

SHORT COMMUNICATION

UTILIZATION OF BIOCHEMISTRY ANALYZERS IN A TERTIARY CARE LABORATORY IN SRI LANKA: A MIXED-METHOD STUDY

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ABSTRACT Background: Efficient utilization of laboratory equipment is essential for high-quality patient care and effective use of healthcare resources. However, evidence on equipment utilization in tertiary-care laboratories with high testing volumes remains limited. This study assessed biochemistry analyzer utilization and contributing operational factors at the National Hospital of Sri Lanka. Methods: A mixed-methods descriptive study was conducted using retrospective laboratory workload data from January to October 2023 and key informant interviews. Utilization coefficient (UC) was calculated as actual tests performed divided by theoretical analytical capacity. A UC below 50% was used as an operational classification criterion for underutilization based on previous medical equipment utilization research, rather than as an optimal utilization target. Qualitative data were analyzed thematically, and Fishbone and Pareto analyses were used to identify and prioritize contributing factors.

Results: Six functional biochemistry analyzers were assessed, with four operating during daytime and two at night. The laboratory processed an average of 182,318 tests monthly, comprising 98,880 daytime and 83,438 nighttime tests. Overall UC was 10.7%, with higher utilization during daytime (16.1%) than nighttime (7.6%). The low UC reflected a substantial difference between theoretical analytical capacity and actual workload. The principal contributing factors identified through Pareto analysis were supply-demand mismatch of equipment, interrupted reagent supply, and reagent wastage. Conclusion: The findings indicate substantial excess theoretical analytical capacity relative to the workload during the study period. Equipment planning should consider historical and projected workload, shift-specific demand, analyzer capabilities, reagent requirements, and reserve capacity. Improved reagent supply management and potential referral of selected routine, non-urgent tests could also support more efficient use of existing laboratory infrastructure.

Key words: Laboratory Equipment Utilization, Utilization coefficient, Clinical biochemistry laboratory, Tertiary healthcare.

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INTRODUCTION:

Laboratory equipment plays a pivotal role in diagnosing, monitoring, and treating diseases. It ensures accurate and timely medical interventions that are essential for high-quality patient care. In tertiary healthcare centers, which function as referral hubs for primary and secondary care, the demand for laboratory investigations is particularly high. Therefore, optimal utilization of laboratory equipment is essential to achieve efficiency, cost-effectiveness, and improved patient outcomes.

Evidence from low- and middle-income countries indicates substantial problems with the availability, functionality and utilization of medical equipment [1-4]. Reported contributing factors include inappropriate procurement, inadequate maintenance, limited technical support, reagent shortages, infrastructure constraints and gaps in user training [1 - 5].

Despite strong emphasis on maximizing equipment utilization in tertiary care hospitals in Sri Lanka, there remains limited empirical evidence on laboratory equipment utilization patterns. Therefore, this study aimed to assess the level of utilization of biochemistry analyzers in a leading tertiary healthcare facility in Sri Lanka and to identify contributing operational factors.

MATERIALS AND METHODS:

This hospital-based cross-sectional study with a mixed-methods approach (quantitative and qualitative components) was conducted at the clinical biochemistry laboratory of the National Hospital Sri Lanka, the primary, tertiary referral center in the country. The study was conducted in November 2023 using retrospective laboratory data from 1st January to 31st October 2023.

Six functional biochemistry analyzers were available in the unit, of which four were used for daytime investigations and two for night-time operations. An additional analyzer was available but had not yet been commissioned and was therefore excluded from the study. Analyzer

throughput capacities were 1200 tests/hour for two analyzers and 435 tests/hour for two analyzers used during daytime operations, while both analyzers used during night-time operations had a throughput capacity of 1200 tests/hour.

Daytime laboratory operations were conducted from 8:00 am to 4:00 pm from Sunday to Friday, including public holidays, while Saturdays operated from 8:00 am to 12:00 pm. Quality control procedures were performed twice daily at the beginning of each shift, with approximately one hour allocated per session. Accordingly, effective operational hours were 7 hours per day (Sunday to Friday) and 3 hours on Saturdays for daytime operations, and 15 hours (Sunday to Friday) and 19 hours on Saturdays for night-time operations.

Two study populations were considered:

1. All functional biomedical analyzers in the clinical biochemistry laboratory.
2. Healthcare personnel involved in the operation, handling, and maintenance of analyzers, including consultant chemical pathologists, biochemists, senior medical laboratory technologists, and medical laboratory technologists.

Inclusion criteria comprised all functional analyzers during the study period and staff engaged in analyzer-related activities. Non-functional analyzers, analyzers not yet commissioned, and staff not involved in analyzer-related activities, including those without roles in operation, supervision, maintenance, or decision-making regarding laboratory investigations, were excluded.

Relevant participant characteristics, including professional category and years of experience, were recorded. All eligible analyzers were included in the quantitative component, while purposive sampling was used to recruit key informants for the qualitative component.

Informed written consent was obtained from all participants prior to data collection, and

confidentiality was maintained throughout the study.

A structured data extraction sheet was developed based on a review of the literature and expert input and was pre-tested prior to use. Secondary data on analyzer utilization and tests performed from 1st January 2023 to 31st October 2023, were collected.

A key informant interview guide was developed to explore factors contributing to underutilization and potential corrective measures. Interviews were conducted face-to-face, lasted approximately 20–30 minutes, and were audio-recorded with participant consent. Each participant was interviewed individually to ensure independent responses.

Standard laboratory procedures and data recording practices were followed throughout the study. Where applicable, established methods were applied in accordance with relevant literature.

The utilization coefficient (UC) was calculated as the actual number of tests performed divided by the theoretical analytical capacity, expressed as a percentage ^[6]:

$$\text{Utilization coefficient (UC)} = (N/M) \times 100$$

where **N** represents the actual number of tests performed and **M** represents the theoretical analytical capacity (design potential).

The theoretical analytical capacity was estimated using the manufacturer-rated throughput of each analyzer, the number of functional analyzers, effective operating hours, and the number of functional days during the study period. Non-functional periods were excluded from the capacity denominator to account for analyzer downtime. This capacity estimate represents theoretical rather than achievable operational capacity and does not account for variations in test mix, STAT testing, staffing constraints, or other workflow-related factors that may reduce practical throughput.

A UC of less than 50% was considered indicative of underutilization based on the operational

criterion used in previous medical equipment utilization research ^[6,7]. This threshold was used as a classification criterion rather than an optimal utilization target, recognizing that tertiary laboratories require reserve capacity for STAT testing, workload surges, maintenance, and analyzer breakdowns.

Quantitative data were analyzed to determine overall, monthly, and shift-specific (day and night) utilization coefficients (UCs). Qualitative data from key informant interviews were analyzed thematically to identify potential causes of analyzer underutilization. Nine key informants participated, comprising one consultant chemical pathologist, two biochemists, two senior medical laboratory technologists, and four medical laboratory technologists. The identified causes were organized using a Fishbone (cause-and-effect) analysis, with low analyzer utilization (UC <50%) defined as the problem. Each participant was asked to select the three causes considered most relevant to analyzer underutilization. The number of votes received by each cause was recorded and used to prioritize the causes. A Pareto chart was subsequently prepared based on the frequency of votes to identify the principal contributing factors. Trustworthiness of the qualitative findings was enhanced through member checking.

Ethical considerations:

This laboratory management and equipment-utilization study involved retrospective analysis of aggregate laboratory workload data and key-informant interviews with healthcare personnel. No patient-identifiable information or additional patient samples were collected. Written informed consent was obtained from all key informants before participation. Participation was voluntary, and confidentiality and anonymity were maintained throughout the study and reporting process. No formal ethics committee approval or waiver was obtained for the study.

RESULTS:

The study revealed average monthly test volume of 182,318, comprising 98,880 tests during

daytime and 83,438 during night-time operations. During the study period, the analyzers were non-functional for a total of 11.67 days, including 10 days due to trade union actions, one day due to water/power interruptions, and 0.67 days for preventive maintenance. The overall utilization coefficient (UC) of the biochemistry analyzers was 10.7%. Daytime analyzers demonstrated a higher utilization (16.1%) compared to night-time analyzers (7.6%) (Table 1).

Table 1: Overall utilization of biochemistry analyzers in National Hospital of Sri Lanka

Parameter	Value
Total calendar days	304
Non-functional days	11.67
Functional days	292.33
Total tests performed (Day)	988,806
Total tests performed (Night)	834,378
Total tests performed (Overall)	1,823,184
Overall Utilization Coefficient (%)	10.7%
Day shift Utilization Coefficient (%)	16.1%
Night shift Utilization Coefficient (%)	7.6%

Figure 1 shows monthly variation in utilization coefficients from January to October 2023. Daytime utilization was consistently higher than night-time utilization, with both showing similar trends, including a dip in February, a peak in March, and relatively stable values thereafter. Overall utilization remained low throughout the study period.

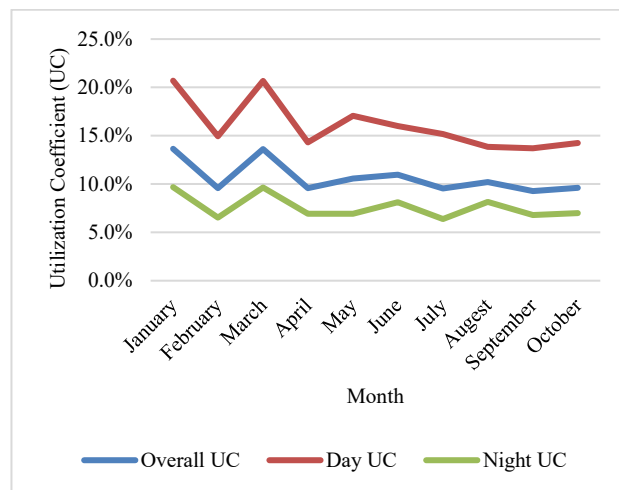


Figure 1: Temporal variation in utilization coefficient (UC)

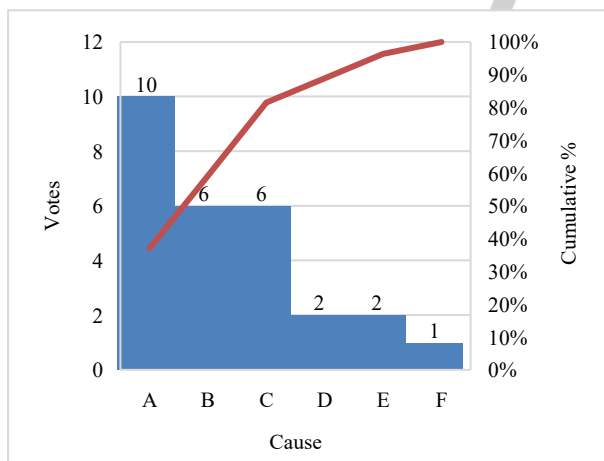
Table 2 shows monthly variations in test volumes and utilization. Overall UC ranged from 9.3% to 13.6%, with higher values in January and March. Lower utilization was observed in some months with a greater number of non-functional days, although the relationship was not formally assessed.

Table 2: Monthly utilization coefficient (UC) of biomedical analyzers

Month	Day tests	Night tests	Overall tests	Day UC%	Night UC%	Overall UC%	Nonfunctional days
January	134,899	112,153	247,052	20.7%	9.7%	13.6%	-
February	84,917	65,921	150,838	15.0%	6.5%	9.6%	1
March	126,021	104,571	230,592	20.7%	9.6%	13.6%	2
April	87,189	75,099	162,288	14.3%	6.9%	9.6%	1
May	100,510	72,306	172,816	17.1%	6.9%	10.6%	3
June	97,521	88,059	185,580	16.0%	8.1%	11.0%	1
July	96,730	72,321	169,051	15.2%	6.4%	9.5%	0.67

August	90,355	94,580	184,935	13.9%	8.2%	10.2%	-
September	77,784	68,404	146,188	13.7%	6.8%	9.3%	3
October	92,880	80,964	173,844	14.2%	7.0%	9.6%	-

The qualitative assessment identified six potential causes of analyzer underutilization: supply-demand mismatch of equipment, interrupted supply of reagents, reagent wastage, time-consuming manual data entry, trade union actions, and issues related to water and power supply. These causes were organized using Fishbone analysis and prioritized based on the participants' votes. Pareto analysis identified supply-demand mismatch of equipment, interrupted reagent supply, and reagent wastage as the principal contributing factors (Figure 2).



A - Supply-demand mismatch of equipment; B - Interrupted supply of reagents; C - Reagent wastage;

D - Time-consuming manual data entry; E - Trade union actions; F - Issues related to water and power supply

Figure 2: Pareto analysis of factors contributing to biochemistry analyzer underutilization based on frequency of votes among key informants.

DISCUSSION:

This study demonstrated marked underutilization of biochemistry analyzers in a tertiary care laboratory, with an overall utilization coefficient (UC) of 10.7%, substantially below the predefined 50% threshold. Importantly, the low utilization

occurred despite a high laboratory workload, with more than 1.8 million tests performed during the 10-month study period. This indicates that the principal issue was not insufficient laboratory activity, but a mismatch between the available analytical capacity and the actual workload. The qualitative findings further identified supply-demand mismatch as the most important contributor to underutilization. Thus, the findings suggest that the laboratory had considerably more analytical capacity than was required to accommodate its existing workload.

The presence of an additional high-throughput analyzer that had not yet been commissioned provides further evidence of potential mismatch between equipment capacity and service demand. While the study cannot establish why the analyzer had not been commissioned, its availability in a laboratory where six existing analyzers were already operating at low utilization raises concerns regarding the alignment of equipment procurement and commissioning decisions with actual workload requirements. In such circumstances, commissioning additional capacity without a corresponding increase in workload could further reduce the overall utilization of available equipment. More importantly, excess capacity has implications beyond the initial acquisition cost, because analyzers require ongoing expenditure for reagents, calibration, preventive maintenance, technical support, infrastructure and eventual replacement. Evidence from LMICs emphasizes the importance of needs assessment and appropriate prioritization when procuring medical equipment [1,2,4]. The World Health Organization similarly emphasizes that medical devices should be selected and managed according to identified health-system needs rather than simply increasing technological capacity [8].

The observed supply-demand mismatch is consistent with findings from other LMIC settings. Geta et al. reported substantial underutilization of medical equipment in public referral hospitals in Ethiopia [2], while Wondafrash et al. identified challenges in the availability and utilization of medical devices in hospitals in Southwest Ethiopia

[4]. Desalign et al. also reported limitations in medical equipment utilization in an Ethiopian specialized hospital [6]. In India, Chaudhary and Kaul identified inadequate utilization of diagnostic medical equipment in a tertiary healthcare setting [7]. Although these studies assessed broader categories of equipment and used different measures of utilization, they collectively indicate that acquisition of medical equipment does not necessarily result in proportional service utilization.

Evidence specifically concerning clinical chemistry analyzers provides further support for the present findings. Belete et al., using a mixed-methods approach in public hospital laboratories in Ethiopia, identified inappropriate analyzer procurement, underuse of clinical chemistry tests, reagent shortages, non-functionality, inadequate user training and poor infrastructure as important challenges to analyzer utilization [9]. The similarity between these findings and the present study is noteworthy, particularly regarding procurement, reagent availability and demand-related underutilization. This suggests that analyzer utilization is influenced by a combination of equipment planning, workload, consumables, infrastructure and operational systems rather than by the technical capacity of the analyzer alone.

The substantial difference between daytime and nighttime utilization provides further evidence that total workload alone does not adequately explain equipment requirements. Daytime analyzers had a UC of 16.1%, compared with only 7.6% for nighttime analyzers. This difference is likely related to the distribution of laboratory demand, as routine investigations are generally concentrated during daytime hours whereas nighttime services are predominantly required for urgent investigations. Consequently, the longer operating period and high-throughput capacity of nighttime analyzers did not translate into higher utilization. This finding indicates that equipment planning should consider not only the total volume of tests but also their temporal distribution, urgency and turnaround-time requirements. Maintaining sufficient capacity for emergency testing may

necessarily result in some degree of underutilization; however, the extent observed in this study suggests that the available capacity substantially exceeded routine demand.

Monthly variation in UC also suggested an influence of operational interruptions. Overall UC ranged from 9.3% to 13.6%, and lower utilization generally occurred during months with greater numbers of non-functional days. During the study period, analyzers were non-functional for 11.67 days, primarily because of trade union actions, with additional downtime related to water/power interruptions and preventive maintenance. Although the study design does not permit causal relationships to be established, these findings indicate that service interruptions further reduced effective equipment availability. This should be distinguished from demand-related underutilization: while excess capacity requires better equipment planning, downtime requires reliable infrastructure, preventive maintenance and timely technical support. Evidence from Sri Lankan hospitals has demonstrated the importance of structured maintenance systems in improving medical equipment use and reducing inefficiencies [10,11]. Laboratory-specific guidance also emphasizes preventive maintenance, calibration, service contracts, equipment documentation and monitoring as important elements of effective equipment management [8].

The lower nighttime utilization also raises an important workflow consideration regarding analyzer allocation. Although the two high-capacity analyzers (1,200 tests/hour) were routinely operated during the night shift, the present study did not evaluate whether the lower-capacity analyzers (435 tests/hour) could have adequately supported the nighttime workload while maintaining required service continuity and backup capacity. Therefore, the observed low nighttime utilization should not be interpreted solely as a consequence of workload variation. Future workload-based workflow assessment should consider analyzer-specific test menus, turnaround-time requirements, reagent consumption, staffing, standby requirements, and

the need for redundancy when determining shift-specific analyzer allocation.

The qualitative findings identified interrupted reagent supply and reagent wastage as additional important contributors to underutilization. An analyzer may have adequate technical capacity but remain unable to generate results when required reagents are unavailable. Conversely, procurement of reagents without sufficient consideration of actual workload may increase wastage and operating costs. The Ethiopian study of clinical chemistry analyzers similarly identified reagent shortages as a major barrier to analyzer utilization [9]. These findings emphasize that equipment planning cannot be considered independently from reagent forecasting and procurement. Sustainable analyzer utilization requires coordination between equipment capacity, anticipated workload and availability of consumables.

The study also identified manual data entry, trade union actions, and water and power interruptions as additional operational constraints. The manual data-entry process may increase turnaround time and introduce workflow inefficiencies, although its contribution to the overall low UC cannot be quantified from the present data. Similarly, industrial action and infrastructure interruptions reduced the opportunity for equipment operation during affected periods. These findings highlight that utilization is a system-level outcome influenced by equipment, demand, consumables, infrastructure, workforce and workflow. Sri Lankan evidence indicates that structured equipment-management programs involving maintenance systems, staff training and stakeholder engagement can improve effective equipment use [11].

The findings have important implications for future laboratory equipment planning. Procurement and commissioning decisions should be based on historical workload, projected demand, existing analytical capacity, shift-specific workload, overlapping analyzer capabilities, reagent requirements and maintenance capacity. Where substantial excess capacity exists, increased referral of selected routine, non-urgent tests from

peripheral or district hospitals, as well as potential service-sharing arrangements with private-sector healthcare institutions, could be considered to improve utilization of existing laboratory infrastructure. Such approaches would require appropriate assessment of specimen transport, turnaround-time requirements, test menus, quality assurance, costs, and service-level arrangements, while ensuring that sufficient capacity remains available for the tertiary hospital's own urgent and routine workload. These approaches are consistent with evidence emphasizing needs-based procurement and life-cycle management of medical equipment in resource-constrained settings [1,9,12]. Importantly, the objective should not be to maximize analyzer utilization at the expense of service readiness, but to achieve an appropriate balance between utilization, efficiency and sufficient reserve capacity for urgent and unexpected demand.

Limitations

This study has several limitations. Utilization was calculated using aggregated workload rather than analyzer-specific test volumes, which may have obscured differences in utilization among individual analyzers. Capacity estimates were based on manufacturer-reported throughput, effective operating hours, and functional days and therefore represent theoretical analytical capacity rather than achievable real-world capacity. The estimates did not account for variations in test mix, staffing constraints, STAT testing, or other workflow-related factors that may reduce practical throughput. The single-center design limits generalizability to other tertiary-care laboratories in Sri Lanka. The qualitative component involved a limited number of key informants and may not have captured all perspectives related to procurement, commissioning, workload planning, and equipment utilization. Finally, the study did not quantify the financial implications of excess analyzer capacity or reagent wastage.

CONCLUSION:

Biochemistry analyzers in the studied tertiary care laboratory were substantially underutilized, with

an overall utilization coefficient of 10.7%. The marked difference between available analytical capacity and actual workload, together with the presence of an additional uncommissioned analyzer, indicates a potential mismatch between equipment capacity and service demand. Lower nighttime utilization and interruptions in reagent supply further contributed to inefficient use of available capacity. These findings highlight the importance of aligning laboratory equipment capacity and commissioning with actual service demand to support efficient use of laboratory resources.

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