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Standardization of Sample Handling Methods to Reduce the Rate of Inadequate Sampling

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Purpose: The predominant approach for mitigating inadequate sampling rates has primarily involved bolstering the volume of education. This study aimed to curtail inadequate sampling rates through the implementation of continuous quality improvement (CQI) activities, tailoring effective methods to the unique needs of each institution.

Methods: We developed a sample handling guidebook and implemented QI activities to address this issue.

Results: These measures resulted in a 4.7% decrease in inadequate sampling rates, concurrently improving knowledge of sample handling and overall nurse satisfaction. We addressed the root causes of inadequate sampling before laboratory pre-processing by: 1) focusing on systematic rather than erratic errors through CQI activities, 2) revising the sample handling guide, and 3) delivering face-to-face education based on the specific needs of the nursing department. These changes resulted in an additional 0.6% decrease in the inadequate sampling rate.

Conclusion: This study demonstrates that the implementation of CQI activities based on evidence derived from a multifaceted causal analysis significantly reduced the inadequate sampling rate compared to previous studies.

Keywords: Quality improvement, Specimen handling, Sampling errors, Standardization

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Ⅰ. Introduction

According to the guidelines provided by the Korean Association of Medical Technologists, inadequate sampling refers to the collection of samples that are unacceptable for lab processing, including samples: 1) for which the patient's name or registration number cannot be identified (such as missing barcodes), 2) with missing doctor's orders or incomplete information on the prescription form (for hand-written prescriptions), 3) collected using improper methods, 4) collected without adhering to collection time or patient condition, 5) with insufficient quantity for testing, 6) collected in inappropriate containers (e.g., improper anticoagulant usage), 7) coagulated samples in anticoagulant containers, 8) not correctly stored after collection (prolonged storage at room temperature), 9) expired, 10) hemolyzed, and 11) incorrectly transported [1].

Inadequate sampling increases the test turnaround time [2], use of medical materials, cumulative damage to testing equipment, and burden on patients due to repeated sample collection. Although various forms of continuous quality improvement (CQI) activities have been implemented to reduce inadequate sampling rates, most methods rely on simply increasing the amount of education [3,4]. Accordingly, this study conducted a multifaceted causal analysis and used the findings to inform methods to reduce the inadequate sampling rate compared with previous studies.

The number of inadequate sampling cases was investigated, and CQI activities were implemented in 2020 under the theme "Establishing Standard Guidelines for Reducing Inadequate Samples." In addition, a questionnaire survey was conducted to investigate the educational needs, methods, and knowledge related to inadequate sampling required by staff members. Based on the survey findings, a sample-handling guidebook and videos were produced and distributed, significantly reducing the inadequate sampling rate. Despite the overall reduction in inadequate samples after preprocessing, including clotting and hemolysis, issues regarding the occurrence of inadequate samples before preprocessing, barcode attachment errors, quantitative insufficient (QNS) errors, and prescription errors, persisted. Based on the determination that a fundamental solution was needed for errors that occur before pre-processing—which can easily be overlooked as erratic errors—CQI activities were implemented in 2022 under the theme "Management of Nursing Department - Diagnostic Laboratory Medicine Protocols for Workflow Improvement."

Ⅱ. Methods

1. 2020 QI Activities

We used Google Docs (https://forms.gle/DaYahMYiUSXz2dxp8) to conduct an online survey between March 15 and April 19, 2020, with 190 ward nurses working in relevant departments to investigate the inadequate sampling rate. We asked the participants about the causes of inadequate sampling [e.g., ethylenediaminetetraacetic acid (EDTA), serum separate tube (SST), sodium citrate, arterial blood gas analysis (ABGA), blood culture, tube identification, barcode attachment method, department name identification, understanding of laboratory workflow, and laboratory location identification] to determine whether they were aware of

such reasons. In addition, we surveyed the following factors: educational experience (if the participants had received relevant education or training), satisfaction with current education, need for additional education, preferred form of education, need for standardized hospital-specific guidelines, consistency of sample handling methods within the nursing department, frequency of calls to the laboratory, satisfaction with communication methods, and perceived burden associated with phlebotomy tasks.

Inadequate samples were visually judged by a medical technologist according to the following criteria: EDTA tube with clots, SST with hemolysis, sodium citrate with clots in the sample or the sample not collected up to the volume line, ABGA with the cap not properly closed, sample not correctly attached to the barcode attachment location, samples collected in smaller quantities than could be tested, samples collected in tubes different from the order, and samples related to other laboratories.

Based on the survey findings, a Sample Handling Guide that included photographs was created and distributed to all departments. Videos explaining each page were created and uploaded to an Internet platform (YouTube) using a private link (https://youtu.be/bHGbEYkEURI) with restricted viewing access. A comprehensive 32-minute video that included explanations of all pages was used for the regular training of new nurses. We also conducted a follow-up survey to assess improvements after the completion of the CQI activities.

2. 2022 CQI Activities

Among the reasons for errors that occurred before preprocessing in the laboratory, there were many cases where the barcode was attached too far above or below the designated location. Additionally, there were frequent cases of QNS due to orders for tests that could be performed with a single test tube printed on two barcodes instead of one, resulting in blood samples collected in two separate tubes. Cases that could be overlooked as erratic errors were reconsidered as possible systematic errors, and improvements were implemented. Therefore, the barcode reading range of the laboratory equipment was adjusted to cover a more comprehensive range. The program was modified to print all orders of tests that could be sufficiently performed using a single blood sample tube on a single barcode.

The existing sample handling guide video was edited to less than 30 min, and the volume was adjusted in some parts as requested by the nursing department. The revised video was uploaded to YouTube and Nurse Note platforms because the latter is more accessible on mobile devices [5]. Moreover, the sample-handling guide booklet was resized (152 × 225 mm) to make it more portable and printed on glossy paper to improve the photograph quality.

As many participants preferred face-to-face instruction, the researcher personally participated in training preceptors (dedicated trainers for new nurses) and conducted discussions. This study was approved by the Institutional Review Board (IRB) of the Gwangju Veterans Hospital (IRB approval no.: human 2022-5-1).

3. Statistical Analysis

The basic characteristics of survey participants were set as nominal variables. As the survey was a complete enumeration survey at our institution, the

analysis was performed without imputing missing values. Cramer's V coefficient was used to examine the correlations between experience and the variables associated with inadequate sampling. The variables associated with inadequate sampling in the surveys before and after the implementation of CQI activities were analyzed by categorizing the responses into "Yes" for those who knew the exact reason and "No" for those who did not. Moreover, the differences in the variables before and after the implementation of CQI activities were derived. To determine whether the decrease in the inadequate sampling rate was proportional to the observed changes, we compared the ratio of inadequate sample cases to the total number of cases before and after the QI activities. All statistical analyses were performed using Stata/MP 14.0 (StataCorp LLC., Texas, USA) with statistical significance set at $p < .05$.

Ⅲ. Results and Discussions

1. Basic Characteristics of the Survey Participants (Table 1)

The study population included 191 participants, with 44.5% aged 20-29, 29.8% aged 30-39, 12.6% aged 40-49, and 13.1% aged ≥50 years. Participants were predominantly female (n=183). Regarding position, non-managerial general nurses accounted for the highest proportion (87.4%). Regarding work experience, 10.5%, 20.9%, 13.6%, 26.2%, and 28.8% of the participants had work experience of < 1, 1 - 2, 3 - 4, 5 - 9, and ≥ 10 years, respectively. Most participants (68.6%) had more than three years of work experience, indicating a skilled workforce. Regarding department affiliation, the results showed similar distributions for the internal medicine ward (40.3%) and surgical ward (41.9%), whereas special units (18.8%) were well distributed relative to department size.

Table 1. Basic characteristics of survey participants.

(N=191)

Variables	n (%)
Age (years)	
20-29	85 (44.5%)
30-39	57 (29.8%)
40-49	24 (12.6%)
50-59	25 (13.1%)
Sex	
Female	183 (95.8%)
Male	8 (4.2%)
Position	
General nurse	167 (87.4%)
Head nurse	10 (5.2%)
Nursing department manager	14 (7.3%)
Experience	
< 1 year	20 (10.5%)
1-2 years	40 (20.9%)
3-4 years	26 (13.6%)
5-9 years	50 (26.2%)
≥10 years	55 (28.8%)
Affiliation	
Internal medicine ward	77 (40.3%)
Surgical ward	80 (41.9%)
Special unit (ER, ICU, AKU)	36 (18.8%)

Data are presented as number (%).
Abbreviations: ER, emergency room; ICU, intensive care unit; AKU, artificial kidney unit.

2. Correlation between Work Experience and Variables Associated with Inadequate Sampling (Table 2)

Among the variables, only "department name identification" (r=0.2470, p=.020) was significantly correlated with work experience, indicating the need to develop standardized guidelines. Generally, the inadequate sampling rate was not corrected, even when proper methods were provided to the nurses, which was attributed to the nurses' explanation that they prioritized senior nurses' practices despite knowing the correct methods.

Table 2. Correlation between work experience and variables associated with inadequate sampling.

Variables	r	p
EDTA	0.1487	.377
SST	0.1660	.261
Sodium citrate	0.0313	.996
ABGA	0.1851	.162
Blood culture	0.1030	.731
Tube identification	0.1722	.226
Barcode attachment method	0.1850	.163
Department name identification	0.2470	.020
Understanding of laboratory workflow	0.2125	.071
Laboratory location identification	0.1954	.121

p-values were calculated by Cramer's V coefficient.
Abbreviations: EDTA, ethylenediaminetetraacetic acid; SST, serum separate tube; ABGA, arterial blood gas analysis.

3. Comparison between Pre- and Post-QI Activity Survey Results (Table 3)

Before the QI activities, 98.4% of the participants indicated the need to establish standardized guidelines. Regarding the preferred form of education, most participants (71.2%) preferred documents including photographs, followed by videos (47.6%), face-to-face sessions (17.8%), and written documents (10.5%).

Table 3. Comparison of survey results between before and after QI activities.

(N=191)

Variables	Before QI Activity		After QI Activity		Difference in Before/After QI Activity
	Yes	No	Yes	No	Yes
Understanding for adequate sampling					
EDTA	123 (64.4%)	68 (35.6%)	164 (86.1%)	27 (13.9%)	41 (21.7%)
SST	169 (88.5%)	22 (11.5%)	184 (96.1%)	7 (3.9%)	15 (7.6%)
Sodium citrate	165 (86.4%)	26 (13.6%)	175 (91.7%)	16 (8.3%)	10 (5.3%)
ABGA	132 (69.1%)	59 (30.9%)	171 (89.4%)	20 (10.6%)	39 (20.3%)
Blood culture	151 (79.1%)	40 (20.9%)	166 (86.7%)	25 (13.3%)	15 (7.6%)
Tube identification	132 (69.1%)	59 (30.9%)	144 (75.6%)	47 (24.4%)	12 (6.5%)
Barcode attachment method	167 (87.4%)	24 (12.6%)	181 (95%)	10 (5%)	14 (7.6%)
Department name identification	76 (39.8%)	115 (60.2%)	119 (62.2%)	72 (37.8%)	43 (22.4%)
Understanding of laboratory workflow	34 (17.8%)	157 (82.2%)	101 (52.8%)	90 (47.2%)	67 (35.0%)
Laboratory location identification	100 (52.4%)	91 (47.6%)	141 (73.9%)	50 (26.1%)	41 (21.5%)
Workload in phlebotomy	172 (90.1%)	19 (9.9%)	155 (81.1%)	36 (18.9%)	-17 (-9.0%)
Educational experience	143 (74.9%)	48 (25.1%)			
Educational satisfaction	74 (38.7%)	117 (61.3%)	166 (86.7%)	25 (13.3%)	92 (48.0%)
Educational demand	137 (71.7%)	54 (28.3%)	61 (31.7%)	130 (68.3%)	-76 (-40.0%)
Preferred form of education					
Written documents	20 (10.5%)				
Written documents with photos	136 (71.2%)				
Videos	91 (47.6%)				
Face-to-face	34 (17.8%)				
Needs for standardized guidelines	188 (98.4%)	3 (1.6%)			
Consistency in sample handling methods	74 (38.7%)	117 (61.3%)	155 (81.1%)	36 (18.9%)	81 (42.4%)
Frequency of calls to laboratory					
< 10%	93 (48.7%)		111 (58.3%)		18 (9.6%)
< 10-49%	80 (41.9%)		64 (33.3%)		-16 (-8.6%)
< 50-79%	15 (7.9%)		14 (7.2%)		-1 (-0.7%)
≥ 80%	3 (1.6%)		2 (1.1%)		-1 (-0.5%)
Satisfaction with communication	74 (38.7%)	117 (61.3%)	136 (71.1%)	55 (28.9%)	62 (32.4%)
Completion of guidebook			173 (90.6%)	18 (9.4%)	

Data are presented as numbers (%).

Abbreviations: QI, quality improvement; EDTA, ethylenediaminetetraacetic acid; SST, serum separate tube; ABGA, arterial blood gas analysis.

The results showed an increase in positive aspects of all variables after QI activities. the variable indicating understanding for adequate sampling increased from as little as 5.3% points(Sodium citrate) to as much as 35% points(Understanding of laboratory workflow). Although not shown in the tables, most participants (86.7%) expressed satisfaction with the booklet, indicating an improvement of 48% in satisfaction with education using the guidebook. Additionally, the guidebook improved the consistency in sample handling among the nurses by 42.4%, while the educational needs decreased by 40%.

The results also revealed an overall decrease in the number of calls to the laboratory. This can be attributed to the provision of guidebooks and education. Satisfaction with hospital-wide communication also increased by 32.4%, indicating that participants perceived improved communication. This has been achieved by establishing standards and providing unidirectional education.

Meanwhile, the burden of the phlebotomy tasks decreased by approximately 9%. Almost all nurses recognized that phlebotomy tasks were not their primary responsibility and expressed that these tasks caused significant burdens and fatigue. After the President vetoed the proposed Nursing Practice Act in Korea, phlebotomy was included on the list of medical practices deemed illegal by the Korean Nurses Association deemed illegal [6]. In contrast, the Korean Intern Resident Association emphasizes that nurses can perform phlebotomies under the supervision of a physician [7]. Moreover, the Constitutional Court of Korea ruled that punishing nurses for performing phlebotomy would violate their rights to equality and pursuit of happiness under the Medical Service Act [8]. The court ruled that phlebotomy may be performed by clinical pathologists under the supervision of a physician and by nurses and nurse assistants under the supervision and guidance of a physician (citing the Constitutional Court case [2017heonma491], Supreme Court precedent [2001do3667])[9]. Taken together, work efficiency is expected to improve when nurses understand and accept their primary responsibilities correctly.

In addition, in the survey conducted after the QI activities, 90.6% of participants indicated that they had read the guidebooks. Considering that one out of ten nurses did not comply with the educational content provided, it is probable that the cause of this was negligence in the management of the nursing department.

4. Comparison of Inadequate Sampling Rates According to CQI Activities (Table 4)

The inadequate sampling rates before and after the QI activities were 5.8% (n=896) and 1.1% (n=167), respectively, showing a decrease of 4.7%. Moreover, the inadequate sampling rate decreased by 0.6% - 0.5% (n=83) after the CQI activities. Such findings demonstrated that inadequate sampling rates could be reduced through CQI activities, including improvement activities at the laboratory, not at the nursing department level, to fundamentally address issues that may sometimes be overlooked, such as erratic errors, improved effective delivery through updates to the guidebook, and consistent changes in educational methods based on the identification of nursing department needs.

Table 4. Comparison of inadequate sampling rates according to CQI activities.

Parameter	Before 2020 QI Activity	After 2020 QI Activity	After 2022 CQI Activity
Number of inadequate samples/total samples	896/15432 (5.8%)	167/15287 (1.1%)	83/15360 (0.5%)

Data are presented as numbers (%).
Abbreviations: CQI, continuous quality improvement; QI, quality improvement.

5. Limitations

This study had some limitations. First, we could not extensively elucidate the issues related to inadequate sampling rates. Specifically, to identify the type of inadequate sampling that occurred most often in which department and how such cases changed according to the knowledge, satisfaction with education, and educational needs of nurses in each department, the inadequate sampling cases that occurred in the initial stage of the study were divided into 25 codes and recorded according to the wards and phlebotomy nurses. This code-based classification was used to derive results by cost-benefit analysis through quantification of the disposal cost of waste boxes and the loss of human resources while discarding inadequate samples. However, because the survey data were anonymized to protect privacy, the departments were only distinguished as "internal medicine ward," "surgical ward," and "special units." Consequently, individual correlations could not be identified and a cost-benefit analysis could not be performed.

Second, departmental transfers among nurses, which occur often, could have undermined the overall reliability of our findings. When the monthly frequency of departmental transfers was investigated, April had the lowest transfer rate. Accordingly, surveys before the QI activities and an investigation of the number of cases were conducted over a period that included April. However, it was unavoidable that some participants changed their departments by the time the survey was conducted after the QI activities. Meanwhile, the investigation of the types of inadequate sampling by department during the months when QI activities were implemented showed similar types and frequencies for each month, indicating that the impact of departmental transfers was not sufficiently significant to undermine the reliability of the findings.

Finally, some characteristics are unique to our institution. The situation at our institution requires nurses to perform phlebotomies in the ward. Although doctors and other healthcare workers may perform phlebotomy, it is generally considered a specialized field for clinical pathologists, and most hospitals have clinical pathologists responsible for phlebotomy [10]. Consequently, the number of inadequately sampled cases during phlebotomy may have been slightly higher at our institution than that at other institutions.

Considering the above limitations, the inadequate sampling rate will be further reduced if these aspects are addressed in future studies.

Ⅳ. Conclusion

The predominant traditional approach for mitigating inadequate sampling rates primarily involves bolstering the volume of education. This study aimed to curtail inadequate sampling rates through the implementation of continuous quality improvement (CQI) activities, tailoring effective methods to the unique needs of each institution. The survey results revealed that the most significant cause of inadequate sampling was the lack of standardized sample handling methods. A Sample Handling Guide was subsequently developed and QI activities were implemented to address this issue. These measures resulted in a 4.7% decrease in inadequate sampling rates, concurrently improving knowledge of sample handling and overall nurse satisfaction.

The root causes of inadequate sampling before laboratory pre-processing were addressed by 1) focusing on systematic rather than erratic errors through CQI activities, 2) revising the existing sample handling guidebook, and 3) delivering face-to-face education based on the specific needs of the nursing department. These changes resulted in an additional 0.6% decrease in the inadequate sampling rate. This study demonstrates that the implementation of CQI activities based on evidence derived from a multifaceted causal analysis significantly reduced the inadequate sampling rate compared to those of previous studies.

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