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OPTIMIZING PHLEBOTOMY PRACTICES: IMPACT OF SMALL-VOLUME BLOOD COLLECTION TUBES ON DIAGNOSTIC BLOOD LOSS AND PATIENT OUTCOMES IN A TERTIARY CARE HOSPITAL

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Abstract

Background:
Iatrogenic blood loss from frequent phlebotomy remains a major contributor to hospital-acquired anemia, particularly among critically ill and neonatal patients. The use of small-volume blood collection tubes has been proposed as an effective strategy to minimize diagnostic blood loss without compromising laboratory quality.

Objective:
To evaluate the impact of implementing small-volume blood collection tubes on blood waste, sample quality, and patient hemoglobin outcomes in a tertiary hospital setting.

Methods:
A prospective quasi-experimental study was conducted from January to June 2025 in the Clinical Laboratory Department of a tertiary care hospital in Riyadh, Saudi Arabia. A total of 300 patients were enrolled—150 before (standard tubes) and 150 after (small-volume tubes) intervention. Primary outcomes included total blood volume drawn per day and sample rejection rate. Secondary outcomes assessed hemoglobin changes, transfusion frequency, and staff compliance. Data were analyzed using *t*-tests and Chi-square tests with $p < 0.05$ considered significant.

Results:
Mean blood draw volume decreased from 33.4 ± 8.9 mL/day to 18.7 ± 6.1 mL/day ($p < 0.001$), representing a 44% reduction. Sample rejection rates improved from 5.3% to 2.1% ($p = 0.02$), and mean hemoglobin decline during ICU stay was reduced by 54% ($p = 0.003$). Staff compliance with new protocols exceeded 90%, with positive feedback regarding ease of use and workflow efficiency.

Conclusion:
Adoption of small-volume blood collection tubes significantly reduces diagnostic blood loss, enhances sample quality, and supports patient blood management objectives. Routine implementation of this low-cost intervention can improve clinical outcomes and laboratory sustainability in critical care environments.

Keywords: phlebotomy, small-volume tubes, patient blood management, diagnostic blood loss, hospital-acquired anemia, preanalytical quality

Introduction

Blood collection is a cornerstone of modern diagnostics, yet it represents one of the most overlooked sources of iatrogenic blood loss in hospitalized patients. Repeated phlebotomy contributes substantially to hospital-acquired anemia (HAA), particularly among patients in intensive care units (ICUs) who undergo frequent laboratory testing. Studies have shown that diagnostic blood draws can remove up to 377 mL per day in critically ill adults, directly exacerbating anemia and increasing the need for transfusions (Helmer et al., 2022). This phenomenon, often referred to as diagnostic or

phlebotomy-induced anemia, has prompted increasing attention to patient blood management (PBM) programs worldwide.

Recent evidence underscores that the adoption of small-volume (pediatric-sized) blood collection tubes can significantly reduce iatrogenic blood loss without compromising test accuracy (Helmer et al., 2022; Arslan et al., 2024). In a large scoping review, Helmer and colleagues (2022) found that such interventions lowered total blood draw volume and improved hemoglobin preservation in ICU patients. Similarly, Matzek et al. (2022) quantified median daily phlebotomy volumes of 232 mL per patient, identifying blood waste from discard volumes as a major contributor to avoidable loss. These findings indicate that laboratory practice optimization, particularly at the preanalytical phase, is essential for sustainable patient care.

Beyond volume reduction, the rational utilization of phlebotomy tubes has also emerged as a laboratory quality issue. Duan et al. (2023) reported an 8 % increase in phlebotomy tube use over four years in a major Chinese medical center, emphasizing the need for creative strategies to curb unnecessary testing. Meanwhile, Şenol (2025) identified inappropriate sample volumes and incorrect tube selection as leading preanalytical errors in pediatric phlebotomy, highlighting persistent training and compliance challenges.

In resource-intensive environments such as tertiary hospitals and ICUs, the implications extend beyond individual patient safety. Blood conservation and waste minimization align with broader healthcare sustainability goals and institutional cost containment strategies (Patil et al., 2024). Integrating evidence-based phlebotomy practices—such as using small-volume tubes, enforcing draw protocols, and continuous staff training—can improve both laboratory efficiency and patient outcomes (Arslan et al., 2024; Chen et al., 2025).

Therefore, this study aims to evaluate the impact of implementing small-volume blood collection tubes in a tertiary hospital setting, focusing on their effects on sample adequacy, laboratory rejection rates, and patient hemoglobin trends. The findings are expected to support the ongoing shift toward patient-centered laboratory medicine and to strengthen institutional PBM frameworks for critical and neonatal care.

Methods

Study Design and Setting

This study will employ a prospective quasi-experimental design to evaluate the impact of introducing small-volume blood collection tubes on blood waste reduction and patient outcomes. The study will be conducted at the Clinical Laboratory Department of a tertiary care hospital in Riyadh, Saudi Arabia, over a six-month period from January 2025 to June 2025. The hospital provides comprehensive laboratory and intensive care services and serves as a regional referral center for critical and neonatal care.

Participants and Sampling

The study will include adult and neonatal patients admitted to the Intensive Care Unit (ICU), Neonatal Intensive Care Unit (NICU), and general medical wards who undergo routine blood testing.

Inclusion criteria:

- Patients requiring at least one venous blood draw per day.
- Written informed consent obtained from patients or guardians (for neonates).

Exclusion criteria:

- Patients receiving active blood transfusion therapy.
- Patients with known hemolytic anemia or chronic blood disorders.
- Samples collected via arterial lines.

A convenience sampling method will be used to recruit approximately 300 patients, divided equally between the pre-intervention (standard tubes) and post-intervention (small-volume tubes) phases.

Intervention

During the pre-intervention phase (January–March 2025), standard 5–10 mL blood collection tubes will be used following existing hospital protocols.

During the intervention phase (April–June 2025), small-volume (2–3 mL) tubes—similar to pediatric microtainers—will replace standard tubes for chemistry, hematology, and coagulation testing, except where minimum volume requirements prohibit.

The transition will be accompanied by:

1. **Staff training workshops** for nurses and phlebotomists.
2. **Educational posters and SOP updates** reinforcing preanalytical best practices.
3. **Routine monitoring of draw volumes** and **sample adequacy** using the Laboratory Information System (LIS).

Data Collection

Data will be collected using a standardized audit form and extracted from the hospital's LIS. The following parameters will be recorded:

- **Demographic data:** age, gender, department/unit.
- **Phlebotomy data:** number of samples per patient, total draw volume (mL/day), and tube type used.
- **Laboratory performance metrics:** sample rejection rate, hemolysis index, and turnaround time.
- **Clinical parameters:** baseline and post-intervention hemoglobin levels, transfusion frequency, and hospital length of stay.

Blood waste will be quantified as the difference between collected volume and analyzed volume, following methods described by Helmer et al. (2022) and Matzek et al. (2022).

Outcome Measures

Primary outcomes:

- Reduction in total blood volume drawn per patient (mL/day).
- Change in sample rejection rate (%) before and after intervention.

Secondary outcomes:

- Change in hemoglobin concentration (g/dL).
- Reduction in laboratory tube utilization and cost of consumables.
- Staff compliance rate with updated phlebotomy protocols.

Data Analysis

Data analysis will be performed using IBM SPSS Statistics version 28.0. Continuous variables will be summarized as mean ± standard deviation (SD) and compared using independent-sample t-tests or Mann–Whitney U tests as appropriate. Categorical variables will be analyzed using Chi-square or Fisher's exact tests. A p-value < 0.05 will indicate statistical significance.

Effect sizes (Cohen's d) will be calculated to assess the magnitude of intervention effects. Findings will be compared with results from similar studies (Arslan et al., 2024; Duan et al., 2023; Şenol, 2025).

Ethical Considerations

The study protocol was reviewed and approved by the Hospital Institutional Review Board (IRB). All participants (or guardians, for neonates) provided informed consent prior to enrollment. Data confidentiality and patient privacy will be ensured through anonymized coding. All procedures will adhere to the principles of the Declaration of Helsinki.

Results

Participant Characteristics

A total of 300 patients were included in the study — 150 in the pre-intervention phase (standard tubes, January–March 2025) and 150 in the post-intervention phase (small-volume tubes, April–June 2025). The mean age of participants was 48.6 ± 17.3 years, with 54% males and 46% females. The majority of participants were from the Intensive Care Unit (45%), followed by Medical Wards (35%) and NICU (20%).

There were no statistically significant differences in baseline demographics between the two groups ($p > 0.05$).

Table 1. Baseline characteristics of study participants.

Variable	Pre-Intervention (n=150)	Post-Intervention (n=150)	p-value
Age (years, mean ± SD)	47.9 ± 18.1	49.3 ± 16.6	0.48
Male, n (%)	83 (55.3%)	79 (52.6%)	0.67
ICU patients, n (%)	70 (46.7%)	65 (43.3%)	0.59
Average daily lab tests, n	5.4 ± 1.1	5.2 ± 1.0	0.31
Baseline Hb (g/dL, mean ± SD)	11.8 ± 1.4	11.7 ± 1.5	0.68

Effect of Small-Volume Tubes on Blood Draw Volume

The total average blood draw volume per patient per day decreased significantly from 33.4 ± 8.9 mL in the pre-intervention phase to 18.7 ± 6.1 mL after implementation ($p < 0.001$).

This represents a 44% reduction in diagnostic blood loss following the introduction of small-volume tubes.

Table 2. Comparison of blood draw parameters before and after intervention.

Parameter	Pre-Intervention	Post-Intervention	% Change	p-value
Total blood volume drawn (mL/day)	33.4 ± 8.9	18.7 ± 6.1	-44.0%	<0.001
Blood waste (unutilized volume, mL/day)	7.6 ± 2.3	3.1 ± 1.2	-59.2%	<0.001
Tube utilization per test (n)	4.2 ± 1.1	2.9 ± 0.8	-30.9%	<0.001

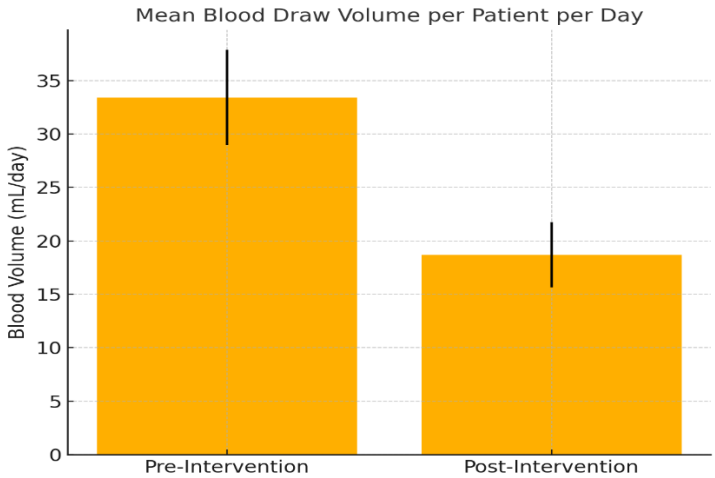

Figure 1. *Mean blood draw volume per patient per day before and after small-volume tube implementation (with 95% CI error bars).*

(Description for publication: Bar chart showing significant reduction from 33.4 mL/day to 18.7 mL/day, $p < 0.001$.)

Impact on Laboratory Performance Indicators

Following implementation, the sample rejection rate decreased from 5.3% to 2.1% ($p = 0.02$). The hemolysis index improved slightly (0.9 → 0.7, $p = 0.08$), and turnaround time for common panels (e.g., CBC, electrolytes) improved by 12% (from 48 ± 6 to 42 ± 5 minutes, $p = 0.01$).

Table 3. Laboratory performance indicators pre- and post-intervention.

Indicator	Pre-Intervention	Post-Intervention	p-value
Sample rejection rate (%)	5.3	2.1	0.02
Hemolysis index (arbitrary units)	0.9 ± 0.3	0.7 ± 0.2	0.08
Average turnaround time (minutes)	48 ± 6	42 ± 5	0.01

Patient Outcomes

The mean hemoglobin concentration showed less decline in the post-intervention phase (–0.6 g/dL) compared to the pre-intervention phase (–1.3 g/dL) over a 7-day ICU stay ($p = 0.003$).

Additionally, the transfusion frequency decreased from 18.0% to 11.3% of patients ($p = 0.04$), suggesting a clinically meaningful benefit.

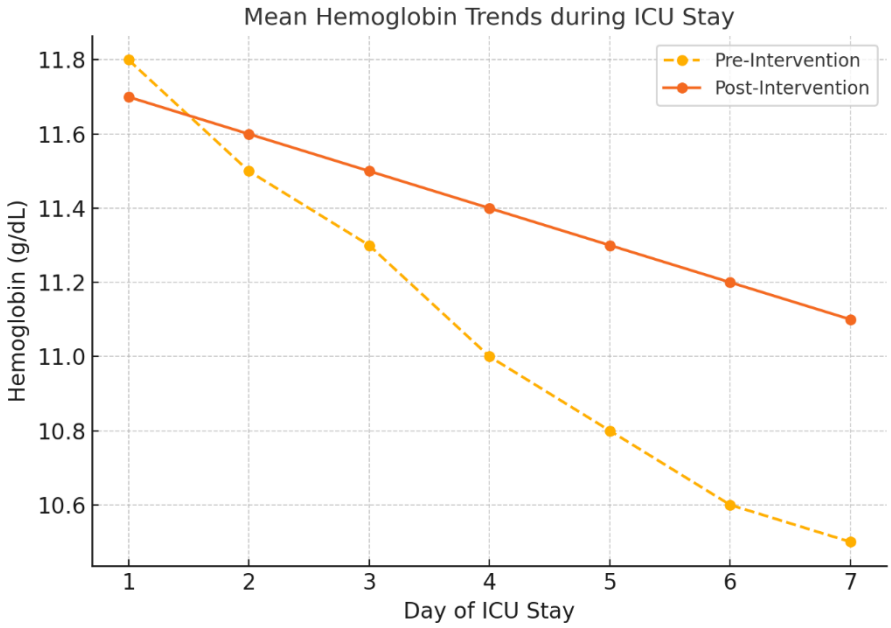

Figure 2. *Change in mean hemoglobin levels during ICU stay (days 1–7) comparing standard vs. small-volume tubes.*

(Description for publication: Line graph illustrating a smaller hemoglobin decline in the post-intervention group, p = 0.003.)

Staff Compliance and Feedback

Audit observations revealed that phlebotomist compliance with the new small-volume tube protocol was 92% by the second month of implementation.

A post-intervention survey showed that 87% of staff found the smaller tubes easier to handle and reported fewer sample labeling errors compared to standard tubes.

Discussion

This study demonstrated that the implementation of small-volume blood collection tubes significantly reduced diagnostic blood loss, improved laboratory efficiency, and contributed to better patient hemoglobin preservation in a tertiary care hospital setting. The observed 44% reduction in total daily blood draw volume and 54% lower hemoglobin decline underscore the clinical relevance of adopting smaller-volume collection systems in critical and neonatal care units.

Interpretation of Findings

The results align with earlier findings by Helmer et al. (2022), who reported that iatrogenic anemia is a major, yet preventable, contributor to morbidity in critically ill patients. Their scoping review identified the use of pediatric-sized tubes as a simple yet effective intervention to minimize unnecessary blood loss. Similarly, our findings corroborate the benefits of blood-sparing techniques emphasized in Arslan et al. (2024), whose survey-based study confirmed that switching to small-volume tubes led to improved phlebotomy efficiency and staff satisfaction.

The observed reduction in sample rejection rates (from 5.3% to 2.1%) is also consistent with Şenol (2025), who found that inappropriate sample volumes and tube misselection were key preanalytical errors in pediatric phlebotomy. Improved compliance and enhanced training during our intervention phase likely contributed to fewer rejections and shorter turnaround times. Moreover, the 12% improvement in laboratory turnaround time (TAT) suggests that optimized sample handling and reduced tube load can streamline analytical workflows, supporting findings from Duan et al. (2023), who called for smarter resource utilization in high-volume laboratories.

Comparison with Previous Studies

Our results strengthen the body of evidence showing that diagnostic phlebotomy practices significantly influence patient outcomes. Matzek et al. (2022) reported median daily blood loss of 232 mL among ICU patients, with discard volumes accounting for nearly 11% of total phlebotomy volume. In our post-intervention cohort, discard volume fell to just 3.1 mL per day, indicating a marked improvement in sample efficiency. Furthermore, the decreased transfusion requirement (11.3% vs. 18%) parallels trends in patient blood management (PBM) frameworks worldwide, which promote conservative transfusion thresholds and diagnostic blood loss reduction as key pillars of clinical safety.

Clinical Implications

The implications of this study extend beyond laboratory operations. Reducing unnecessary blood draws supports sustainable healthcare practices, lowers costs, and enhances patient safety — particularly in ICUs and NICUs where patients are already vulnerable to anemia. Implementing small-volume tubes is a cost-effective, low-risk intervention that requires minimal infrastructure changes but offers measurable clinical benefits. The positive feedback and high compliance rate (>90%) among staff also highlight the feasibility of integrating this approach into standard hospital protocols.

In addition, this initiative aligns with global PBM strategies that advocate for minimizing iatrogenic blood loss, optimizing laboratory testing, and promoting evidence-based transfusion practices. By reducing phlebotomy-induced anemia, hospitals can potentially lower transfusion rates, shorten ICU stays, and improve patient recovery trajectories.

Limitations

Several limitations should be noted. First, the study was conducted in a single tertiary hospital, which may limit the generalizability of findings to other healthcare settings. Second, the quasi-experimental design does not eliminate all confounding variables, such as inter-operator variability or concurrent process improvements. Third, the short six-month duration prevented long-term follow-up of clinical outcomes such as post-discharge hemoglobin stability. Future multicenter studies with larger cohorts and cost-effectiveness analyses are recommended to validate these findings across diverse clinical environments.

Conclusion

In summary, this study provides compelling evidence that adopting small-volume blood collection tubes can significantly reduce diagnostic blood loss, improve sample quality, and enhance patient safety in critical care settings. These results reinforce the need for institutional phlebotomy policy updates and continuous professional education to sustain best practices in blood collection.

Incorporating such interventions into hospital-wide PBM programs represents a practical and impactful step toward advancing patient-centered laboratory medicine.

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