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ORIGINAL ARTICLE

Improvement of blood culture contamination rate, blood volume, and true positive rate after introducing a dedicated phlebotomy team

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Abstract

The introduction of dedicated phlebotomy teams certified for blood collection has been reported to be highly cost-effective by reducing contamination rates. However, data on their effects on blood volume and true positive rate are limited. Therefore, we investigated the effect of replacing interns with a phlebotomy team on blood culture results. We performed a 24-month retrospective, quasi-experimental study before and after the introduction of a phlebotomy team dedicated to collecting blood cultures in a 2700-bed tertiary-care hospital. The microbiology laboratory database was used to identify adult patients with positive blood culture results. During the study period, there were no changes in blood collection method, blood culture tubes, and the application of antiseptic measures. Blood volume was measured by the BACTEC™ FX system based on red blood cell metabolism. A total of 162,207 blood cultures from 23,563 patients were analyzed, comprising 78,673 blood cultures during the intern period and 83,534 during the phlebotomy team period. Blood volume increased from a mean of 2.1 ml in the intern period to a mean of 5.6 ml in the phlebotomy team period ($p < 0.001$). Introduction of the phlebotomy team also reduced contamination rate (0.27% vs. 0.45%, $p < 0.001$) and led to a higher true positive rate (5.87% vs. 5.01%, $p < 0.05$). The increased true positive rate associated with the phlebotomy team involved both gram-positive and gram-negative bacteria. The introduction of a dedicated phlebotomy team can increase blood volumes, reduce blood culture contamination rate, and increase true positive rate.

Keywords Phlebotomy team · Blood volume · Blood culture · Contamination rate · True positive rate

Introduction

Bloodstream infection continues to be an important public health concern [1]. Blood culture is an essential laboratory test for diagnosing bloodstream infections, but false positive blood culture results caused by inadequate blood culture technique can lead to patient morbidity, unnecessary antibiotic treatment, and additional medical costs [2]. There are several ways to decrease contamination rates such as the use of a phlebotomy team, prepackaged prep kits, and alcohol-containing antiseptics [3–5]. Introducing a dedicated phlebotomy team is an effective strategy [6, 7]. However, to the best of our knowledge, there are no data on its effect on blood volumes and true positive blood culture rate.

Successful management of bloodstream infection depends on accurate blood culture results and the early institution of appropriate antibiotics. Hence, improving blood culture yield is an important aim in the management of

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bloodstream infection [8]. Several studies have shown that the volume of blood inoculated had an important influence on the recovery of microorganism from bloodstream infections [9–12]. Therefore, automated monitoring of blood volumes has been suggested as a way to increase blood culture yield. The BACTEC™ FX system, an automated blood culture monitoring system, provides reliable estimates of the blood volume in blood culture bottles with a mean error of 0.2 ml, and is considered a useful tool to guide quality improvement policies [13].

In this study, we investigated the effect on blood volumes, estimated by the BACTEC™ FX system, of replacing interns with a dedicated phlebotomy team. In addition, we evaluated its effect on the rate of contamination of blood cultures and the rate of true positive blood cultures.

Materials and methods

Patients and blood culture method

This was a retrospective, quasi-experimental study over 24 months before and after the introduction of a dedicated phlebotomy team for collecting blood cultures. The study was conducted in Asan Medical Center, a 2700-bed, university-affiliated tertiary-care teaching hospital in Seoul, Republic of Korea. The microbiology laboratory database was used to identify adult patients (> 17 years old) with positive blood culture results who were hospitalized between Mar. 2015 and Apr. 2017. Blood cultures were performed by 141 interns from Mar 2015 to Feb 2016, while from March 2016, a full-time phlebotomy team (composed of 34 phlebotomists) collected blood culture specimens from adult patients in three shifts. The transition period from March to May 2016 was excluded from the analysis. Blood culture data for adult patients were obtained from 54 wards: 46 general wards, 6 hematology-oncology wards, and 6 intensive care units (ICUs). We did not include the emergency department, because blood for cultures was drawn by nurses, members of the phlebotomy team, and interns in that department. We also excluded 991 blood cultures where only one blood culture set was performed.

All blood culture bottles were in paired sets, consisting of an anaerobic bottle and an aerobic bottle. During the two study periods, there were no changes in blood collection method, blood culture bottles, or antiseptic measures. Venipuncture sites and central venous catheter hubs were disinfected with 2% chlorhexidine gluconate in 70% isopropyl alcohol. All blood cultures underwent standard incubation and processing using the BACTEC™ FX system (Becton Dickenson, Sparks, MD, USA). They were incubated in the system until bacterial growth was detected or for 5 days. The instruction for performing blood culture was prepared in accordance with the 2007 Clinical and Laboratory Standards Institute (CLSI) guidelines [14], and the education on this instruction was periodically provided to healthcare workers.

Definition of contamination rate and true positive rate

Bacterial contaminants were identified in positive blood culture sets was in accordance with 2007 CLSI guidelines [14]. A blood culture was considered contaminated if one or more of the following organisms were identified in only one of a series of blood cultures: coagulase-negative *Staphylococcus* species, *Propionibacterium* species, *Micrococcus* species, viridans streptococci, *Corynebacterium* species, and *Bacillus* species [7]. A blood culture series was defined as two or more blood cultures (sets) collected serially within a 24-h period to examine a bacteremic episode.

Contamination rates were determined by dividing the number of cultures considered contaminated by the total number of cultures [15]. The true positive rate was determined by dividing the total number of true positive blood cultures by the total number of cultures [16]. The total number of true positive blood cultures was calculated by subtracting the number of cultures that was considered contaminated from the total number of positive blood cultures. If multiple true pathogens were isolated in one blood culture, they were counted as one for calculating contamination rate and true positive rates.

Measurement of blood volume

The BACTEC™ FX blood volume monitoring system (BD, Sparks, MD, USA) was used to monitor volumes of blood in blood culture bottles. This system measures blood volumes in batches of 25 BACTEC™ Plus Aerobic/F (BD) bottles [13]. The overall averages or the averages of individual wards or departments were collected through the EpiCenter™ Microbiology Data Management System (BD). Species identification data for culture isolates were collected using the laboratory information system.

Statistical analysis

Contamination rates and true positive rates of blood cultures were compared between the intern period and the phlebotomy team period by the χ^2 test. The difference in blood volumes between the two periods was analyzed by Student's t test. A P value less than 0.05 was considered statistically significant. The computer software used to run these statistical analyses was SPSS 24.0 (SPSS, Chicago, IL, USA).

Results

Baseline characteristics

A total of 162,207 blood cultures from 23,563 adult patients were analyzed, comprising 78,673 blood cultures during the intern period and 83,534 during the phlebotomy team period. Most blood cultures were obtained from general wards, followed by hematology-oncology wards and ICUs (Table 1). The total number of blood culture series performed to detect possible bacteremic episodes was 27,510 during the intern period and 30,005 during the phlebotomy team period. Three or more sets per blood culture series were obtained in most blood culture series (75.1%).

Blood volumes

The mean blood volume collected by the phlebotomy team was significantly higher than that collected by the interns (5.6 ml vs. 2.1 ml, $p < 0.001$) (Table 2). The differences in blood volume between the two periods were significant in all wards and ICUs. Among hospital units, the increase in blood volume was most prominent in general wards and least prominent in ICUs.

Blood culture contamination rates

A total of 10,146 isolates were identified from 9420 positive blood cultures, which means that multiple microorganisms were identified in 726 positive blood cultures. They were classified into 6 contaminants and 720 true pathogens. The total contamination rate in the intern period was higher than that in the phlebotomy team period (0.45% vs. 0.27%, $p < 0.001$) (Table 3) and a significant decline in contamination rates between the two periods was found in all hospital units. The most common contaminant was coagulase-negative *staphylococcus* (74.2%).

True positive blood culture rates

The total true positive rate in the phlebotomy team period was significantly higher than that in the intern period (5.01% vs. 5.87%, $p < 0.001$) (Table 4). The increase in true positive rates between the two periods was statistically significant in all hospital units, and the magnitude of the increase was highest in hemato-oncology wards and lowest in the general wards. Since we thought that the increase in the true positive rate was associated with an increase in blood volumes, we examined whether the increase of true positive rate differed between gram-positive and gram-negative bacteria (Table 4). We found that the magnitude of the increase was similar for gram-positive and gram-negative bacteria.

The main true pathogens in the study periods were *Enterococcus* species (21.2%), *Candida* species (12.0%), *Escherichia coli* (11.3%), *Klebsiella pneumoniae* (9.6%), and *Staphylococcus aureus* (9.5%). The distributions of microorganisms isolated in the intern versus the phlebotomy team period did not differ (Supplementary Table 1).

Discussion

In this study, we found that the introduction of a dedicated phlebotomy team led to a decrease in the contamination rate of blood cultures, an increase in drawn blood volume, and an increase in true positive blood culture rate. Since previous data on the effects of a dedicated phlebotomy team on blood volume and true positive rate are limited, our findings could be useful for improving the diagnostic yield of blood cultures.

The CLSI recommends collecting 10 ml of blood per bottle and taking two to three blood cultures per episode for adult patients [14]. However, in the phlebotomy team period, the mean blood volume was only about 5.6 ml per bottle, less than that recommended. In several previous

Table 1 Number of blood culture sets and series collected by interns and the phlebotomy team

Variable	Number of blood culture sets or series, *n* (%)	
	Intern period	Phlebotomy team period
No. of total blood culture sets	78,673	83,534
General wards	45,005 (57.2)	51,229 (61.3)
Hemato-oncology wards	16,981 (21.6)	17,447 (20.9)
Intensive care units	16,687 (21.2)	14,853 (17.8)
No. of blood culture series[a]	27,510	30,005
3 or more sets per series	21,339 (77.8)	21,805 (72.7)
2 sets per series	6111 (22.2)	8200 (27.3)

[a] A blood culture series was defined as two or more blood culture sets collected serially within a 24-h period to detect a possible bacteremic episode

Table 2 Comparison of blood culture volumes collected by interns and the phlebotomy team

Hospital unit	Mean blood culture volume[a] (ml) (± SD)		*P* value
	Intern period	Phlebotomy team period	
Total	2.1 ± 0.7	5.6 ± 1.3	< 0.001
General wards	2.0 ± 0.6	6.1 ± 1.1	< 0.001
Hemato-oncology wards	2.1 ± 0.7	5.2 ± 0.8	< 0.001
Intensive care units	2.8 ± 0.8	3.7 ± 0.8	< 0.001

[a] Mean blood volume per aerobic bottle

studies, the proportion of underfilled bottles (< 8 ml of blood per bottle) was reported to vary from 54.0 to 97.9% in the real world [17–20]. In a multicenter, cross-sectional study in South Korea, the mean blood volume per bottle was approximately 3.8 ml in adult patients [21]. Although the recommended blood volume was not reached, the increase in mean blood volume per bottle from 2.1 to 5.6 ml as a result of using a dedicated phlebotomy team could be a significant finding.

The total contamination rate in the phlebotomy team period was 0.27%, which represents a 60% reduction compared with that in the intern period. The CLIS recommends contamination rates not exceeding 3%, and our study satisfied this recommendation. Our finding was consistent with previous reports for a dedicated phlebotomy team [4–7, 22]. The reduction of blood culture contamination rate by the implementation of the dedicated phlebotomy team may eventually lead to a decrease in medical costs, as shown in the previous study [23]. There are two potential explanations for the decrease of blood culture contamination rate brought about by a dedicated phlebotomy team: (1) The phlebotomy team is highly trained and motivated, and/or (2) they can concentrate on phlebotomy under less time pressure than interns who usually find it hard to concentrate on taking blood cultures [5], given their many other roles [7].

The American Society of Microbiology (ASM) suggests that an adequate positive rate of blood culture is 6–12% [24]. The true positive blood culture rate was 9.8–12.9% in five Belgian tertiary-care hospitals in a previous study [12]. The true positive blood culture rate (5.9% in the phlebotomy team periods) was relatively low in our study but close to the lower limit of the standard value. This could be because the volume of blood in most of the blood cultures was less than optimal and because the results of blood cultures performed in the emergency department, which had a high true positive blood culture rate, were excluded in our analysis.

The difference in blood volume between the intern period and the phlebotomy team period in ICUs was about 1 ml, less than in the other hospital units. However, the improvement in the true positive rate in ICUs was similar to that in the general wards. This discrepancy between the extent of the improvement in blood volume and the increase in true positive rate could be explained by the possibility that bloodstream infections were more common in these critically ill patients than in the patients in general wards. The reduction of contamination rate in ICUs was higher than in general wards, probably because the dedicated phlebotomy team complied well with the blood culture protocol in the critically ill patients even though vascular access was difficult.

Our study had several limitations. First, we did not analyze the individual clinical data to identify contamination, infection type, and cause of fever, which could affect blood culture parameters. Because of the large number of blood cultures, it was impossible to analyze all the individual data. However, our definitions of the blood culture contamination rate and true positive blood culture rate were the same with those in most previous studies [4, 6, 7, 22], so that our findings can be directly compared with those of other studies. Second, blood culture results in the emergency department were not evaluated, and a further study is needed comparing the parameters of blood culture in an emergency department before and after interns are replaced by a dedicated phlebotomy team. Third, true positive blood culture rate and blood volume in this study were relatively lower than those in previous studies. As mentioned above, the small amount of blood volume was thought to contribute to the low true positive rate. Therefore, proper coaching and feedback to phlebotomists are needed to increase the amount of blood volume.

Table 3 Blood culture contamination rates for interns and the phlebotomy team

Hospital unit	Contamination rate, % (n/total sets)		Odds ratio[a]	*P* value
	Intern period	Phlebotomy team period	(95% CI)	
Total	0.45 (354/78,673)	0.27 (222/83,534)	0.59 (0.50–0.70)	< 0.001
General wards	0.32 (146/45,005)	0.24 (123/51,229)	0.74 (0.58–0.94)	0.01
Hemato-oncology wards	0.48 (81/16,981)	0.31 (54/17,447)	0.65 (0.46–0.91)	0.01
Intensive care units	0.76 (127/16,687)	0.30 (45/14,858)	0.40 (0.28–0.56)	< 0.001

[a] The ratio of the odds of contamination in the phlebotomy period to the odds of contamination in the intern period

Table 4 True positive blood culture rates during the intern and phlebotomy team periods (true positive blood culture rates according to gram-positive and gram-negative bacterial type were compared between the intern period and the phlebotomy team period in the different hospital units)

Hospital unit	Intern period, % (*n*/total sets)			Phlebotomy team period, % (*n*/total sets)		
	Total	Gram-positive bacteria	Gram-negative bacteria	Total	Gram-positive bacteria	Gram-negative bacteria
Total	5.01 (3943/78,673)	2.30 (1808/78,673)	2.37 (1864/78,673)	5.87 (4901/83,534)	2.95 (2463/83,534)	2.72 (2272/83,534)
General wards	4.51 (2031/45,005)	2.27* (1020/45,005)	2.12* (952/45,005)	5.05 (2588/51,229)	2.59* (1325/51,229)	2.43* (1243/51,229)
Hemato-oncology wards	6.48 (1101/16,981)	2.77 (470/16,981)	3.33 (565/16,981)	8.21 (1432/17,447)	4.26 (744/17,447)	3.69 (643/17,447)
Intensive care units	4.86 (811/16,687)	1.91 (318/16,687)	2.08* (347/16,687)	5.93 (881/14,858)	2.65 (394/14,858)	2.60* (386/14,858)

All values between the two periods are significantly different; $p < 0.001$, $*p < 0.01$

In conclusion, our study suggests that the implementation of a dedicated phlebotomy team can decrease the contamination rate of blood cultures and improve the true positive blood culture rate by increasing drawn blood volumes. In addition, bloodstream infection management can be greatly improved in critically ill patients by introducing a dedicated phlebotomy team.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Informed consent For this type of study formal consent is not required.

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