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Evaluation of the Knowledge Levels of Medical Interns at Suleyman Demirel University Faculty of Medicine Regarding the Pre-Analytical Phase of the Laboratory and Rational Test Ordering

Fevziye Burcu ŞİRİN[1], Giray KOLCU[2]

[1] Suleyman Demirel University, Faculty of Medicine, Department of Medical Biochemistry, Isparta, Türkiye
[2] Suleyman Demirel University, Faculty of Medicine, Department of Family Medicine, Isparta, Türkiye

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Abstract

Objective
Since the majority of errors in the medical laboratory testing process occur in the pre-analytical phase and unnecessary test ordering adversely affects patient safety and healthcare system costs, this study aimed to assess the knowledge and awareness levels of sixth-year medical students (medical interns) regarding the laboratory pre-analytical phase and rational test ordering, and to contribute to the development of pre-internship training programs based on the findings.

Material and Method
This cross-sectional survey study included 167 medical interns from the 2024–2025 (n = 57) and 2025–2026 (n = 110) academic years. Data were collected using an online questionnaire. Descriptive statistics are expressed as frequencies, percentages, and mean ± standard deviation. Pearson's chi-square test was used to compare categorical variables between cohorts. Total pre-analytical knowledge scores and total rational test ordering scores were calculated by summing the correct responses to the relevant items. Statistical significance was set at $p < 0.05$.

Results
No statistically significant differences were observed between the 2024–2025 and 2025–2026 cohorts across all knowledge domains (Cramer's V: 0.01–0.05). Although nearly all participants reported phlebotomy experience, formal education about pre-analytical processes and rational laboratory use was limited, and awareness of national policies was low. Significant deficiencies were identified for technical pre-analytical topics, including order of draw, diurnal variation, tube handling, and coagulation sample analysis time limits. Knowledge of minimum test repetition intervals was generally insufficient, with higher accuracy for HbA1c and lower accuracy for commonly requested tests such as AST, ALT, TSH, and CRP. Overall knowledge scores indicated low competency, with no differences between cohorts.

Conclusion
Practical experience alone does not ensure standardized knowledge. Structured, compulsory, and scenario-based training focused on pre-analytical quality management and evidence-based test repeat intervals should be integrated into internship education to improve patient safety and resource utilization.

Keywords: Laboratory, Medical interns, Pre-analytical phase, Rational test ordering

Correspondence: F.B.Ş. / fevziyesirin@sdu.edu.tr
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ORCID IDs of the Authors: F.B.Ş: 0000-0001-5304-1007; G.K: 0000-0001-8406-5941

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Introduction

The medical laboratory testing process begins with a physician ordering tests and encompasses the acceptance of patient samples by the laboratory and their preparation for analysis (pre-analytical phase), the analysis of the samples (analytical phase), and the interpretation and delivery of test results to the relevant physician (post-analytical phase) (1). It is estimated that errors occurring particularly in the pre-analytical phase account for as much as 70% of all laboratory errors (2-3). The accuracy and reliability of laboratory test results largely depend on the quality of the pre-analytical phase (3).

In rational test ordering, all activities aiming to reduce the number of unnecessary test requests in healthcare settings are included within the scope of "Rational Laboratory Practices" implemented by the Ministry of Health. This program was initiated to increase the clinical utility of test results and to ensure that test orders can be maintained in a cost-effective manner. Physicians are not allowed to reorder the same test without justifying the specified minimum retesting interval. These intervals apply only to outpatient visits and do not cover emergency department, intensive care unit, or inpatient ward settings (4-5).

In addition to assessing knowledge levels, evaluating educational programs addressing pre-analytical laboratory processes and rational test ordering is essential to ensure the effectiveness and sustainability of competency-based medical education (6-7). Program evaluation enables the systematic identification of learning gaps in laboratory practice and provides evidence about whether current clinical training adequately prepares interns for safe and rational diagnostic decision-making (8-9). Continuous evaluation of training activities allows curriculum developers to align educational content with national healthcare policies and patient safety standards, while supporting outcome-based improvements in internship training (6,10). Furthermore, program evaluation contributes to the optimization of educational resources by guiding targeted interventions that strengthen procedural competence, reduce preventable laboratory errors, and promote cost-effective healthcare delivery (7,11). Integrating structured program evaluation into internship training therefore represents a critical step toward improving both clinical performance and healthcare system efficiency (7,10,12).

Sixth-year medical students (medical interns) are directly involved in ordering tests, blood sampling, specimen preparation, and management of sample transport to the laboratory during their clinical practice (8-9). Therefore, any lack of knowledge regarding the pre-analytical phase is directly associated with laboratory errors (13-14). Ordering unnecessary tests may result in both unwarranted interventions for the patient and increased workload and costs in laboratories (12,15,16). It is critically important for interns to be familiar with these procedures, for both patient safety and efficient use of healthcare resources (4,7,8).

Assessing interns' knowledge of the laboratory pre-analytical phase and rational test ordering, identifying areas of deficiency, and improving these competencies will contribute to correct clinical decision-making as they prepare for independent medical practice. Therefore, this study aimed to evaluate the knowledge levels of medical interns at Suleyman Demirel University Faculty of Medicine regarding the pre-analytical phase of laboratory testing (sample collection, sample transport/labeling, and pre-analytical errors) and rational test ordering within the scope of "Rational Laboratory Practices" implemented by the Ministry of Health. The data obtained from this survey study will contribute to planning pre-internship training programs.

Material and Method

This study was approved by the Suleyman Demirel University Health Sciences Ethics Committee (meeting no. 105, decision no. 8, dated November 3, 2025) and was conducted in accordance with the principles of the Declaration of Helsinki. Based on a population of 253 medical interns at Suleyman Demirel University Faculty of Medicine in the 2025–2026 academic year, the minimum required sample size was calculated as 153. This cross-sectional survey was conducted using an online questionnaire and included 167 medical interns from the 2024–2025 (n = 57) and 2025–2026 (n = 110) academic years.

The questionnaire was designed to assess the knowledge, awareness, and competence of medical interns at Suleyman Demirel University Faculty of Medicine regarding the laboratory pre-analytical phase and rational test ordering. The questionnaire was developed by the researchers following a review of national and international literature about the pre-analytical phase of laboratory medicine, laboratory errors, phlebotomy, specimen handling, and rational test ordering (1-5). The questionnaire consisted of two main domains: knowledge of pre-analytical laboratory processes and knowledge of rational test ordering, including minimum test repetition intervals. Items were prepared in accordance with the learning objectives expected of medical interns who actively participate in blood sampling,

specimen transport, and laboratory test ordering during clinical rotations. To ensure content validity, the draft questionnaire was reviewed by experts in medical biochemistry and medical education. The expert review focused on the clarity, relevance, scientific accuracy, and educational appropriateness of each item. Based on expert feedback, ambiguous wording was revised, and items not directly aligned with the study objectives were removed or modified. This process supported the content validity; however, no formal content validity index calculation or psychometric validation was performed. Therefore, the absence of formal validity and reliability testing should be taken into account when interpreting the findings. The questionnaire was not pilot-tested before data collection, which is acknowledged as a methodological limitation of the study.

The questionnaire included items assessing educational background and clinical rotation experiences of participants (Questions 1-5), as well as their level of awareness regarding the role of laboratory testing in diagnostic and treatment processes. In addition, critical pre-analytical aspects were evaluated—such as knowledge of the distribution of laboratory errors in the pre-analytical phase, recognition of the processes that make up the pre-analytical stage, awareness of proper blood collection techniques, and sample handling and transport requirements (11 questions). The questionnaire also assessed participants' familiarity with the Ministry of Health's Rational Laboratory Use and Rational Test Ordering Procedure (15 questions) and their educational experiences related to these topics. Finally, participant knowledge of recommended minimum retesting intervals for commonly requested laboratory tests was evaluated, providing a comprehensive assessment of their understanding of appropriate laboratory test utilization.

The correct answers to the knowledge questions were based on the Turkish Ministry of Health's Rational Laboratory Use and Rational Test Ordering Procedure, the Medical Biochemistry Total Testing Process Guidelines, and relevant laboratory medicine literature (1-5). This approach ensured that the scoring system reflected both national policy requirements and internationally accepted pre-analytical quality standards.

During the study period, the target population consisted of 253 medical interns. A total of 167 interns completed the online questionnaire, corresponding to a response rate of 66.0%. Although the achieved sample size exceeded the minimum required sample size, the possibility of non-response bias should be considered, as the characteristics of non-respondents and their reasons for non-participation could not be evaluated.

Data were analyzed using SPSS version 22.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics are presented as frequencies and percentages for categorical variables and as mean±standard deviation for continuous variables. The proportions of correct, incorrect, and no idea responses were calculated for each knowledge item. Pearson's chi-square test was used to compare the distribution of correct responses between the 2024–2025 and 2025–2026 academic cohorts. Cramer's V was calculated as the effect size for categorical comparisons and was interpreted as negligible, small, moderate, or large according to conventional thresholds. A p-value of <0.05 was considered statistically significant.

In addition to item-level analyses, composite knowledge scores were calculated. The Total Pre-Analytical Knowledge Score was obtained by summing the number of correct responses to items related to pre-analytical processes, whereas the Total Rational Test Ordering Score was calculated by summing the number of correct responses to items related to minimum test repetition intervals and rational laboratory use. Higher scores indicated higher knowledge levels. These total scores were used to provide a more comprehensive assessment of interns' knowledge and to allow comparison between academic cohorts and relevant subgroups.

The comparison between the 2024–2025 and 2025–2026 academic cohorts was performed to examine whether knowledge levels differed between two consecutive groups of interns exposed to the same institutional curriculum and similar clinical training environment. Since no formal curriculum revision specifically targeting pre-analytical laboratory processes or rational test ordering had been implemented between these two cohorts, the comparison was not intended to evaluate the effect of a curricular intervention. Rather, the aim was to determine whether the observed knowledge gaps were cohort-specific or reflected a persistent educational need across consecutive intern groups.

Results

Descriptive analysis indicated that the study sample consisted of 167 participants (n = 167). The mean age of the participants was 25.01± 1.71 years. The ages ranged between 23 and 34 years. Frequency analysis demonstrated that Group 1 (2024–2025 academic year) consisted of 57 participants representing 34% of the total sample, while Group 2 (2025–2026 academic year) included 110 participants, corresponding to 66% of the total sample.

Gender distribution analysis showed that 70 participants were male, representing 42% of the total sample, while 97 participants were female, corresponding to 58% of the participants. The cumulative distribution demonstrated that female participants constituted the majority of the study population.

The survey about awareness of the pre-analytical process and rational laboratory use indicated that awareness and educational exposure related to the pre-analytical process and rational laboratory use among intern physicians were limited (Table 1). Less than half of the participants reported prior participation in training related to pre-analytical processes, while the majority stated that they had not received such education. Despite this limited formal training background, almost all participants reported prior experience with blood sampling for laboratory testing, which suggested adequate procedural exposure during clinical practice. Awareness of the Ministry of Health's rational laboratory use and rational test ordering procedure was notably low, as only a small proportion of participants reported being informed about the existence of this policy. Similarly, an overwhelming majority indicated that they had not previously received any structured education specifically focused on rational laboratory use (Table 1). These findings demonstrated a discrepancy between clinical practice experience and theoretical or policy-level awareness.

Regarding health policy perspectives, the participants had heterogeneous opinions about the implementation of restrictions on laboratory test ordering within the scope of rational laboratory use. While a considerable proportion supported these limitations, nearly half of the participants did not favor restrictive approaches, and a smaller group remained undecided. Additionally, although participants reported practical exposure to laboratory-related procedures, lower levels of awareness, training, and policy-level understanding were observed related to rational laboratory utilization (Table 1).

The distribution of responses related to the correct knowledge level about pre-analytical processes and rational laboratory use demonstrated considerable variability in medical interns' knowledge levels regarding pre-analytical processes and rational laboratory use (Table 2, Table 5). Participants had relatively high accuracy in identifying the required fasting duration before blood sampling, indicating adequate awareness of commonly encountered clinical preparation procedures. In contrast, knowledge of the more technical components of the pre-analytical phase was limited.

Awareness of the contribution of laboratory results to diagnostic and therapeutic decision-making was moderate, whereas understanding of the proportion of laboratory errors originating from pre-analytical processes was notably low. Knowledge concerning tests affected by diurnal rhythm was particularly insufficient, suggesting limited familiarity with physiological factors influencing laboratory variability.

Similarly, participants demonstrated inadequate knowledge regarding the correct order of blood collection tubes and post-sampling tube handling procedures. The low proportion of correct responses related to tube inversion practices indicated deficiencies in procedural standardization despite routine exposure to blood sampling in clinical settings. Knowledge concerning the appropriate transport time for gel separa-

Table 1 Awareness of medical interns regarding the pre-analytical process and rational laboratory use

	Yes	No	No Opinion
	n(%)	n(%)	n(%)
Have you previously attended any training related to pre-analytical processes?	72 (42%)	95 (58%)	
Have you previously performed blood sampling on a real patient for laboratory testing?	160 (96%)	6 (4%)	
Are you aware of the Ministry of Health's rational laboratory use and rational test-ordering procedure?	32 (19%)	133 (81%)	
Have you received training on rational laboratory use before?	6 (4%)	159 (96%)	
Should restrictions be implemented in laboratory test ordering within the scope of rational laboratory use policies?	64 (39%)	77 (47%)	24 (15%)

tor tubes and acceptable analysis time for coagulation tests also remained at moderate levels.

Overall, the results suggest that intern physicians possess satisfactory knowledge of the basic patient preparation steps but exhibited substantial gaps related to pre-analytical laboratory management principles. These findings indicate a need for structured educational interventions that focus on procedural accuracy, standard laboratory workflows, and rational test utilization within clinical training programs (Table 2).

Comparative analysis between interns from the 2024–2025 and 2025–2026 academic years demonstrated no statistically significant differences in knowledge levels related to pre-analytical processes and rational laboratory use. Pearson chi-square analyses revealed comparable proportions of correct responses across all domains. The absence of statistical significance was supported by consistently small effect sizes with Cramer's V values ranging between 0.01 and 0.04, indicating a negligible association between academic year and knowledge performance. Knowledge regarding patient preparation, procedural laboratory handling, and pre-analytical workflow parameters was homogeneously distributed across cohorts. Confidence intervals overlapped substantially, and all comparisons remained below the threshold for practical or statistical relevance. These findings suggest that progression between consecutive academic years did not produce measurable differences in knowledge acquisition related to rational laboratory utilization (Table 3).

The total knowledge scores indicated generally low knowledge levels among interns. The Total Pre-Analytical Knowledge Score was 2.66±1.32 out of 8, corresponding to approximately one-third of the maximum possible score. Similarly, the Total Rational Test Ordering Score was 4.11±2.34 out of 12, suggesting limited knowledge regarding recommended minimum test repetition intervals and rational laboratory use. The Overall Total Knowledge Score was 6.78±2.97 out of 20, further supporting the presence of substantial knowledge gaps.

Although the 2025–2026 cohort had numerically higher mean scores than the 2024–2025 cohort in all three domains, these differences were not statistically significant. The Total Pre-Analytical Knowledge Score increased from 2.42±1.12 to 2.79±1.40, the Total Rational Test Ordering Score increased from 3.82±2.30 to 4.26±2.35, and the Overall Total Knowledge Score increased from 6.25±2.82 to 7.05±3.02. However, the corresponding p values were above the conventional significance threshold, and the rank-biserial effect sizes were small. These findings indicate that the two consecutive cohorts had similar overall knowledge profiles and that the observed deficiencies are likely to reflect a persistent curriculum-level educational need rather than a cohort-specific difference (Table 4).

Table 2 Distribution of responses according to the correct knowledge level on pre-analytical processes and rational laboratory use

Question*	Correct n (%)	Incorrect n (%)	No Idea n (%)
Estimated contribution of laboratory results to diagnosis and treatment processes	80 (48%)	87 (52%)	0 (0%)
Estimated proportion of laboratory errors originating from pre-analytical processes	43 (26%)	124 (74%)	0 (0%)
Required fasting duration before blood sampling	138 (83%)	28 (17%)	0 (0%)
Identification of tests affected by diurnal rhythm	23 (14%)	144 (86%)	0 (0%)
Knowledge of the correct blood collection tube order	56 (34%)	76 (46%)	35 (20%)
Identification of tubes requiring inversion after blood collection	15 (9%)	127 (76%)	25 (15%)
Maximum transfer time of blood samples in gel separator tubes to the laboratory	56 (37%)	96 (63%)	0 (0%)
Maximum allowable analysis time for coagulation tests (PT/aPTT)	59 (39%)	92 (61%)	0 (0%)

*Correct answers were defined according to the Turkish Ministry of Health's Rational Laboratory Use document, the Medical Biochemistry Total Testing Process Guideline, and relevant laboratory medicine literature.

The knowledge level of intern physicians regarding recommended minimum test ordering intervals showed substantial variability. Overall correct response rates remained limited across most laboratory tests, suggesting insufficient awareness of rational test ordering principles. The highest level of correct knowledge was observed for HbA1c testing, where a clear majority of participants correctly identified the recommended test ordering interval. Moderate levels of correct responses were observed for vitamin B12, vitamin D, urine culture, and anti-toxoplasma IgG tests. In contrast, knowledge regarding frequently ordered tests, such as AST-ALT, TSH, and CRP, remained notably low, with a considerable proportion of participants selecting incorrect intervals. Awareness related to ferritin testing was also insufficient, with similar distributions of correct and incorrect responses among participants. A substantial proportion of participants indicated a lack of knowledge regarding several tests, particularly hemoglobin variant analysis, urine culture, and infectious serology markers. These findings suggest that intern physicians experience difficulty distinguishing between tests requiring periodic monitoring and those that should not be routinely repeated. Overall, the results demonstrate gaps in rational laboratory utilization knowledge despite routine clinical exposure and highlight the need for structured educational interventions focusing on evidence-based test repetition intervals and cost-effective laboratory use (Table 5).

A comparison of intern physicians from the 2024–2025 and 2025–2026 academic years showed no statistically significant differences in knowledge regard-

Table 3 Comparison of knowledge levels on pre-analytical processes and rational laboratory use between academic year cohorts

Knowledge Item*	Group 1 Correct n (%)	Group 2 Correct n (%)	χ^2	p value	Cramer's V
Contribution of laboratory results to diagnosis and treatment	26 (46%)	54 (49%)	0.14	0.71	0.03
Awareness of the pre-analytical error proportion	14 (25%)	29 (26%)	0.02	0.88	0.01
Correct fasting duration before blood sampling	46 (81%)	92 (84%)	0.21	0.64	0.04
Identification of diurnal rhythm-dependent tests	7 (12%)	16 (15%)	0.32	0.57	0.04
Knowledge of the correct blood collection tube order	18 (32%)	38 (35%)	0.18	0.67	0.03
Identification of required tube inversion	5 (9%)	10 (9%)	0.00	0.99	0.01
Maximum transfer time of gel separator tubes	20 (35%)	36 (33%)	0.06	0.80	0.02
Maximum analysis time for coagulation tests	21 (37%)	38 (35%)	0.05	0.82	0.02

*Pearson's chi-square test was used for cohort comparisons. Cramer's V was reported as an effect size. Higher Cramer's V values indicate stronger associations between academic cohort and correct response status.

Table 4 Descriptive statistics of total knowledge scores and comparison of total knowledge scores between academic cohorts

Score	n	Mean±SD	2024–2025 n	2024–2025 Mean±SD	2025–2026 n	2025–2026 Mean±SD	p	Rank-biserial r
Total Pre-Analytical Knowledge Score	167	2.66±1.32	57	2.42±1.12	110	2.79±1.40	0.095	-0.154
Total Rational Test Ordering Score	167	4.11±2.34	57	3.82±2.30	110	4.26±2.35	0.338	-0.090
Overall Total Knowledge Score	167	6.78±2.97	57	6.25±2.82	110	7.05±3.02	0.103	-0.153

Table 5 Knowledge level of medical interns regarding recommended minimum test ordering intervals

Test Ordering Range*	Correct n (%)	Incorrect n (%)	No Idea n (%)
AST–ALT	31 (19%)	88 (53%)	48 (29%)
Urinalysis (TİT)	44 (27%)	82 (49%)	41 (25%)
TSH	30 (18%)	79 (47%)	58 (35%)
Ferritin	47 (28%)	73 (44%)	47 (28%)
Vitamin B12	63 (38%)	79 (47%)	25 (15%)
Vitamin D	52 (31%)	76 (46%)	39 (23%)
HbA1c	119 (71%)	24 (14%)	24 (14%)
Hemoglobin variant analysis	47 (28%)	33 (20%)	87 (52%)
CRP	57 (34%)	87 (52%)	23 (14%)
Urine culture	64 (38%)	45 (27%)	58 (35%)
Anti-HAV IgM (+)	54 (32%)	51 (31%)	62 (37%)
Anti-Toxoplasma IgG (+)	79 (47%)	21 (13%)	67 (40%)

*Recommended minimum test ordering intervals were based on the Ministry of Health's Rational Test Ordering Procedure. "No idea" responses were analyzed separately from incorrect responses to distinguish lack of knowledge from incorrect knowledge.

Table 6 Comparison of knowledge on recommended minimum laboratory test ordering intervals between academic year cohorts

Test Ordering Interval*	Group 1 Correct n (%)	Group 2 Correct n (%)	χ^2	p value	Cramer's V
AST–ALT	10 (18%)	21 (19%)	0.02	0.88	0.01
Urinalysis (TİT)	15 (26%)	29 (26%)	0.00	0.97	0.01
TSH	9 (16%)	21 (19%)	0.23	0.63	0.04
Ferritin	15 (26%)	32 (29%)	0.18	0.67	0.03
Vitamin B12	20 (35%)	43 (39%)	0.29	0.59	0.04
Vitamin D	17 (30%)	35 (32%)	0.07	0.79	0.02
HbA1c	39 (68%)	80 (73%)	0.48	0.49	0.05
Hemoglobin variant analysis	14 (25%)	33 (30%)	0.44	0.51	0.05
CRP	18 (32%)	39 (35%)	0.17	0.68	0.03
Urine culture	21 (37%)	43 (39%)	0.06	0.80	0.02
Anti-HAV IgM (+)	17 (30%)	37 (34%)	0.32	0.57	0.04
Anti-Toxoplasma IgG (+)	25 (44%)	54 (49%)	0.41	0.52	0.05

*Pearson's chi-square test was used for cohort comparisons. Cramer's V was reported as an effect size. Higher Cramer's V values indicate stronger associations between academic cohort and correct response status.

ing recommended minimum laboratory test ordering intervals. Pearson chi-square analyses indicated comparable distributions of correct responses across all evaluated laboratory tests. All p-values exceeded the predefined significance threshold. Effect size analysis revealed very small Cramer's V coefficients ranging between 0.01 and 0.05, indicating negligible associations between academic year and rational laboratory test ordering knowledge. The highest correct response rate was observed for HbA1c testing in both cohorts, whereas knowledge of follow-up testing intervals remained limited and comparable between groups. Overall findings suggest that consecutive academic cohorts exhibited similar competency profiles regarding rational laboratory utilization and that progression between academic years did not significantly influence knowledge of evidence-based test repetition intervals (Table 6).

Discussion

This study comprehensively evaluated the knowledge, awareness, and practical approaches of sixth-year medical students regarding rational laboratory use and the laboratory pre-analytical phase. The findings reveal that students are largely aware of the critical role laboratory tests play in diagnostic and treatment processes; however, their level of knowledge and education concerning pre-analytical processes and rational test ordering is noticeably insufficient and heterogeneous (17). One of the most important findings of this study is the discrepancy between interns' high level of clinical exposure and their limited standardized knowledge of pre-analytical processes and rational test ordering (18). Although almost all participants had performed blood sampling on real patients, their knowledge of technical issues such as order of draw, tube inversion, coagulation sample stability time, and diurnal variation was limited (19). This suggests that participation in clinical procedures alone may not be sufficient to ensure standardized knowledge acquisition unless supported by structured teaching, supervision, and feedback. However, because this study was cross-sectional, this interpretation should be considered an educational inference rather than evidence of causality.

The findings of this study are consistent with previous international reports indicating that medical students and interns often have insufficient knowledge of laboratory medicine, particularly regarding the pre-analytical phase and appropriate test utilization (6,8,9,10,14). Similar studies emphasized that laboratory medicine receives limited curricular time in undergraduate medical education despite its central role in diagnosis, monitoring, patient safety, and healthcare resource management (20-22). The present study contributes to this literature by providing data from the Turkish medical education context and by linking interns' knowledge gaps to the national Rational Laboratory Use initiative (4). This national policy perspective strengthens the relevance of the findings, as rational test ordering is not only an educational issue but also a matter of healthcare quality, patient safety, and cost-effectiveness.

Knowledge assessment further indicated that interns performed relatively well in basic patient preparation tasks, such as identifying the appropriate fasting duration prior to blood sampling. These findings likely reflect the frequent clinical repetition of routine procedures during internship training. However, knowledge of complex pre-analytical variables, including diurnal variation, sources of laboratory error, specimen transport conditions, and tube handling procedures, remained insufficient. Given that pre-analytical errors constitute the majority of laboratory-related mistakes worldwide, these deficiencies represent a critical patient safety concern (1,3). Incorrect specimen handling or inappropriate transport conditions may directly compromise diagnostic accuracy and subsequently influence clinical decision-making (2,3,20).

Another important observation was the limited awareness of national health policies related to rational laboratory use. This finding highlights a gap between healthcare policy implementation and undergraduate medical training. Despite the implementation of the Ministry of Health's Rational Test Ordering regulations, many interns were unfamiliar with these procedures. Effective integration of national clinical governance policies into internship curricula appears essential to ensure the sustainable adoption of rational laboratory practices.

The analysis of knowledge regarding recommended minimum test ordering intervals revealed considerable variability across laboratory investigations (Table 5). Kılıç et al. (15) reported that 80.8% of physicians correctly identified HbA1c, whereas only 36.0% correctly identified the AST/ALT reference range, and knowledge of thyroid hormones was even lower (17.3%). Similarly, in our study, HbA1c was the most accurately recognized item among interns (71%), while substantially lower correct response rates were observed for TSH (18%) and AST/ALT (19%). The relatively high accuracy for HbA1c suggests better familiarity with well-established chronic disease monitoring intervals that are commonly emphasized in clinical education. Furthermore, approximately half of the interns lacked knowledge related to tests that do not require routine repetition, such as hemoglobin variant analysis and

serological markers. Consistent with these findings, Fidan et al. (16) highlighted that unnecessary repeat serological testing imposes a significant financial and workload burden on laboratory services. Collectively, these findings indicate difficulty in distinguishing between monitoring and confirmatory diagnostic tests among interns, which may contribute to unnecessary test repetition in clinical practice (11,16).

Comparative analyses between the 2024–2025 and 2025–2026 academic cohorts demonstrated no statistically significant differences across all domains, and Cramer's V values indicated negligible effect sizes (Table 3 and Table 6). These findings suggest that progression between consecutive academic years did not meaningfully influence knowledge acquisition. The absence of cohort differences may reflect stable curricular structures rather than temporal variations between student groups, highlighting the need for curriculum-level rather than cohort-specific interventions.

From an educational perspective, these findings underscore the importance of structured program evaluation in internship training (8,10). Evaluating learning outcomes related to laboratory processes allows educators to identify persistent competency gaps and support data-driven curriculum revisions (6-8). The integration of targeted educational strategies, such as simulation-based laboratory training, clinical decision support exercises, and case-based rational test ordering modules, may enhance both procedural accuracy and clinical reasoning (7,8,14). Pre-analytical quality management and rational test ordering should be addressed as compulsory learning outcomes before and during the internship period. Minimum test repetition intervals should be reinforced during clinical rotations, particularly in departments where laboratory tests are frequently ordered. Embedding rational laboratory use principles into competency-based medical education frameworks may further contribute to improved patient safety, reduced healthcare costs, and optimized laboratory workload management (7,10,11,14).

There are several limitations to consider when interpreting the results of this study. The main methodological limitation of this study is that the questionnaire was developed by the researchers and was not subject to a comprehensive psychometric validation process. Although the items were prepared based on national guidelines, laboratory medicine literature, and expert opinion, formal content validity analysis, construct validity assessment, pilot testing, and reliability testing were not fully performed. Therefore, the findings should be interpreted as an assessment of medical interns' responses to a structured knowledge questionnaire rather than results obtained from a fully validated measurement instrument. Future studies should focus on the development and validation of standardized tools for assessing medical students' competencies in pre-analytical laboratory processes and rational test ordering. This was a single-center study conducted at Suleyman Demirel University Faculty of Medicine; the generalizability (external validity) of the findings to other medical faculties with different educational curricula may be limited. As data were collected through an online survey, there is a risk of social desirability bias, and it is uncertain to what extent self-reported knowledge levels reflect actual clinical performance. Although the response rate was acceptable and the sample size exceeded the calculated minimum requirement, selection bias cannot be completely excluded. Since the demographic and educational characteristics of non-respondents were not available, it was not possible to determine whether participants differed from non-participants in terms of knowledge, motivation, or previous training exposure. Owing to the cross-sectional design of the study, changes in knowledge over time could not be assessed; the study provides only a snapshot of knowledge at a single point in time. Future multi-center and longitudinal studies would provide a broader perspective on the effectiveness of laboratory management training.

In conclusion, this study demonstrated that medical interns had clinically relevant knowledge gaps regarding pre-analytical laboratory processes and rational test ordering. Although interns were highly exposed to blood sampling and laboratory-related clinical activities, their knowledge of technical pre-analytical procedures and evidence-based test repetition intervals was insufficient. No meaningful differences were observed between two consecutive academic cohorts, suggesting that these deficiencies may reflect a persistent curriculum-level need rather than a cohort-specific issue. The internship period represents a critical opportunity for developing appropriate laboratory utilization habits and strengthening awareness of patient safety risks associated with pre-analytical errors. These findings support the integration of compulsory, structured, and scenario-based laboratory medicine training into undergraduate medical education. Future multi-center longitudinal studies using validated assessment tools are needed to evaluate the effectiveness of these educational interventions.

Conflict of Interest Statement

The authors declare that there are no conflicts of interest.

Ethical Approval
Ethical approval for this study was obtained from the Suleyman Demirel University Health Sciences Ethics Committee (meeting no:105, decision no:8, approval date: November 3, 2025).

Consent to Participate and Publish
Participation in the survey was voluntary, and informed consent was obtained electronically from participants who completed the online questionnaire.

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Availability of Data and Materials
Data available on request from the authors.

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Artificial intelligence tools were used only for language editing. The authors take full responsibility for the content of the manuscript.

Authors Contributions
F.B.Ş: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Validation; Visualization; Writing-original draft.

G.K: Formal analysis; Investigation; Methodology; Writing-original draft.

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