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Reduction of pre-analytical errors in the clinical laboratory at the University Hospital of Korea through quality improvement activities

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ABSTRACT

Background: The clinical laboratory is responsible for reporting accurate and expeditious results. However, the pre-analytical phase is directly related to the procedure of specimen collection and is mostly out of the direct control of the laboratory; further, most pre-analytical errors are related to human factors. Therefore, education and training programs for the phlebotomy teams are considered the most significant and necessary measures to reduce these errors.

Methods: A cross-sectional study was conducted to investigate the types and frequencies of pre-analytical errors in the hospital laboratory. Pre-analytical errors were categorized into four main categories: rejected sample, error related to test ordering, misidentification, and others. Several activities were performed for quality improvement in order to reduce the rates of these errors. The data were analyzed by comparing the pre-intervention and post-intervention results along with the results of questionnaires to assess knowledge to investigate the effects of the activities.

Results: The rates of pre-analytical errors decreased from 0.42% in the pre-intervention period to 0.32% in the post-intervention period. The rejected sample category accounted for the highest rates in the pre- and post-intervention periods. In the questionnaires, the overall average score after the intervention was 71.5, which was a significant increase from 46.0 in the pre-intervention period.

Conclusions: Each clinical laboratory has various types of pre-analytical errors due to the complexity of the healthcare environment. Therefore, targeted intervention including a quality improvement program and its continuous maintenance should be conducted to reduce pre-analytical errors and to improve patient safety.

1. Introduction

The clinical laboratory plays an important role in diagnosis and follow-up monitoring after treatment and is responsible for reporting accurate and expeditious results. The requirement for credibility and accuracy in laboratory testing is gradually increasing in healthcare settings. However, various mistakes related to laboratory testing can occur in the process from ordering tests to reporting results, leading to laboratory errors. These mistakes can lead to inappropriate diagnosis or treatment, resulting in additional unnecessary investigation, and dissatisfaction with healthcare services. Re-collection of samples due to sample rejection can also cause prolongation of turn-around time (TAT), delayed diagnosis or treatment, and a negative impact on patient outcome.

A laboratory error is any defect that occurs during the entire testing process and is one of the major factors related to overall medical errors caused by the complexity of the healthcare environment [1–9]. Laboratory errors include pre-analytical, analytical, and post-analytical phases [1]. Among these, pre-analytical errors account for the highest percentage. Several studies have reported that pre-analytical errors account for 46.0%–84.5% of total laboratory errors [1–6,9–11].

The ISO 15189:2012(en) standards for laboratory accreditation define the pre-analytical phase as processes that start from the clinician's request and include the examination request, preparation and identification of the patient, collection of the primary sample(s), and transportation to and within the laboratory, and they end when the analytical examination begins [12].

Various mistakes in the procedure of specimen collection have been reported as the leading causes of pre-analytical errors [6,9,12]. In our hospital, the processes in the pre-analytical phase are out of the direct control of the laboratory except for blood collection at the Outpatients'

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Department (OPD) and in some parts of the Inpatients' Department (IPD). Most of these errors are susceptible to human factors. Therefore, laboratory errors are more likely to occur in the pre-analytical phase [1,4,8,9,13], and the types of pre-analytical errors are heterogeneous [2–4,9,10]. Nevertheless, clinical laboratories are required to carefully monitor all the steps in laboratory testing in order to detect and correct these errors [10].

The pre-analytical phase can be subdivided into specimen collection, specimen transport, and specimen processing [14]. Systems such as EMR–LIS (Ku2.0, Hyundai Information System, Seoul, Korea), automated tube labelling systems for the OPD (GNT-511, Seoul, Korea), pneumatic tube system (Swisslog, Villingen-Schwenningen, Germany), auto-tracking for specimen transport (SNS Eng., Japan), and the automated blood sample processing system AutoMate 800 (Beckman Coulter, California, USA) are currently being operated at the clinical laboratory of Kyungpook National University Chilgok Hospital. The remaining processes associated with specimen collection can commonly cause laboratory errors due to human factors in the pre-analytical phase, which is clearly a vulnerable part of the laboratory process. Therefore, it is not likely possible to entirely eliminate these pre-analytical errors. However, they are preventable to some extent because they can be reduced by some efforts [2,5,6,9]. Efforts for quality improvement related to reduction of laboratory errors can be established through communication with clinical coworkers, implementation of a comprehensive error detecting system, and education and training programs for staff in charge of sample collection [9–11,15–20]. Most of all, education and training programs for phlebotomy teams are considered the most important and essential for reducing pre-analytical errors.

The first step in reducing pre-analytical errors is to recognize the existence of these errors and to analyze their reasons [5,18]. In addition, improving the quality of samples is the most important factor to prevent pre-analytical errors [15–17,19,20].

This study aimed to investigate the types and frequencies of unacceptable samples that can occur during the procedure of sample collection as objective indicators for pre-analytical errors, to find the reasons of these errors, and to reduce them. Several activities were performed including education and training programs for phlebotomy teams for quality improvement in order to reduce pre-analytical errors. The effects on pre-analytical errors before and after the activities were then investigated. Pre- and post-intervention questionnaire surveys related to sample collection procedures and the pre-analytical phase were conducted with phlebotomy teams to investigate the degree of quality improvement.

2. Materials and methods

2.1. Laboratory setting

The department of laboratory medicine in Kyungpook National University Chilgok Hospital receives about 1.0×10^6 samples and performs about 4.5×10^6 tests per year.

Three professors as well as 35 staff members are currently working in the laboratory that performs various testing for samples from the IPD and OPD. The sections in the laboratory include hematology, clinical chemistry, immunology, coagulation, microbiology, transfusion medicine, molecular pathology, urinalysis, point of care testing (POCT), stat, external commissioning for tests, and a section with tests performed by doctors.

Suitably qualified laboratory staff in charge of the reception for samples decide whether to accept or reject them according to the sample rejection criteria of the laboratory. The pre-analytical errors are categorized into four main categories: (A) rejected sample, (B) error related to test ordering, (C) misidentification, and (D) others. Category (A) includes improper volume, undue clotting, improper container, grossly hemolyzed sample, empty container, and improper transport. Category (B) includes duplicate order, incorrect test, error of the test date and inappropriate time of sample collection. Category (C) includes both patient misidentification and incorrectly labelled containers such as unlabeled samples, mislabeled samples, insufficiently labelled samples, and samples suspected of coming from the wrong patient. Category (D) includes bar-code error, sample not available, and collection date not available.

If the sample is to be rejected according to these criteria, the laboratory staff in charge of sample reception are to notify the clinical personnel responsible for the patient's care regarding the reason for sample rejection and simultaneously record the same in a systematic manner using the LIS. The reasons are all coded. The laboratory operates a system that allows the clinical personnel to check the notifications immediately after the laboratory staff inputs the information for rejected samples in the LIS. The rejected samples do not undergo the prescribed tests and therefore the samples have to be re-collected. The sectional heads of the laboratory periodically review all the recorded data for rejected samples in the LIS.

2.2. Methods of data collection

A retrospective study was conducted to identify the rate, and the types and frequencies of pre-analytical errors in the laboratory from January to December 2017 as basic data.

The data recorded in the LIS are collected monthly, analyzed statistically, and reviewed comprehensively by professors as a quality improvement activity for samples.

A cross-sectional study was also conducted to determine the degree of quality improvement in the phlebotomy teams after these activities. Data were compared pre-intervention - from March to May 2018 - and post-intervention - from October to December 2018 - to investigate the degree of quality improvement.

2.3. Activities for quality improvement in the pre-analytical phase

2.3.1. Update of the information in LIS

The information for laboratory tests included basic information about the test, reference range, test method, clinical significance, points of caution during sample collection, proper use of containers, use of bar-code labels, and criteria for sample rejection. However, it was found that changes in test methods, introduction of new tests, and other changes related to the laboratory were not properly updated. Activity was conducted to correct these errors from June to September 2018.

2.3.2. Distribution of the brochure for blood collection procedure

The contents of the brochure included the correct method and cautions in blood sample collection, tube order of draw, reasons for rejected samples, effects of rejected samples on the test results and their significance, appropriate sample collection methods for special tests such as IGRA (interferon-gamma release assay) and ICG (Indocyanine Green) test. This activity was conducted during the month of June 2018.

2.3.3. Education and training

This intervention, *i.e.* the education and training program, was accomplished by targeting phlebotomy teams comprising 10 ward

nurses (Group 1), 12 medical laboratory technologists (Group 2), and 29 medical interns (Group 3). Ward nurses and medical interns are in charge of collecting blood samples from the intensive care unit (ICU), neonatal ICU (NICU), pediatric ICU (PICU), and the emergency room (ER) and from other IPDs only when the requisition is a stat order. In all other cases, medical laboratory technologists are in charge of collecting blood samples. The author developed the education and training program by referring to several studies [16,17,19,21], and the same program was conducted for all three groups and twice for each group. The program contents included the correct method of blood sample collection, reinforcement of the knowledge on standardized blood sample collection procedures, causes of analytical interference, and methods for sample storage and transport.

2.3.4. Pre- and post-intervention questionnaires

Each pre- and post-intervention questionnaire to assess knowledge contained the same 10 questions. The author developed the questions by referring to the study by Aykal et al. [21]. The content of the questionnaire assessed awareness of the sample state (Part 1, Question numbers 1–3), awareness of the blood collection procedure (Part 2, Question numbers 4–7), and awareness of sample transport and storage (Part 3, Question numbers 8–10) (Table 1). Part 1, Question numbers 1–3 were given 9.8 points each. Part 2, Question numbers 4, and 6–7 were given 9.8 points each, whereas Question number 5 was given 11.8 points. Part 3, Question numbers 8–10 were given 9.8 points each. This totaled 100. The scores for each part were then calculated on a scale of 100. These surveys were also conducted in the targeted phlebotomy teams, Groups 1, 2, and 3.

Table 1
The questionnaire is composed of 10 questions on the pre-analytical phase. The phlebotomy teams participated in the investigation at the pre-intervention stage and post-intervention stage with the same questionnaire.

Part 1: Awareness of sample state
1. Which of the following doesn't require fasting for the test?
   ① Glucose ② Calcium ③ ALP ④ Triglyceride
2. Which of the following is the least likely to be affected by hemolysis of the specimen?
   ① K ② AST ③ LDH ④ Glucose ⑤ Phosphorus
3. Which of the following stages is the most likely to cause the highest rate of error during the test?
   ① Pre-analytical stage ② Analytical stage ③ Post-analytical stage

Part 2: Awareness of blood collection procedure
4. Choose all the possible impacts that could occur to the patient or the sample when the alcohol applied on the blood extraction area for disinfection is not completely dry.
   ① dilution of blood ② induction of pain
   ③ induction of turbid blood ④ induction of hemolysis
5. List the order of tubes for placing the blood sample when collecting blood using the vacuum blood vessels.
   ① EDTA tube (purple cap)
   ② Plain tube with clot activator (red cap)
   ③ Sodium citrate tube (light blue cap)
   ④ Heparin tube (green cap) ⑤ Blood culture bottle
   (→ → → →)
6. Choose the tube in which the exact amount of blood should be placed after sampling.
   ① Plain tube ② EDTA tube ③ SST
   ④ Heparin tube ⑤ Sodium citrate tube
7. After sampling, if the sample is placed in the EDTA tube and invert mixing is required, how many times or more should it be mixed?
   ① 2–4 times ② 4–6 times ③ 8–10 times
   ④ 16–18 times ⑤ 20–22 times

Part 3: Awareness of sample transport and storage
8. Which test sample item should be carried with ice?
   ① Hormone ② Ammonia ③ Blood gas analysis
   ④ Blood culture bottle ⑤ Cryoglobulin
9. If CSF samples taken for various examinations cannot be transported immediately and must be stored in the wards, what storage method should be used?
   ① refrigerated storage ② freezing storage
   ③ room temperature storage ④ It doesn't matter.
10. For blood samples, how long (Turn-around time, TAT) would it take to send them to the laboratory after blood collection?
    ① 1/20 ② 1/10 ③ 1/5 ④ 1/3

2.4. Statistical analysis

All statistical analyses were performed using IBM SPSS Statistics for Windows (version 23.0 IBM Corporation, Armonk, New York, USA) and Microsoft Excel (Microsoft Corporation, Redmond, WA, USA). Data were analyzed using the Chi-square test. A P value of less than 0.05 was considered statistically significant.

3. Results

3.1. Rate and distribution of pre-analytical errors in 2017

In total, 989,888 samples were received for laboratory testing in one year and of these, 63% were from the IPD and 37% were from the OPD; of these, 4347 samples were identified as pre-analytical errors and were rejected from the laboratory testing. The overall rate of pre-analytical errors was 0.44%.

The categories and frequencies of pre-analytical errors are shown in Table 2. The most common pre-analytical error was Category (A) (85.28%) and the major types of Category (A) were improper volume and undue clotting, followed by Category (B) (11.30%). Category (C) was very low, accounting for only 0.12%.

Of the 4347 unacceptable samples, the majority, 3673 samples (84.50%) were blood samples.

3.2. Comparison of pre-analytical errors of IPD and OPD in 2017

The difference between IPD and OPD was noticeable: 97.6% of the errors occurred from the IPD and 2.4% were from the OPD (P = .000). The rates of pre-analytical errors of the IPD and OPD were 0.68% and 0.03%, respectively, and showed a significant difference (P = .000). The results showed that considerably more sample rejections were associated with IPD compared with OPD. The frequency of Category (B) in the OPD was relatively higher than that in the IPD (Table 2). The frequencies of pre-analytical errors according to the categories showed significant differences between the IPD and OPD (P = .000).

Table 2
Rate and distribution of pre-analytical errors in 2017.

Category	Total (%)	IPD (%)	OPD (%)	P value
(A) Rejected sample	3707 (85.28)	3667 (86.40)	40 (38.84)	.000
Improper volume	2005			
Undue clotting	1352			
Improper container	239			
Grossly hemolyzed sample	56			
Empty container	28			
Improper transport	27			
(B) Error related to test ordering	491 (11.30)	442 (10.41)	49 (47.57)	
(C) Misidentification	5 (0.12)	5 (0.12)	0 (0.0)	
(D) Others	144 (3.31)	130 (3.06)	14 (13.59)	
Total unacceptable samples	4347 (100.0)	4244 (100.0)	103 (100.0)	
Total samples	989,888	626,777	363,111	
Rate (%)	0.44	0.68	0.03	.000
Proportion (%)		97.6	2.4	.000

Table 3
Comparison of the rates and distribution of pre-analytical errors in the pre- and post-intervention period.

Category	Pre-intervention (%)	Post-intervention (%)	*P* value
(A) Rejected sample	928 (82.56)	771 (83.62)	.426
Improper volume	379	337	
Undue clotting	452	319	
Improper container	55	73	
Grossly hemolyzed sample	32	28	
Empty container	4	11	
Improper transport	6	3	
(B) Error related to test ordering	141 (12.55)	117 (12.69)	
(C) Misidentification	1 (0.09)	2 (0.22)	
(D) Others	54 (4.80)	32 (3.47)	
Total unacceptable samples	1124 (100.0)	922 (100.0)	
Total samples	264,872	289,496	
Rate (%)	0.42	0.32	.000

3. Rates and distribution of pre-analytical errors in the pre- and post-intervention period.

The rate of pre-analytical errors in the pre-intervention period, which was shown as 0.42%, was significantly decreased during post-intervention period and accounted for 0.32% ($P = .000$) (Table 3). The frequencies of pre-analytical errors according to categories did not show significant differences between the pre- and post-intervention period ($P = .426$).

3.3. Results of the pre- and post-intervention questionnaires

In the questionnaires, the overall average score after the activities for quality improvement including the intervention was 71.5 and showed a significant increase compared with the pre-intervention score of 46.0 ($P = .000$) (Fig. 1).

In the pre-intervention survey, the average scores in Group 1, 2, and 3 were 48.0, 59.0, and 40.0, respectively. However, in the post-intervention survey, the average scores in Group 1, 2, and 3 were 76.1, 75.6, and 68.3, respectively. Comparing the pre- with post-intervention average scores according to groups showed significant differences in all groups (Fig. 1). The magnitude of the changes in the averages for Group 1, 2, and 3 were 36.9%, 22.0%, and 41.4%, respectively. The magnitude of the change in the overall average was 35.7%. There were significant differences of pre- and post-intervention between Group 1 and 3 ($P = .000$) and Group 2 and 3 ($P = .000$) in Part 2, along with Group 1 and 3 ($P = .000$) and Group 2 and 3 ($P = .027$) in Part 3. All three groups had the lowest scores in Part 2 and the highest scores in Part 1 in the pre-intervention, whereas all of them had the lowest scores in Part 2 and the highest scores in Part 3 in the post-intervention. The average scores of compared pre- and post-intervention showed significant differences in Part 2 and 3 ($P = .000$ and $P = .000$).

4. Discussion

The majority of laboratory errors are caused by the complex processes of the pre-analytical phase. To reduce the pre-analytical errors, the current blood collection practice that is directly related to these errors should be thoroughly checked and the sources of these errors should be reviewed through proactive tools such as FMEA (failure mode and effect analysis) or RCA (root cause analysis) [4,5,18]. The first step in these analyses is to identify the existence of these errors along with their types and frequencies [5,18]. After identifying and analyzing these errors, suitable risk management strategies and efforts should be put into operation for quality improvement. These are the best ways to avoid and prevent risks in patient care [4–6,16–18,22].

In the present study, the overall rate of pre-analytical errors identified was 0.44% (4347/989,888) in 2017; other studies showed similar error rates from 0.309% to 0.47% [3,10,11]. However, it is known that comparing the types and frequencies of pre-analytical errors from country to country or among laboratories is difficult because of different healthcare environments such as the national health care systems, prevalence of diseases, and many other factors [2,8–10]. The rates of pre-analytical errors were reported with a large variation according to the healthcare environment of the countries and the services provided by the laboratories. The reported error rates also varied depending on how they were detected [2,10]. It is not easy to detect pre-analytical errors accurately because reporting these errors is also difficult. The errors detected by laboratory staff members would be mostly included in this study, but those incurred by ward nurses and medical interns could have been missed.

The highest frequency of error in this study was for rejected samples, and several other studies also reported the same results [2,11,15–17,19,20]. Among the reasons for rejected samples, improper volume and undue clotting accounted for high frequencies of 54.09% and 36.47%, respectively, and both accounted for nearly 91% of the rejected samples. In addition, the majority of unacceptable samples (84.50%) were blood samples. Therefore, the main causes of these errors were analyzed to be directly related to the blood collection process and almost all of them were attributed to human factors. Lack of awareness of blood collection procedures in phlebotomy teams was also noted as the biggest problem. Three-part questionnaires to assess knowledge were conducted with the blood collection teams in this study. In both the pre- and post-interventions, the part with the lowest score was Part 2, which included the content about awareness of the blood collection procedure. This definitely showed a lack of identification of the problem related to blood collection and a lack of general knowledge and awareness of blood collection. There has been no

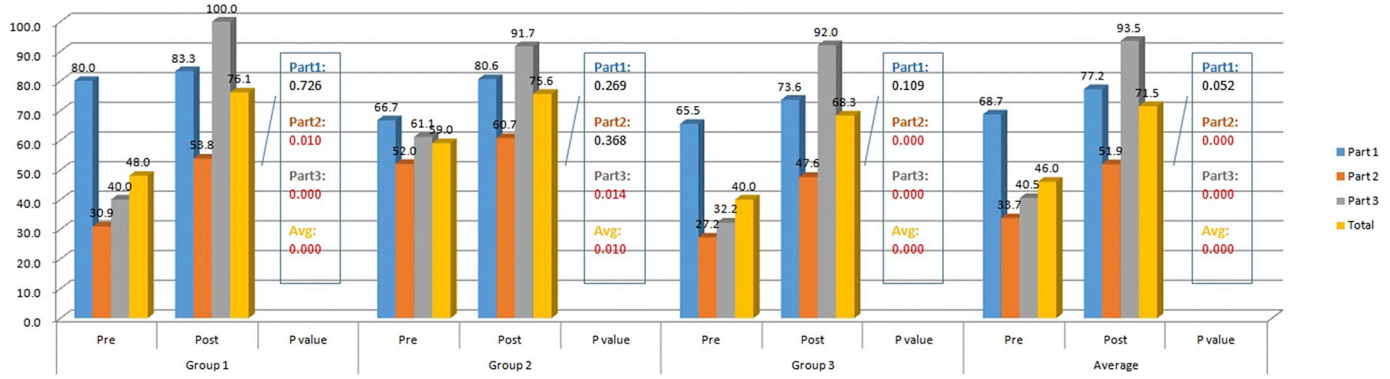

Fig. 1. Pre; Pre-intervention, Post; Post-intervention, Avg; Average. Scores calculated on a scale of 100 according to each part. Comparison of the results of post-intervention with those of pre-intervention shows the effect of education and training programs.

certification system for phlebotomists in Korea. Therefore, the author was strongly aware that education and training programs on blood collection for laboratory testing should be implemented for the staff in charge of blood sample collection, especially ward nurses and medical interns.

The frequency of misidentification was a relatively low percentage of 0.12% but this error can seriously influence the credibility of laboratory testing. This error can also result in misdiagnosis, delayed diagnosis or treatment, unnecessary investigation, and more serious outcomes in blood transfusion [22]. In addition, this error is entirely caused by human factors and should thus be reduced.

The overall rates of pre-analytical errors in the IPD and OPD were 97.6% and 2.4%, respectively; the rate was overwhelmingly high in the IPD. Blood collection in the OPD is performed by trained medical laboratory technologists using evacuated tube systems and is also under the direct control of the laboratory, whereas that of the IPD is performed by medical laboratory technologists as well as ward nurses and medical interns, which is partly outside the laboratory control. The difference between the IPD and OPD is due to human factors related to the skill and awareness of the blood collection process and due to the complexity of the procedure of blood collection being performed by ward nurses and medical interns [2,8,9]. Previous studies have reported that ward nurses and medical interns need more education [23,24]. In the present study, about 52% of pre-analytical errors in the IPD were found to have been made by ward nurses and medical interns. However, the frequency of 'error related to test ordering' was relatively high in the OPD. This is considered to be due to unfamiliar test ordering in the OPD. Therefore, better communication or inter-department cooperation between the laboratory and OPD is required to reduce this error.

Problems with pre-analytical errors include extra work from re-collection, additional unnecessary investigation, dissatisfaction with healthcare services, increase in cost, misdiagnosis, prolongation of TAT, delayed diagnosis or treatment, and negatively impacted outcome [2,5,22]. Therefore, it is more effective to prevent these errors in advance. There have been many reports that these errors can be corrected only through interventions such as education and training programs because they are mainly caused by human factors [15–18,20,23]. Education for phlebotomy teams has been emphasized for patient safety and satisfaction of the medical staff. It is also possible to prevent pre-analytical errors simply with a little attention to detail, such as staff being aware of the effects of rejected samples on test results, and of the correct blood collection procedures, and of staff concentrating on their work.

In the present study, some quality improvement activities such as LIS updating, distribution of the brochure, and the three-part questionnaire survey of the phlebotomy teams were conducted before the intervention measures of education and training programs. The total average scores of pre-intervention were lower in Group 1 and 3. This result confirmed the need for more education and training programs for ward nurses and medical interns [23,24]. Therefore, the author recognized that education on the blood collection procedure was urgently needed and thus, education and training programs for each group were prepared and implemented. The programs were focused on blood sample collection techniques including proper preparation for patients such as fasting, use of appropriate containers, correct techniques for venipuncture, collection through IV catheters, use of bar-code labels, and criteria for sample rejection and their implications.

The rate of pre-analytical errors during the pre- and post-intervention period reduced from 0.42% to 0.32% and the magnitude of the decrease was 23.8%.

Comparative analysis of total average scores in the pre- and post-intervention period according to the groups showed significant differences in all three groups. In Group 1 and 3, the average score of Part 2, Part 3, and Total showed a significant increase post-intervention (Fig. 1). Group 2 did not improve significantly in Part 2 after implementation of the education and training program. However, the frequency of rejected samples showed an increase of 1.3% in the post-intervention period. The study reported that the error rate between the pre- and post-intervention period was reduced by a magnitude of 20.5% and 28.0% for the rejection rate of coagulation in anticoagulant samples and sample inadequacy after one year of interventions; thus, the effects of the interventions were very good [17]. Therefore, the author confidently believes that phlebotomy teams need to be continuously educated and trained. Romero et al. reported that one stage intervention was not effective enough [24]. Implementation of interventions including ongoing education and training programs for quality improvement will thus be necessary for blood collection teams [20]. The author strongly considers that education and training programs should be implemented as ongoing systems.

High quality standards of clinical laboratories in Korea, Laboratory Medicine Accreditation Program, are ensured by the Laboratory Medicine Foundation, Seoul, Korea. This measure including the control of quality indicators such as the rate of patient/sample misidentification has helped laboratory medicine to function at a high level of reliability with many laboratories of medical institutes participating. Laboratory Medicine Accreditation Program Standards 2017 has been certified by the International Society for Quality in Health Care (ISQua).

"Guidelines and recommendations of the European Federation of Clinical Chemistry and Laboratory Medicine (EFLM)" have been continuously published to manage pre-analytical errors worldwide [25]. In addition, the Working Group "Laboratory Errors and Patient Safety" (WG-LEPS) of the International Federation of Clinical Chemistry and Laboratory Medicine (IFCC) is focusing on reducing errors in laboratory medicine [26].

The way to reduce these errors is to detect all the factors involving errors [27] and to make an effort to improve the quality of the systemic, total testing process, and all healthcare providers [28]. Implementation of interventions suitable for the medical institution and its continuous maintenance is considered to be strongly related to the continuous reduction of pre-analytical error rate. This can lead to better economic management and improvement in patient safety [5,24].

Each clinical laboratory of medical institutes has various reasons of pre-analytical errors due to the complexity of the healthcare environment. Therefore, targeted intervention including quality improvement programs should be performed to reduce pre-analytical errors and to improve patient safety.

This hospital is specialized for the care of patients with cancers or senile diseases and the care of children with serious and incurable diseases; thus, it is difficult to access peripheral veins in the IPD. Therefore, in order to reduce pre-analytical errors, it is also necessary to maintain highly skilled professional phlebotomy teams. In addition, this laboratory will continue to participate in the accreditation program.

5. Conclusions

Clinical laboratories should make efforts to identify the types and frequencies of pre-analytical errors and analyze their reasons as each clinical laboratory may have various types of pre-analytical errors due to the complexity of the healthcare environment. Therefore, targeted intervention including a quality improvement program and its continuous maintenance should be performed by clinical laboratories to reduce pre-analytical errors and improve patient safety. Steady efforts to reduce pre-analytical errors in the clinical laboratory will improve the satisfaction of medical staff and laboratory staff and ensure patient safety by reducing the occurrence of these errors.

Ethical approval

This study was exempted by the Institution Review Board of this hospital (Reference number: KUNCH 2018-10-011).

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Declarations of interest

None.

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