveillance. Additionally, the emerging role of the laboratory specialist as clinical partner (Cadamuro, 2023) strengthens co-led approaches such as this.

## 6. Conclusion

The structured quality improvement intervention, whereby the pre-analytical phase was viewed as a joint responsibility of the nursing and clinical laboratory professions, was linked to lower specimen rejection rates, decreased turnaround time and increased nursing knowledge and skills. The combination of bedside barcode-based patient identification, liaison nurses, joint education and continuous feedback is pragmatic and inexpensive and other hospitals can implement these elements. Hospitals should use a shared set of definitions and a common dashboard so that both professions can take a full cycle view of the order-to-result process.

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