

TSH newborn screening dried blood spot rejection rates: A two-year experience from low-middle income country

Fauqa Arinil Aulia^{1,2,3} , Ferdy Royland Marpaung^{2,3*} 

¹ Clinical Pathology Subspecialist Program, Faculty of Medicine, Universitas Airlangga, Surabaya, INDONESIA

² Department of Clinical Pathology, Faculty of Medicine, Universitas Airlangga, Surabaya, INDONESIA

³ Department of Clinical Pathology, Dr. Soetomo General Academic Hospital, Surabaya, INDONESIA

*Corresponding Author: ferdyoke@gmail.com

Citation: Aulia FA, Marpaung FR. TSH newborn screening dried blood spot rejection rates: A two-year experience from low-middle income country. *Electron J Gen Med.* 2026;23(5):em757. <https://doi.org/10.29333/ejgm/19567>

ARTICLE INFO

Received: 08 May 2026

Accepted: 02 Sep. 2026

ABSTRACT

Background: Preanalytical errors in dried blood spot (DBS) sampling delay critical congenital hypothyroidism diagnosis, particularly in resource-limited settings. This study evaluates temporal shifts in DBS rejection rates across East Java, Indonesia (2024 vs. 2025), and identifies evolving clinical patterns of sampling errors to guide targeted quality improvement strategies.

Methods: This retrospective study combined aggregated district-level data (38 districts; N = 770,854 screenings) with individual-level data from a subset of rejected samples (N = 931). Wilcoxon signed-rank tests compared paired programmatic outcomes; Mann-Whitney U and Chi-square tests analyzed individual-level data using IBM SPSS statistics version 29.0 for Windows.

Results: Total screenings increased 7.0% from 2024 (N = 372,454) to 2025 (N = 398,400). Median rejected samples per district decreased significantly from 373.0 to 359.5 ($p = 0.004$), but rejection rates did not change significantly (4.07% to 3.61%; $p = 0.243$). Extreme inter-district disparity persisted (0.44%-25.20%). Monthly analysis revealed significant improvements in January ($p = 0.003$), February ($p < 0.001$), and June ($p = 0.023$). A total of 931 DBS samples were rejected, with the distribution of rejection causes shifting significantly ($p < 0.001$). The rejection type of “small sample” decreased from 16.8% to 7.9%, while samples with “hemolysis” increased from 20.0% to 29.2%.

Conclusion: While overall rejection rates remained stable, the newborn screening (NBS) program drove a significant structural transition in preanalytical error patterns—successfully reducing basic collection errors while encountering an emerging vulnerability in specimen handling (hemolysis). These novel insights demonstrate that scaling up NBS in low- and middle-income countries requires a strategic evolution from universal training to data-driven, precision quality interventions.

Keywords: congenital hypothyroidism, dried blood spot testing, preanalytical error, specimen quality, quality improvement, low-middle income country

INTRODUCTION

Congenital hypothyroidism (CH) is a leading cause of preventable intellectual disability. The adverse effects of CH on neurodevelopment can largely be avoided through timely diagnosis and treatment. Newborn screening (NBS) is a crucial public health strategy for the early detection of CH. This screening relies on measuring thyroid-stimulating hormone (TSH) levels in dried blood spot (DBS) specimens collected on filter paper [1]. The pre-analytical phase is particularly susceptible to laboratory errors. This phase encompasses blood collection, drying, transportation, and storage. Specimens that are insufficient in quantity, incompletely absorbed, exhibit overlapping spots or compression marks, show signs of hemolysis, or are mishandled can yield unreliable data. Such issues lead to sample rejection, necessitating repeat collection [2, 3].

DBS rejection carries both clinical and operational significance; repeat collection can delay diagnosis and treatment, increase parental anxiety, and add avoidable workload and costs to the screening system [4]. Studies confirm that DBS quality issues vary widely. It was reported striking inter-institutional differences regarding the rates of unsuitable specimens and the predominant types of defects. These findings underscore the need for continuous quality monitoring and targeted feedback [5]. A 2024 multicenter assessment of NBS laboratories in the UK revealed significant inconsistencies in the application of DBS acceptance and rejection criteria, highlighting the importance of standardized quality assessment [6]. Experimental evidence published in 2025 indicates that inadequate drying can significantly reduce the concentration of NBS analytes, demonstrating that specimen quality is also influenced by proper post-collection handling [7].

These challenges can be particularly acute in low- and middle-income countries (LMICs). Large-scale screening

networks must operate across geographically dispersed facilities characterized by diverse infrastructure, transportation conditions, and levels of personnel experience. Knowledge and skill gaps vary across regions. Previous studies have largely focused on the analytical consequences of poor-quality DBS specimens, acceptance criteria, or quality patterns within specific institutions. Evidence from real-world practice regarding how DBS rejection patterns evolve over time during the expansion of large-scale NBS programs in LMICs remains limited. Few studies have simultaneously evaluated temporal trends, geographic variability across administrative regions, and the characteristics of rejected specimens at the individual level. It remains unclear whether the expansion of screening coverage is accompanied by sustained improvements in specimen quality or, conversely, a shift in the predominant types of pre-analytical errors. East Java is a highly populous province. It provides a relevant setting to address these gaps through an NBS network that spans diverse geographic areas and is coordinated by 38 district/city health offices. This study compares DBS sample rejection patterns between 2024 and 2025, based on over 770,000 newborn TSH screening tests. We evaluated changes in rejection outcomes at the district level and on a monthly basis. We analyzed a randomly selected subset of rejected samples to identify newborn demographic characteristics and specific causes of rejection. This study aims to clarify how pre-analytical vulnerabilities evolve during large-scale NBS expansion. It also seeks to generate evidence to inform more targeted, data-driven quality improvement strategies in resource-limited settings.

MATERIALS AND METHODS

Study Design and Setting

This was a retrospective, comparative study utilizing secondary data from the East Java Provincial Health Office's neonatal screening program. This study used all DBS data submitted to Dr. Soetomo General Academic Hospital for TSH analysis over a two-year period (January 1, 2024, to December 31, 2025). The Clinical Pathology Laboratory of Dr. Soetomo General Academic Hospital used DELFIA (GSP Revvity) and TRFIA (AyoTes AT2000) platforms for neonatal TSH screening. The data collected were then analyzed at the district level (38 District Health Offices across East Java). For each district, the total number of DBS tests performed, the number of samples rejected by the laboratory, and the number of samples accepted were recorded. A sub-analysis was also conducted at the individual patient level, including a subset of 931 rejected samples (524 from 2024 and 407 from 2025). A total of 931 reject samples were selected using random sampling. For these cases, the following variables were extracted: gestational age at birth (weeks), birth weight (grams), sex, birth multiplicity (singleton, twin, etc.), and the primary reason for sample rejection as documented by the laboratory.

Rejection criteria are based on standard operational procedures in accordance with the CLSI NBS01-A6 guideline, which include insufficient blood volume (spot diameter < 8 mm), multiple layers of blood (multi-spotted), serum rings, clotting, evidence of hemolysis (lysis), improper compression (compressed), or a broken filter paper [8].

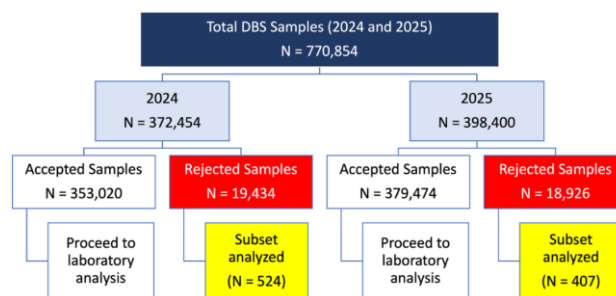


Figure 1. Flowchart of DBS samples included in the neonatal congenital hypothyroidism screening program in East Java, Indonesia during 2024-2025 (created by the authors using the original research data, 2026)

Statistical Analysis

The distribution of the data was first assessed. The primary outcome variables (total number of rejected samples per district and the percentage of rejected samples per district) were found to be non-normally distributed (Shapiro-Wilk test, $p < 0.001$). Consequently, non-parametric statistics were employed. Data are presented as median and interquartile range (IQR) for continuous variables. To compare the paired data from the same 38 districts between 2024 and 2025, the Wilcoxon signed-rank test was used. This test was applied to the total number of rejected samples per district, the total number of accepted samples per district, the percentage of rejected samples per district, the monthly percentage of rejected and accepted samples per district.

For the individual-level sub-analysis, the Mann-Whitney U test was used to compare continuous, non-normally distributed variables (gestational age and birth weight) between groups (2024 vs. 2025; male vs. female). To compare categorical variables (gender, birth multiplicity, and reason for rejection) between years, the chi-square test was used. A p value of less than 0.05 was considered statistically significant. Data were compiled and analyzed using IBM SPSS statistics version 29.0 for Windows.

RESULTS

Demographic and Sample Characteristics

A total of 372,454 individual DBS screening samples were performed, with 19,434 samples (5.22%) rejected in 2024. Furthermore, in 2025, the sample volume increased to 398,400 samples in total, with 18,926 (4.75%) rejected. This represents a 7.0% increase in screening coverage. In 2024, the rejection rate across districts ranged from 0.44% to 25.20%. The rejection rate was between 1.38% and 17.71% in 2025. Two districts, Situbondo and Tuban, consistently showed high rejection rates ($> 15\%$) in both years (Figure 1).

In fact, the median number of rejected samples per district decreased significantly from 373.00 (IQR: 140.00-1789.00) in 2024 to 359.50 (IQR: 48.00-1847.00) in 2025 ($p = 0.004$). Conversely, the median number of accepted samples increased significantly from 8,132.00 to 9,161.50 ($p = 0.004$). The regencies or cities that successfully reduced their rejection rates by the third highest percentage from 2024 to 2025 were Sampang Regency (13.57% to 2.38%), Situbondo Regency (25.2% to 16.4%), and Pamekasan Regency (14.01% to 8.02%).

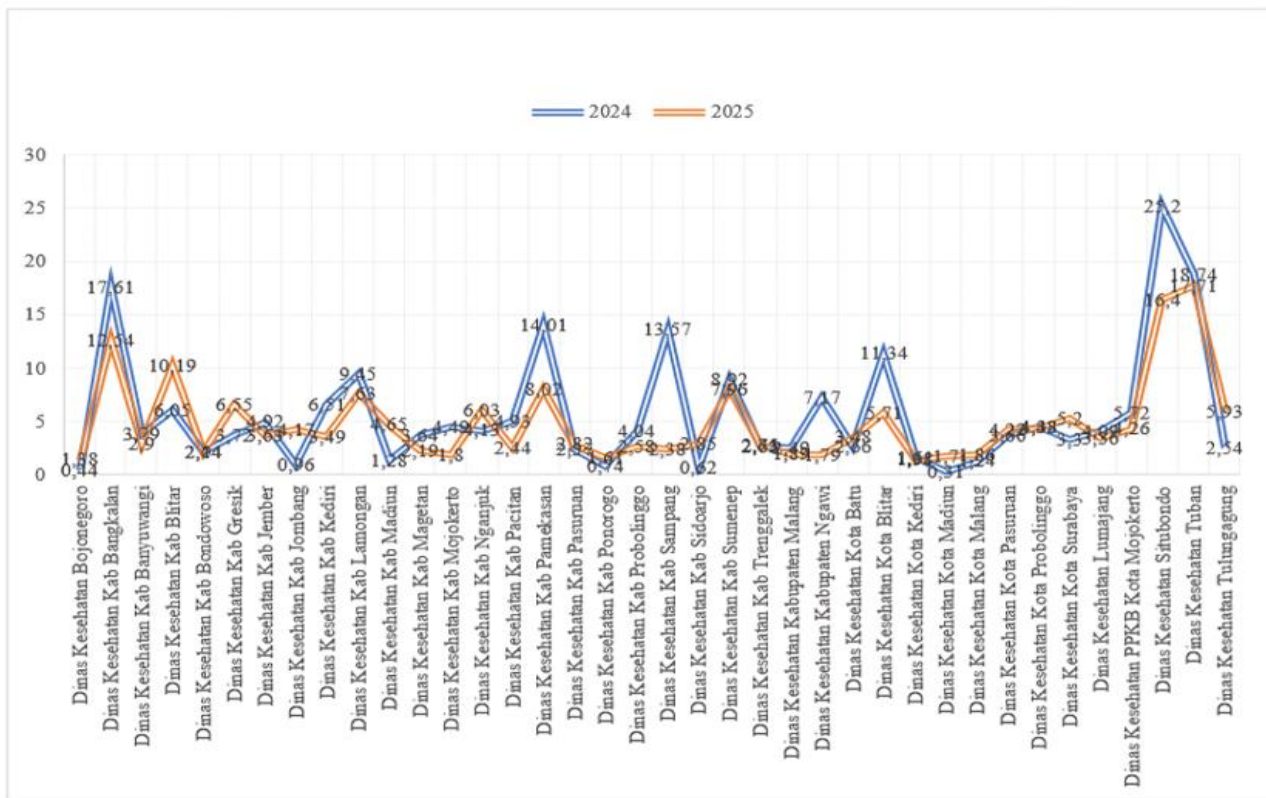


Figure 2. Rejection rate (%) comparison in 2024 and 2025 from Each District and City in East Java, Indonesia (Swalab Aplication of Dr. Soetomo General Academic Hospital Surabaya Indonesia)

Table 1. Comparison of DBS sample rejections and acceptances per district (2024 vs. 2025)

Variable	Year	N (districts)	Median (IQR)	p*
Total rejected	2024	38	373.00 (140.00-1789.00)	0.004
	2025	38	359.50 (48.00-1847.00)	
Total accepted	2024	38	8132.00 (2127.00-28722.00)	0.004
	2025	38	9161.50 (1332.00-28906.00)	
Rejection rate (%)	2024	38	4.07 (0.32-33.69)	0.243
	2025	38	3.61 (1.40-21.52)	

Note. *Wilcoxon signed-rank test

A comparison of the rejection rates of 38 cities and regencies in East Java Province in 2024 and 2025 is shown in **Figure 2**.

Table 1 showed median rejection rate across cities/regencies that decrease in 2024 and 2025 from 4.07% to 3.61%. It was not statistically significant ($p = 0.243$). Rejected specimens median absolute number per cities/regencies decreased from 373.0 to 359.5 significantly ($p = 0.004$). The median number of specimens accepted increased significantly. These findings are not contradictory because the total screening volume increased by 7.0% from 2024 to 2025. The changes in absolute numbers and proportional rejection rates reflect different denominators. It need to be interpreted separately. Significant decreases in the rejection rate were observed in January ($p = 0.003$), February ($p < 0.001$), and June ($p = 0.023$). These changes were not statistically significant in the other months (**Table 2**).

Sub-Analysis of Rejected Samples

The median gestational age was 39 weeks for rejected samples in both years, with no significant difference ($p = 0.517$). The median birth weight of infants with rejected samples was significantly lower in 2024 (3,000 g, range 750-4,700) compared

Table 2. Monthly comparison of DBS rejection rates (%), 2024 vs. 2025

Month	2024 median % rejection (IQR)	2025 median % rejection (IQR)	p*
January	5.13 (0.42-21.54)	1.87 (0.00-21.01)	0.003
February	4.51 (0.00-26.37)	1.82 (0.00-17.95)	< 0.001
March	3.91 (0.00-27.33)	2.32 (0.00-21.54)	0.249
April	4.02 (0.00-25.78)	2.75 (0.00-18.93)	0.789
May	3.31 (0.00-28.60)	4.08 (0.16-19.20)	0.446
June	3.22 (0.00-28.35)	2.77 (0.00-15.33)	0.163**
July	3.45 (0.00-29.63)	4.47 (1.55-21.72)	0.204
August	3.51 (0.00-26.19)	5.21 (1.89-22.34)	0.109
September	2.21 (0.00-29.02)	3.69 (0.65-19.21)	0.232
October	2.72 (0.00-33.14)	3.13 (0.00-16.47)	0.822
November	2.93 (0.00-32.50)	2.12 (0.00-15.54)	0.071
December	2.32 (0.00-22.59)	1.94 (0.00-19.89)	0.722

Note. *Wilcoxon signed-rank test comparing 2024 and 2025 for each month & **the p for the corresponding "acceptance" rate in June was significant ($p = 0.023$)

to 2025 (3,045 g, range 500-5,230) ($p = 0.036$). The distribution of sex ($p = 0.669$) and plurality ($p = 0.169$) among rejected samples did not differ significantly between the two years (**Table 3**).

The distribution of rejection reasons changed significantly between 2024 and 2025 ($p < 0.001$). The most notable changes were "too small (< 8 mm)", decreased sharply from 16.8% ($n = 88$) of all rejections in 2024 to just 7.9% ($n = 32$) in 2025. "Multi-spotted" decreased from 12.0% ($n = 63$) to 4.9% ($n = 20$). "Lysis" (hemolysis) increased substantially from 20.0% ($n = 105$) to 29.2% ($n = 119$), becoming the second most common reason in 2025. "Not completely soaked" remained the most common reason, increasing slightly from 48.7% to 53.1%. (**Table 3** and **Figure 3**).

Table 3. Demographic and clinical characteristics of neonates with rejected DBS samples (N = 931)

Parameter	Total (N = 931)	2024 (N = 524)	2025 (N = 407)	p
Gestational age (weeks), median (range)	39 (20-43)	39 (20-43)	39 (24-42)	0.517 ^a
Birth weight (grams), median (range)	3,000 (500-5,230)	3,000 (750-4,700)	3,045 (500-5,230)	0.036^a
Sex, n (%)				0.669 ^b
Male	489 (52.5)	272 (51.9)	217 (53.3)	
Female	442 (47.5)	252 (48.1)	190 (46.7)	
Plurality, n (%)				0.169 ^b
Singleton	917 (98.5)	514 (98.1)	403 (99.0)	
Twin	13 (1.4)	10 (1.9)	3 (0.7)	
Triplet +	1 (0.1)	0 (0.0)	1 (0.2)	
Reason for rejection, n (%)				< 0.001^b
Too small (< 8 mm)	120 (12.9)	88 (16.8)	32 (7.9)	
Compressed	6 (0.6)	2 (0.4)	4 (1.0)	
Clotting	20 (2.1)	10 (1.9)	10 (2.5)	
Multi-spotted	83 (8.9)	63 (12.0)	20 (4.9)	
Not completely soaked	471 (50.6)	255 (48.7)	216 (53.1)	
Lysis (hemolysis)	224 (24.1)	105 (20.0)	119 (29.2)	
Broken	7 (0.8)	1 (0.2)	6 (1.5)	

Note. ^aMann-Whitney U test & ^bChi-square test

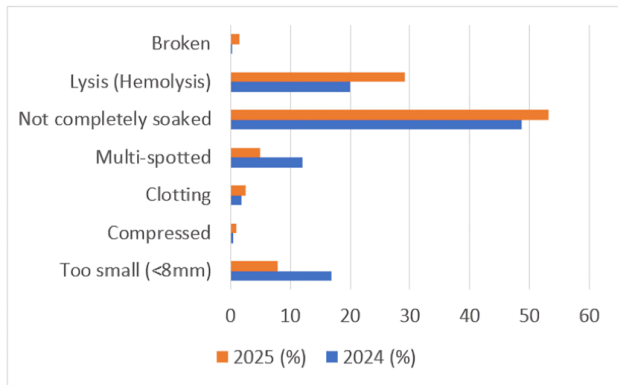


Figure 3. Comparison of DBS sample rejection categories East Java neonatal screening program 2024 vs. 2025 (created by the authors using the original research data, 2026)

A comparison of all rejected samples by sex revealed a significant difference in birth weight. Female infants with rejected samples had a significantly lower median birth weight (3,000 g, IQR: 750-4,700) compared to male infants with rejected samples (3,080 g, IQR: 500-5,230) ($p = 0.005$). No other significant differences were found between males and females regarding year of rejection, plurality, or the distribution of rejection causes (**Table 4**).

DISCUSSION

This study presents an analysis of DBS sample quality in a large-scale neonatal screening program. During the two-year evaluation of East Java's NBS expansion, total screening volume rose by 7.0% alongside a significant reduction in median district-level absolute rejections ($p = 0.004$), even

Table 4. Comparison of neonatal characteristics by sex among rejected DBS samples (N = 931)

Parameter	Male (N = 489)	Female (N = 442)	p
Gestational age (weeks), median (range)	39 (24-43)	39 (20-43)	0.648 ^a
Birth weight (grams), median (range)	3,080 (500-5,230)	3,000 (750-4,700)	0.005^a
Year, n (%)			0.669 ^b
2024	272 (55.6)	252 (57.0)	
2025	217 (44.4)	190 (43.0)	
Reason for rejection, n (%)			0.789 ^b
Too small (< 8 mm)	58 (11.9)	62 (14.0)	
Compressed	2 (0.4)	4 (0.9)	
Clotting	11 (2.2)	9 (2.0)	
Multi-spotted	43 (8.8)	40 (9.0)	
Not completely soaked	245 (50.1)	226 (51.1)	
Lysis (hemolysis)	126 (25.8)	98 (22.2)	
Broken	4 (0.8)	3 (0.7)	

Note. ^aMann-Whitney U test & ^bChi-square test

though the overall rejection rate remained statistically stable ($p = 0.243$). These data indicate significant progress in the overall quality and efficiency of the preanalytical phase, as reducing rejections means fewer babies needing retesting, resulting in faster time to diagnosis, reduced morbidity and mortality, and improved health care delivery. However, the stable rejection percentage underscores that program expansion presents ongoing challenges, requiring sustained efforts to further reduce the error rate [9]. Furthermore, individual-level data analysis highlights the importance of designing next-generation interventions, where significant shifts in error types provide critical insights.

The significant reduction in “too small (< 8 mm)” and “double spot” samples from 2024 to 2025 is evidence of success. These errors are known to be classic indicators of inexperienced/in hasty drawing, resulting in failure to fill the loop completely or attempting to layer blood to compensate for an insufficient first drop. The significant improvements in these specific categories strongly suggest that the basic training on “how to fill a circle” has been effective and has reached a large number of midwives and sample collectors. The significant improvements seen in January, February, and June may well correlate with the timing of such training cycles.

However, the opposite trend is occurring with a significant increase in the number of samples rejected due to “lysis” (hemolysis). This phenomenon is a major cause for concern. This suggests that as collectors have mastered the basics of filling a circle, new or different errors are emerging. Hemolysis in DBS samples is often caused by excessive squeezing of the heel, prolonged contact with alcohol used for antisepsis before it dries, or improper drying and transport of the sample card. This finding indicates that training programs must now evolve beyond the fundamentals. They must incorporate more advanced content on proper capillary blood collection technique to prevent hemolysis, as well as reinforce correct post-collection handling.

Demographic analysis of rejected samples found that, in 2024, rejected samples came from infants with a statistically significantly lower birth weight. This suggests that sample collectors face greater challenges with smaller, potentially more vulnerable newborns. It may be technically more difficult to obtain adequate capillary samples from low birth weight

Table 5. Multidimensional quality improvement framework applied to East Java NBS program

Dimension	Quality indicator	2024 finding	2025 finding	Interpretation & action
Structural	Inter-district range of rejection rates	0.44%-25.20%	1.38%-17.71%	Persistent disparity; requires targeted infrastructure/logistics support for outliers
Process (basic)	% rejections due to “too small”	16.8%	7.9%	Success: Basic training effective
Process (advanced)	% rejections due to “lysis”	20.0%	29.2%	Emerging challenge: Training must evolve to address hemolysis
Outcome	Median rejection rate (IQR)	4.07% (0.32-33.69)	3.61% (1.40-21.52)	Modest, non-significant improvement; next gains require advanced interventions
Patient-level	Birth weight difference (rejected samples, 2024 vs. 2025)	3,000 g	3,045 g (p = 0.036)	LBW infants may have been at higher risk in 2024; improvement seen in 2025

(LBW) infants without excessive pressure on their feet (which can cause hemolysis, edema, or injury). The fact that this difference disappeared in 2025 may indicate an increased awareness and skill in handling LBW infants, possibly as a result of the same training that reduced the “too small” errors.

The sex-based analysis provides a further, and somewhat surprising, insight. Among all rejected samples, female infants had a significantly lower birth weight than males. Given that male newborns are, on average, heavier than females, this finding may simply reflect the normal physiological distribution. However, it raises the question of whether the very smallest and most vulnerable infants (who are disproportionately female) are at the highest risk of sample rejection. This hypothesis requires further research, as delayed CH diagnosis has been shown to have more severe consequences in this group.

The persistent and wide variability in data between districts highlights a major issue. The gap between the best- and worst-performing districts is substantial. The data show that some districts consistently had refusal rates above 10% in both years. This is not a new phenomenon in NBS. Several studies from other LMICs have also identified geographic and infrastructure differences that contribute to preanalytical errors, such as inadequate transportation of samples and lack of trained personnel, which can exacerbate refusal rates in NBS [10-12]. Districts/cities in East Java with consistently high rates of rejection, such as Situbondo, Tuban, and Bangkalan, likely face systemic challenges. Such issues could be due to a higher proportion of rotation of health workers, greater difficulty in transporting samples from remote areas to health facilities, or a higher turnover rate of health staff responsible for sample collection.

The analysis by month reveals important insights into the timing and potential drivers of quality improvement. The significant increase in January and February 2025 compared to the same period in 2024 is particularly noteworthy. This may be related to the scheduling of the NBS refresher training program. This improvement is indicated by the fact that the East Java Health Office or partner organizations held large-scale training sessions for midwives and sample collectors in late 2024, with the most visible impact in the following months, namely, early 2025. This “training effect” appears to wane in March, as subsequent months did not show significant improvements. A similar trend occurred in June, which may also correlate with a separate mid-year training cycle (early June is the month of the NBS campaign) or a specific quality improvement campaign.

Table 5 shows the operational strategies identified from the analysis to reduce sample rejections and increase coverage in NBS across districts. First, monitoring and improved resource allocation should be focused on districts/cities with

consistently lower performance than expected targets and compared to other districts. The goal is to better understand the situation on the ground and better address operational challenges in these districts. Second, disseminating practical guidelines and tools for DBS collection is crucial, particularly for premature and low-birth-weight infants. The challenges in collecting samples in these cases are greater than in full-term infants.

This study demonstrates the importance of implementing a continuous quality improvement (CQI) approach, which involves not only one-time or episodic training but also a system that incorporates regular performance feedback, peer learning, and short, periodic educational reinforcement activities. More appropriate corrective action will be achieved by implementing a structured system for detailed root cause analysis of rejected samples and systematically documenting and categorizing the underlying causes of rejections. Finally, the research data concludes that there is a need for digital device integration, including the exploration of mobile health (mHealth) applications that can facilitate timely training, provide checklist guidance, and enable real-time photo-based quality verification of DBS cards before they are sent to the laboratory, thus reducing rejection rates in the future. These programmatic measures collectively reflect the operational responses derived from the data analysis to strengthen the overall quality of the screening process (**Table 5**).

The lack of significant improvement over most of the year (9 out of 12 months) highlights the important lesson that episodic training is not sufficient to maintain high-quality performance, necessitating ongoing local (primary healthcare center) training for midwives/traditional midwives. The data suggest a “decay” in skills or knowledge over time. This aligns with implementation science principles, which advocate for CQI methodologies, including regular audits, feedback loops, on-site mentoring, and low-dose, high-frequency refresher education, rather than one-off training events [13, 14].

From a laboratory perspective, these findings demonstrate the importance of monitoring preanalytical quality indicators. The DBS rejection rate is the best and most easily measured metric, reflecting the effectiveness of the entire screening chain, from collection to transport. District-specific and monthly data, when combined with local health offices, can foster ownership and motivate targeted interventions. For example, districts with consistently high rejection rates should be prioritized for supportive surveillance and root cause analysis.

This study has several limitations. Individual-level data may not be fully representative. The limitation is because we were unable to link rejected samples to specific districts of origin or health facility types, which would have allowed us to contextualize demographic findings with district-level

performance data. Reasons for rejection were based on laboratory staff assessments of the samples, and although standardized, some degree of subjectivity may exist.

CONCLUSION

The two-year evaluation of East Java's NBS expansion demonstrates substantial program progress, marked by a significant reduction in the absolute number of rejected samples alongside a 7% increase in screening coverage. However, marked inter-district disparities and monthly performance fluctuations indicate that expanding coverage alone is insufficient without sustained quality control. Addressing these gaps requires transitioning from episodic training to a CQI framework—incorporating targeted oversight for high-rejection districts, tailored protocols for vulnerable low-birth-weight infants, and digital tools for real-time sample verification prior to transport. Ultimately, strengthening these operational mechanisms is critical to minimizing preventable preanalytical errors, accelerating time to diagnosis, and ensuring the long-term sustainability of large-scale neonatal screening in low- and middle-income settings.

Author contributions: **FAA:** conceptualization, data curation, formal analysis, investigation, project administration, software, writing – original draft, writing – review & editing & **FRM:** conceptualization, formal analysis, investigation, methodology, project administration, resources, software, supervision, validation, visualization, writing – original draft, writing – review & editing. Both authors have agreed with the results and conclusions.

Funding: No funding source is reported for this study.

Acknowledgments: The authors would like to thank Vita Ratnasari from Central Laboratory, Dr. Soetomo General Hospital for her support in processing the samples, Dr. Hartono Kahar for substantial support as a NBS team for Dr. Soetomo General Academic Hospital and East Java Province.

Ethical statement: This study was approved by the Health Research Ethics Committee of Dr. Soetomo Surabaya Academic Hospital (Ref No: 1608/LOE/301.4.2/III/2024). The Ethics Committee waived the need for consent because our study was considered retrospective.

AI statement: The authors declared that no generative AI or AI-assisted technologies were used in the preparation, writing, analysis, or creation of this manuscript and its accompanying work.

Declaration of interest: No conflict of interest is declared by the authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

REFERENCES

- Rose SR, Wassner AJ, Wintergerst KA, et al. Congenital hypothyroidism: Screening and management. *Pediatrics*. 2023;151(1):e2022060419. <https://doi.org/10.1542/peds.2022-060419> PMID:36827523
- Nordin N, Ab Rahim SN, Wan Omar WFA, et al. Preanalytical errors in clinical laboratory testing at a glance: Source and control measures. *Cureus*. 2024;16(3):e57243. <https://doi.org/10.7759/cureus.57243>
- George RS, Moat SJ. Effect of dried blood spot quality on newborn screening analyte concentrations and recommendations for minimum acceptance criteria for sample analysis. *Clin Chem*. 2016;62(3):466-75. <https://doi.org/10.1373/clinchem.2015.247668> PMID:26647314
- Mesganaw B, Hassen F, Molla H, Misganaw K. Laboratory specimen rejection rate and associated factors among referred specimens at Debre Markos Referral Hospital, Ethiopia: Prospective cross-sectional study. *Pan Afr Med J*. 2024;47:112. <https://doi.org/10.11604/pamj.2024.47.112.33795> PMID:38828425 PMCID:PMC11143071
- Dantonio P, Tavakoli NP, Migliore B, et al. Multi-laboratory evaluation of prototype dried blood spot quality control materials for creatine kinase-MM newborn screening assays. *Int J Neonatal Screen*. 2023;9(1):13. <https://doi.org/10.3390/ijns9010013> PMID:36975851 PMCID:PMC10053407
- Moat SJ, Bonham JR, Cavanagh C, et al. Consistency in the assessment of dried blood spot specimen size and quality in U.K. Newborn screening laboratories. *Int J Neonatal Screen*. 2024;10(3):60. <https://doi.org/10.3390/ijns10030060> PMID:39311362 PMCID:PMC11417764
- Moat SJ, Levi M, Birch M, et al. The effect of inadequate drying of blood spots on newborn screening analyte concentrations. *Ann ClinBiochem*. 2025;62(6):473-8. <https://doi.org/10.1177/00045632251337608> PMID:40220017
- CLSI. NBS01-A6 blood collection on filter paper for newborn screening programs; approved standard. 6th Ed. Wayne, PA: Clinical and Laboratory Standards Institute; 2013.
- Therrell BL, Padilla CD, Loeber JG, et al. Current status of newborn screening worldwide: 2015. *Semin Perinatol*. 2015;39(3):171-87. <https://doi.org/10.1053/j.semperi.2015.03.002> PMID:25979780
- Berhan A, Sharew B, Almwaw A, et al. Types and frequency of preanalytical errors occurring in the hematology laboratory at Debre Tabor comprehensive specialized hospital, North Central, Ethiopia, 2025. *Sci Rep*. 2026;16(1):7300. <https://doi.org/10.1038/s41598-026-38458-y> PMID:41639323 PMCID:PMC12923850
- Giugliani R, Taucher CS, Hafez S, et al. Opportunities and challenges for newborn screening and early diagnosis of rare diseases in Latin America. *Front Genet*. 2022;13:1053559. <https://doi.org/10.3389/fgene.2022.1053559> PMID:36568372 PMCID:PMC9773081
- Lillo R, Salinas M, López-Garrigós M, Cruz L, López-Pérez J, Uris J. Variability of preanalytical errors between decentralized phlebotomy centers: A challenge for patient safety. *Enferm Clin*. 2010;20(1):36-9. <https://doi.org/10.1016/j.enfcli.2009.07.009> PMID:19854666
- Pantoja T, Opiyo N, Lewin S, et al. Implementation strategies for health systems in low-income countries: An overview of systematic reviews. *Cochrane Database Syst Rev*. 2017;9(9):CD011086. <https://doi.org/10.1002/14651858.CD011086.pub2> PMID:28895659
- Devis L, Catry E, Honore PM, et al. Interventions to improve appropriateness of laboratory testing in the intensive care unit: A narrative review. *Ann Intensive Care*. 2024;14(1):9. <https://doi.org/10.1186/s13613-024-01244-y> PMID:38224401 PMCID:PMC10789714