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Trends and patterns of laboratory utilization in a community hospital: A 10-year retrospective study for rational laboratory utilization development

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ABSTRACT

Background: Irrational use of laboratory services directly impacts hospital resources and financial management, particularly in community hospitals with limited resources. Analyzing long-term trends is a crucial first step in developing strategic policies for Rational Laboratory Utilization (RLU).

Objectives: To investigate trends in laboratory testing frequency and expenditure at Khok Pho Hospital and to analyze utilization patterns over a decade (2013-2022).

Materials and methods: A retrospective descriptive study using aggregate secondary data from the laboratory information system (LIS). Data were analyzed using descriptive statistics, Pareto analysis, simple linear regression for trend analysis, and the Pearson correlation coefficient to examine the relationship between the number of patients and test volume and cost.

Results: Over the ten years, total laboratory test volume increased by 79.1%, rising from 125,865 tests in 2013 to 225,400 tests in 2022. Total laboratory service costs increased 2.07-fold compared with the base year. Linear regression demonstrated significant increasing trends in both test volume ($\beta=12,083$ tests/year, $R^2=0.829$, $p<0.001$) and total expenditure ($\beta=1.32$ million THB/year, $R^2=0.918$, $p<0.001$). After test volume peaked in 2021 due to the expansion of COVID-19 screening, volume declined in 2022 to 225,400 tests, reflecting post-pandemic normalization. Pareto analysis showed that a small number of tests accounted for most total expenditure, particularly HbA1c and lipid profile testing. The number of patients tested correlated strongly with both test volume ($r=0.90$) and total cost ($r=0.95$, both $p<0.001$), indicating that growth in service users was a key driver of rising laboratory costs. The proportion of off-hour workload increased from 23.5% to 26.8%.

Conclusion: Laboratory utilization has grown steadily, driven by the prevalence of chronic diseases and the impact of COVID-19. These findings support implementing Rational Laboratory Utilization policies that focus on high-cost tests and optimize off-hour ordering to improve cost efficiency in community hospitals.

Introduction

Medical laboratory testing constitutes a fundamental component of healthcare systems, supporting more than 70% of clinical decision-making.^{1,2} However, the rapid growth in test ordering has become a global challenge. Meta-analytic evidence indicates that inappropriate testing-encompassing both overutilization and underutilization-occurs at rates of 20-50% across diverse settings,^{3,4} adversely affecting not only budgetary allocation but also patient-care quality and resource-management efficiency.⁵

In Thailand, healthcare expenditure has risen continuously, consistent with National Health Security Office statistics,⁶ particularly in community hospitals operating under limited budgetary and personnel constraints. Khok Pho Hospital is a 60-bed community hospital located in the southern border region of Pattani Province and serves a population with a high prevalence of non-communicable diseases (NCDs). Laboratory workload and costs have expanded substantially over the past decade. Total test volume increased by more than 79%, and cumulative expenditure more than doubled compared with the base year (2013), driven by NCD management demands and the COVID-19 pandemic response.

The Ministry of Public Health, through the Department of Medical Sciences, has promoted the Rational Laboratory Use (RLU) policy to enhance diagnostic value and reduce unnecessary expenditure.⁷ A community-hospital case study from Lamphun Hospital reported that implementation

of an RLU system, supported by utilization data, clinical practice guidance, and multidisciplinary processes, was associated with improvements in selected laboratory-ordering indicators.⁸ Diagnostic stewardship provides a complementary framework for improving the appropriateness of test ordering and resource utilization.⁹ However, successful local-level RLU implementation requires rigorous baseline data to identify utilization patterns and priority problems before interventions are designed.

The investigators therefore conducted a 10-year retrospective analysis of laboratory test frequency and expenditure at Khok Pho Hospital to establish an evidence base for developing a rational test-ordering system and supporting the institution's financial sustainability. The objectives were: 1) to investigate the frequency of laboratory test ordering at a community hospital over 10 years (2013-2022), 2) to analyze the expenditure burden associated with laboratory testing over the same period, and 3) to examine temporal utilization patterns as baseline evidence for developing an RLU system.

Materials and methods

Study design

This retrospective descriptive study used aggregate secondary data extracted from Khok Pho Hospital Laboratory Information System (LIS). The data contained no individual patient identifiers and therefore posed no privacy risk. This study followed the Strengthening the Reporting of Observational Studies

in Epidemiology (STROBE) guidelines for descriptive/cross-sectional studies.¹⁰

Population and data source

The study population comprised all laboratory test records entered in the hospital LIS between 2013 and 2022, analyzed as a complete census.

Records were included if they contained complete documentation, encompassing test type, test volume, service cost, and time of ordering. Conversely, records were excluded if they were canceled or lacked complete volume or service-cost data.

Data collection and quality control

Aggregate annual reports were exported from the LIS, classified by department, test item, total test count, total service cost, and work shift (00:00-07:59 am, 08:00 am-15:59 pm, and 16:00-23:59 pm). The medical technologist responsible for the data, together with the head of the medical technology section, cross-validated the raw data against the laboratory's annual statistical reports. Where discrepancies were identified between the LIS data and the original statistical reports, the records were traced back to the laboratory's source records, reconciled, and corrected before analysis. In addition, the investigators compiled the number of patients with at least one laboratory test order each year (2013-2022) to analyze the relationship between patient numbers and test volume and cost using the Pearson correlation coefficient.

Statistical analysis

Data were analyzed both overall and with COVID-19-related tests excluded from the dataset to assess the pandemic's impact on long-term trends. Analyses were performed using R version 4.3.2 (R Foundation for Statistical Computing, Vienna, Austria). Descriptive statistics included percentages, means, and the compound annual growth rate (CAGR). Pareto analysis was used to identify the "vital few" tests accounting for the highest utilization. Simple linear regression was applied for trend analysis, reporting the slope coefficient (β), coefficient of determination (R^2), and two-tailed p-value to evaluate the direction and strength of trends; statistical significance was set at $p < 0.05$. The proportion of off-hour workload was compared with routine-hour workload for each year.

Laboratory service costs were calculated using charge-based costing according to the public-health service-rate announcements of the Ministry of Public Health and the Comptroller General's Department, Ministry of Finance,¹¹ which were revised twice during the study period (2013-2022): the 2017 announcement¹² and the 2019 announcement.¹³ To eliminate the effect of tariff changes during the study period on the reported cost trend, all costs were calculated using fixed prices from the most recent announcement as the basis for retrospective calculation across the full 10 years,¹⁴ as shown in Table 1.

Table 1. Unit price comparison of the top 10 laboratory tests across four MoPH tariff announcements (2004, 2017, 2019, 2025).

Test	Code	2004 (THB)	2017 (THB)	2019 (THB)	2025 (THB)	Net change over study period
CBC	30101	90	90	90	90	No change
FBS/Glucose	32203	40	40	40	40	No change
Creatinine	32202	50	50	40	40	Decreased 10 THB (-20%)
Lipid profile	32004	200	200	200	200	No change
Electrolytes	32001	80	80	100	100	Increased 20 THB (+25%)
BUN	32201	50	50	40	40	Decreased 10 THB (-20%)
ALT (SGPT)	32311	50	50	40	40	Decreased 10 THB (-20%)
HbA1c	32401	150	150	150	150	No change
Uric acid	32205	60	60	60	60	No change
UA (urinalysis)	31001	50	50	60	60	Increased 10 THB (+20%)

As shown in Table 1, the two highest-volume tests (CBC and FBS) and the two tests with the highest cumulative cost (HbA1c and lipid profile) had constant prices across all four announcement periods, while the remaining tests changed only slightly (± 10 -20 THB) in partially offsetting directions. The costs reported in this study should therefore be interpreted as a standardized cost indicator rather than the hospital's actual annual reimbursement. To support the design of Rational Laboratory Utilization (RLU) policy, the investigators classified the "RLU priority" of each laboratory test into four levels-low, medium, high, and critical-using a Volume-Cost Matrix as the classification framework.

The quadrant boundaries were defined by the mean volume and the mean 10-year cumulative cost of the top 10 tests. Tests with below-average volume but above-average cost were designated the primary RLU targets; within this group, the test with the highest cumulative cost was classified as critical and the others as high. Tests with both above-average volume and above-average cost were classified as medium, as they are workload drivers that warrant monitoring rather than restriction, whereas tests with below-average cost were classified as low regardless of volume. The classification also considered clinical importance and whether the test is included in clinical practice

guidelines for NCDs and other significant conditions. The RLU priority classification is intended to serve as a framework for identifying tests that should receive governance and policy development first, rather than to judge the quality of any individual laboratory test.

Results

Trends in laboratory test volume (2013-2022)

Figure 1 summarizes annual test volume and service costs from LIS data spanning 2013 to 2022.

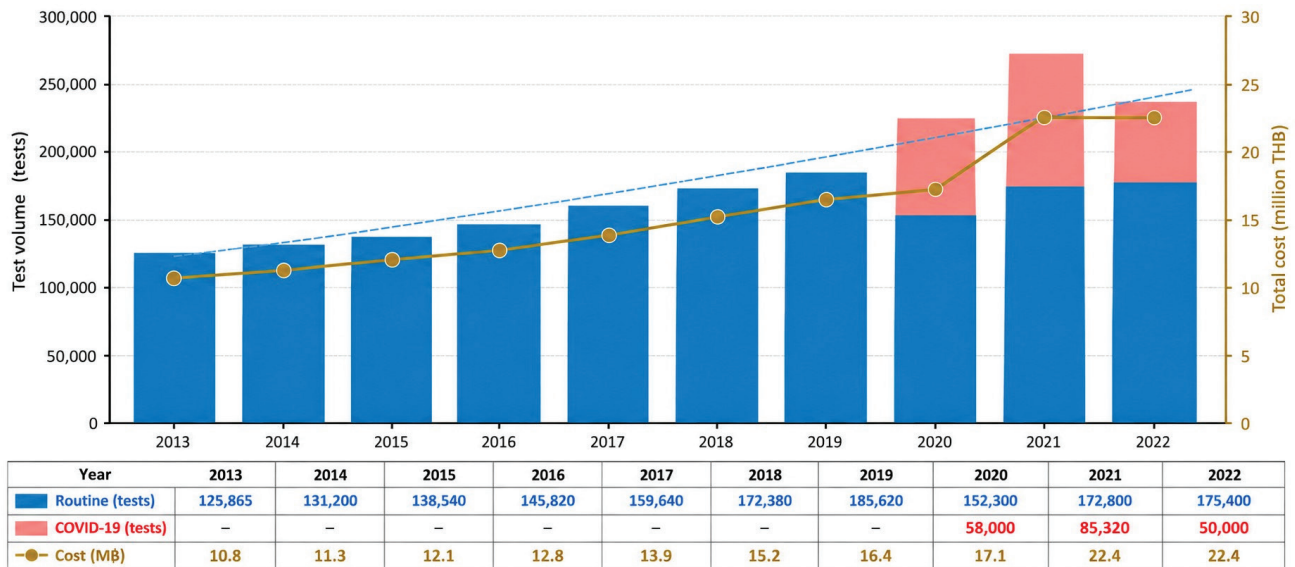


Figure 1. Annual laboratory test volume and total cost trend, 2013- 2022.

Over the decade, total laboratory test volume increased continuously. During the first seven years (2013-2019), volume grew at approximately 5-7% per year. The COVID-19 pandemic period (2020-2021) produced a marked surge, with test volume peaking at 258,120 in 2021, a 39% increase over the previous year. Linear regression confirmed a significant upward volume trend over the full decade ($\beta=12,083$ tests/year, $R^2=0.829$, $p<0.001$). The mean cost per test rose from 86.17 THB (2013) to 108.91 THB (2021), and total service costs increased at $\beta=1.32$ million THB/year ($R^2=0.918$, $p<0.001$), reflecting the higher unit cost of biomolecular testing relative to routine assays. When COVID-19-related tests were excluded from the analysis, laboratory test volume during 2020- 2022 declined from 186,040-258,120 to 157,800- 177,800 tests per year, but remained clearly higher than the base-year (2013) volume of 125,865 tests. Meanwhile, tests for NCDs such as HbA1c and lipid profile continued to increase even after COVID-19 tests were removed from the data, indicating that the NCD burden was the principal driver of the growth in laboratory volume and cost rather than the transient effect of the COVID-19 pandemic.

Analysis of the relationship between the number of patients receiving laboratory tests and test volume and cost ($N=10$ years) showed that the number of patients increased from 30,938 in 2013 to 55,361 in 2022, a 78.9% rise that closely paralleled the increase in test volume (79.1%). Correlation analysis showed that the number of patients was significantly and positively correlated with both test volume ($r=0.90$, $p<0.001$) and total cost ($r=0.95$, $p<0.001$). Because both series followed a monotonic upward trend over the study period, this correlation reflects a shared long-term pattern rather than a direct causal link, but nonetheless indicates that the growing number of service users was closely associated with rising laboratory workload and expenditure. The mean number of tests per patient ranged from 3.7 to 4.3 tests/patient/year before the pandemic, rose temporarily to 5.5 tests/patient/year in 2020, and then decreased to 4.1 tests/patient/year in 2022.

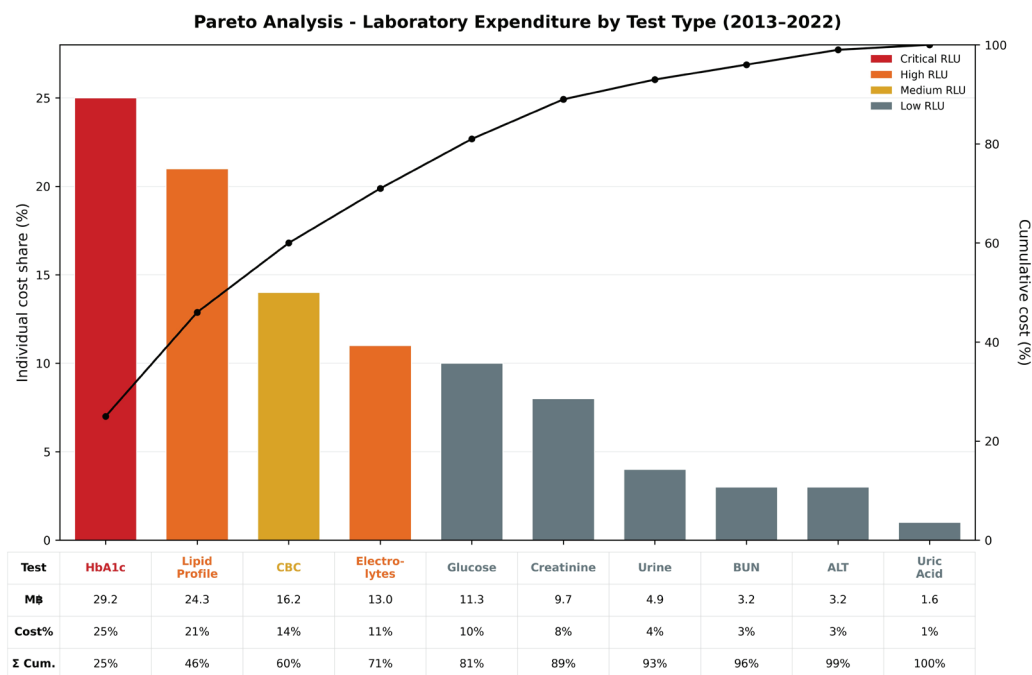
Analysis of laboratory expenditure and cost burden

The tests with the highest cumulative volume and expenditure were analyzed using Pareto analysis, as shown in Table 2 and Figure 2.

Table 2. Top 10 laboratory tests-Volume-Cost Matrix and RLU priority classification (2013-2022).

Volume rank	Test name	10-year volume	Volume (%)	Cost (M THB)	Cost (%)	Cost rank	RLU priority
1	Complete blood count (CBC)	384,870	22.5	16.2	10.0	3	Medium
2	Glucose (FBS)	314,890	18.4	11.3	7.0	6	Low
3	Creatinine	262,410	15.3	9.7	6.0	7	Low
4	Urinalysis (UA)	174,940	10.2	4.9	3.0	9	Low
5	Lipid profile (Chol/TG/HDL/LDL)	139,950	8.2	24.3	15.0	2	High
6	BUN	122,460	7.1	3.2	2.0	10	Low
7	Electrolytes (Na/K/Cl/CO ₂)	104,960	6.1	13.0	8.0	4	High
8	ALT (SGPT)	87,470	5.1	3.2	2.0	11	Low
9	HbA1c	69,970	4.1	29.2	18.0	1	Critical
10	Uric acid	52,480	3.1	1.6	1.0	12	Low
*	SARS-CoV-2 Ag (COVID era 2020-2022)	45,000	2.6	18.5	11.4	1**	Critical**
Top 10 total		1,714,400		116.6	72.0		

Note: *SARS-CoV-2 Ag data were recorded only during 2020-2022. **RLU priority depends on the epidemiological context; Volume % is calculated from the total top 10 volume (N=1,714,400); Cost % is calculated from the 10-year cumulative expenditure; RLU priority classification follows the Volume-Cost Matrix principle.

**Figure 2.** Pareto analysis of laboratory expenditure by test type at Khok Pho Hospital, 2013-2022.

Pareto analysis (Figure 2) showed that the critical-to-high-priority group (HbA1c, lipid profile, and electrolytes) accounted for 41% of total 10-year expenditure, confirming the Pareto principle^{15,16} whereby

a minority of tests drives most budget consumption. To compare the dynamics of the chronic (NCD) burden with the acute burden from the pandemic, Figure 3 presents annual expenditure for both categories.

Figure 3 illustrates that NCD-related expenditure increased steadily throughout the study period ($\beta=0.81$ million THB/year, $R^2=0.921$, $p<0.001$), whereas

COVID-19 testing generated a pronounced cost spike during 2020–2021 before subsiding.

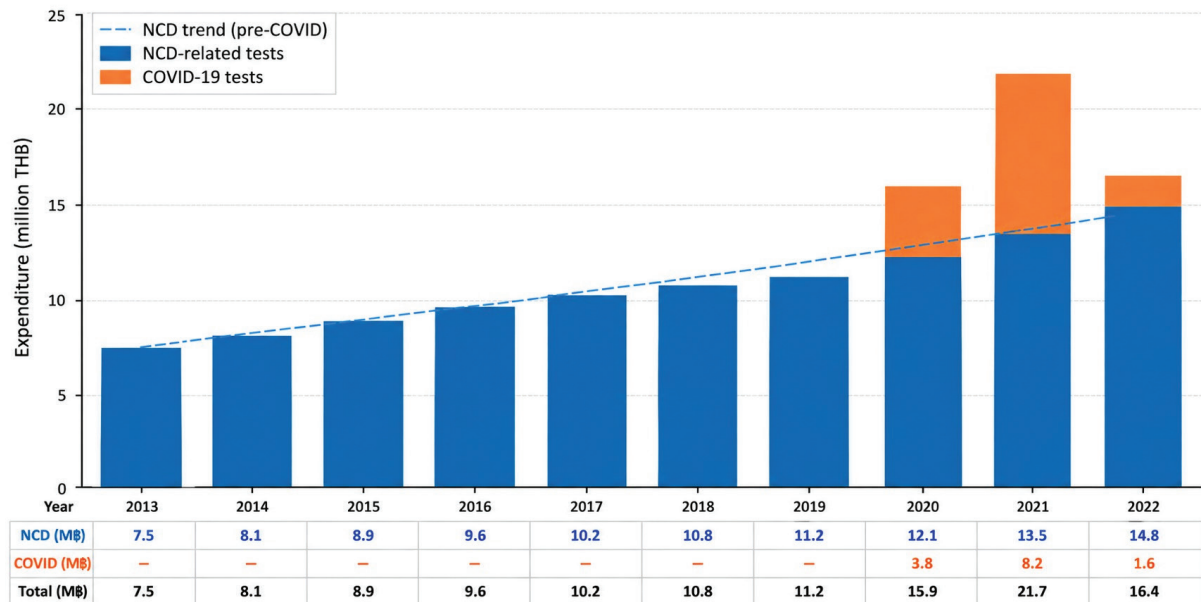


Figure 3. Annual laboratory expenditure comparing NCD-related tests and COVID-19 testing, 2013-2022.

Temporal trends and longitudinal utilization patterns

The cumulative workload and expenditure of the top 10 tests (2013-2022) were plotted on a Volume–Cost Matrix (Figure 4) to prioritize RLU targets.

Figure 4 shows that HbA1c and lipid profile occupy the upper-left quadrant (low volume/high cost) and were designated the primary RLU targets (Priority 1). CBC lies in the upper-right quadrant (high volume/high cost), representing a high-workload driver that warrants monitoring rather than restriction. Pareto analysis confirmed that these 10 tests accounted for 72% of the total 10-year expenditure (116 million of

162 million THB). Notably, HbA1c ranked ninth in volume but had the highest cumulative cost (29.2 million THB), reflecting its high unit cost and frequent repeat testing in the diabetic population. The proportion of off-hour workload trended upward from 23.5% (2013) to 26.8% (2022), peaking at 32.2% in 2021, consistent with round-the-clock COVID-19 screening. Linear regression demonstrated a statistically significant increase over the decade ($\beta=0.65\%/year$, $R^2=0.585$, $p=0.010$); even after the pandemic had subsided, the proportion remained above the pre-pandemic baseline (Figure 5).

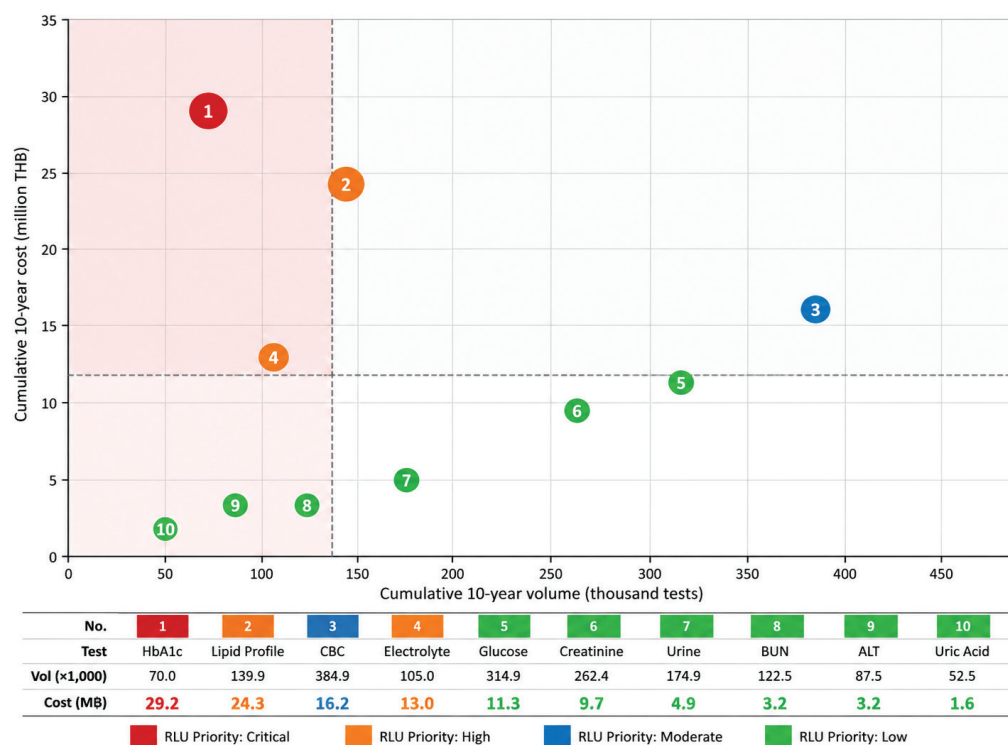


Figure 4. Volume-Cost Matrix: RLU priority classification of laboratory tests, 2013-2022.

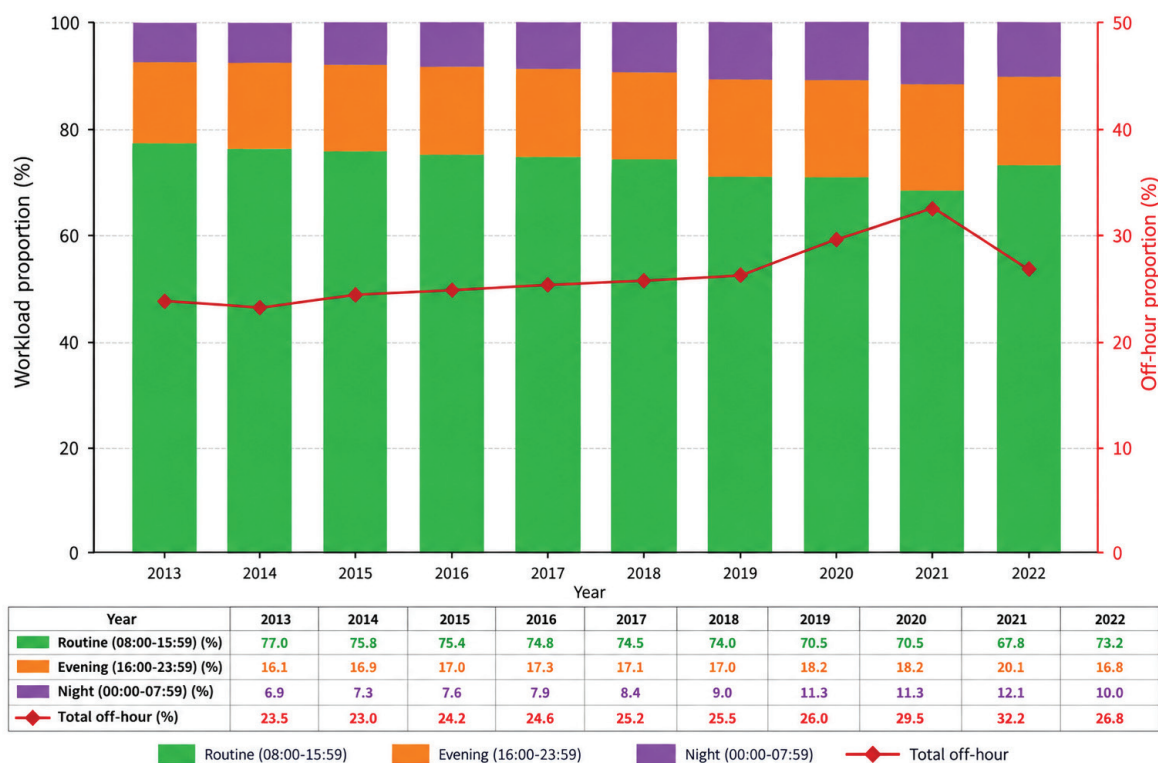


Figure 5. Workload distribution by time interval, 2013-2022.

Temporal rationality analysis of off-hour test ordering

A review of off-hour test-ordering records (evening and night shifts) for 2022 revealed three patterns indicating opportunities for RLU improvement in the community hospital context:

1. Non-urgent chronic-disease monitoring: HbA1c was ordered an average of 24 times per year, and TSH/FT4 seven times per year, during critical-care shifts normally managed by the emergency department. Because these tests monitor disease status over a three-month cycle and do not influence acute management decisions, ordering them during periods of limited staffing constitutes unnecessary workload and contributes to high cumulative expenditure.

2. Pre-analytical interference from improper patient preparation: lipid profiles (cholesterol/TG/HDL/LDL) were ordered on average 18 times per year during 16:00-23:59 pm, contrary to the requirement for a minimum 9-12 hour fast. Such ordering not only wastes laboratory resources but also risks producing analytically unreliable results that cannot support accurate clinical assessment.

3. Elective screening tests that could be scheduled in advance: uric acid was ordered approximately 15 times per year and microalbuminuria five times per year during off-hours, although these tests are used primarily to screen for long-term complications and could readily be scheduled during routine chronic-disease clinic visits. Off-hour ordering of these tests reflects resource use that is incongruent with system-level cost-effectiveness.

Discussion

Analysis of the top 10 tests by cumulative volume over the decade revealed that the laboratory's workload structure is dominated by routine clinical chemistry and hematology tests-CBC, glucose, creatinine, lipid profile, and hepatic/renal function panels. Although individually low in unit cost, these tests are ordered repeatedly in chronic-disease, inpatient, and outpatient populations, producing substantial cumulative expenditure driven by volume. This concentration pattern is consistent with the Pareto principle (80/20 rule),¹⁵ whereby a minority of test types drives the majority of workload and cost. Pareto analysis thus identified the major cost drivers and defined the most strategic targets for RLU intervention.³ These findings indicate that focusing RLU measures on high-cost, vital-few tests will yield greater fiscal impact than applying broad controls across all test categories.¹⁶

In the context of Khok Pho Hospital, aligning the ordering frequency of HbA1c and FBS with national clinical guidelines^{7,8} is a priority action. Applying Diagnostic Stewardship principles^{9,17,18} to regulate the off-hour ordering of non-urgent tests such as lipid profiles would effectively reduce hidden costs-both reagent expenditure and personnel workload-consistent with the transformation of laboratory utilization review into laboratory stewardship^{19,20} and with Value-Based

Healthcare frameworks that aim to maximize health outcomes per unit of expenditure.^{2,21} Comparison with evidence from other settings confirms that NCD-driven long-term expenditure growth is a consistent global pattern, as reported by Zhi *et al.*³ and the Lamphun Hospital case study.⁸ The similar trajectory observed at a southern-border community hospital supports the generalizability of centrally developed RLU frameworks to local community hospital contexts. The reliability of the LIS data used in this analysis is further supported by the accreditation of the Khok Pho Hospital laboratory to the international standards ISO 15189:2012 and ISO 15190:2003,²² and this quality foundation has since been extended to primary-care units across the district, where the STAR Model raised the proportion of units meeting laboratory quality criteria from 14.3% to 100% between 2017 and 2022.²³

The data on the number of patients with laboratory test orders are consistent with this observation: the number of patients was highly correlated with both test volume and total cost across the 10-year study period, consistent with national reports of a continuously rising NCD burden, indicating that expansion in the number of service users rather than changes in service prices alone is a key factor associated with long-term laboratory costs.

Limitations

This study has several limitations. The use of aggregate data precluded assessment of clinical appropriateness at the individual patient level. Some off-hour test volume data represent estimated figures. Moreover, as a single-institution study that used service cost rather than true production cost, the findings may not be directly transferable to hospitals with different cost structures.

Conclusion

This 10-year retrospective analysis (2013-2022) provides a robust evidence base for developing an RLU system in a southern-border community hospital. The key findings are that (1) total test volume increased by 79.1%, driven by both NCDs and COVID-19; (2) cumulative costs rose 2.07-fold, with HbA1c recording the highest expenditure outside the pandemic period; (3) off-hour workload trended upward throughout the decade; and (4) the top 10 tests accounted for 72% of total expenditure, clearly confirming the Pareto principle. These findings indicate that an RLU program targeting the vital few- especially NCD-related tests - will have the greatest impact on the hospital's financial sustainability and provide actionable data for implementing Diagnostic Stewardship and HIS-integrated alert systems. This baseline supports the development of the KHOKPHO RLU Model and serves as a foundation for implementing evidence-based Rational Laboratory Utilization in community hospitals with similar resource-limited contexts.

Ethical approval

This study was approved by the Human Research Ethics Committee of Sirindhorn College of Public Health, Yala, Thailand (Protocol ID: SCPHYLIRB-2569/195; approved on 20 March 2026, valid until 20 March 2027).

Declaration of generative AI and AI-assisted technologies

During the preparation of this manuscript, the authors used ChatGPT/Claude (Anthropic) solely to assist with English-language editing, grammar refinement, and paragraph structure in accordance with the journal's guidelines. After using these tools, the authors reviewed and edited the content as necessary and take full responsibility for the published article.

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Conflict of interest

The authors declare no conflict of interest.

CRedit authorship contribution statement

Noppadon Srisuk: conceptualization, methodology, formal analysis, investigation, data curation, writing-original draft, visualization; **Amonrat Srisuk:** writing-review and editing, resources; **Udomkiat Poolsawat:** supervision, validation.

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