Original Article

Effectiveness of Multimodal Intervention to Improve Blood Culture Collection in the Emergency Department

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Abstract

Introduction: The blood culture (BC) contamination was a significant problem in our hospital, especially in the emergency department (ED). The study, therefore, was undertaken to improve the BC collection in the ED. **Methods:** The study was conducted for 1 year divided into two phases of 6 months each: Preintervention phase and intervention phase (regular and phlebotomist groups). The interventions comprised implementing standard protocol for BC collection and conducting educational sessions. In preintervention and regular groups, the BCs were collected by interns and technicians, while dedicated phlebotomist did so in the phlebotomist group. Data were analyzed and interpreted for the contamination rate as well as compliance in adequate filling of the requisition form. Statistical Package for the Social Sciences (SPSS) version 22. A value of $P < 0.005$ was considered statistically significant, and $P < 0.01$ was considered statistically significant. **Results:** In the preintervention group, 13.7% of specimens were reported as contaminated which was reduced to 4.2% and 3.2% in the regular and phlebotomist group, respectively, after intervention. Compliance of health-care workers to various elements of BC collection protocol was also found to be significantly improved in the intervention phase compared to the preintervention phase ($P < 0.001$). **Conclusions:** Implementation of this multimodal intervention resulted in a drastic reduction in BC contamination and improvement in compliance to BC collection protocol and filling of various parameters in the BC requisition form, thus improving the overall effectiveness of BC testing. It was also noted that the contamination rate was further reduced by implementing dedicated phlebotomist.

Keywords: A quality improvement, blood cultures, blood stream infection, contamination, emergency department, phlebotomist

Introduction

Blood cultures (BCs) remain the most definite investigation in any patient with suspected bloodstream infections (BSIs) and sepsis. BCs have long been recognized as one of the critically important and potentially life-saving diagnostic tests performed in clinical microbiology laboratories.[1,2] Sample collection for BC is a technically demanding procedure. Strict asepsis is followed during collection to prevent the growth of skin commensals/colonizers or environmental contaminants, which may overgrow and hence mask the actual pathogens in the blood if present, thus delaying or preventing the diagnosis of true bacteremia.[3] Furthermore, the growth of commensals/contaminants creates confusion for both clinicians and laboratorians, which may lead to inappropriate antimicrobial usage due to spurious diagnosis.[4-6] Unfortunately, BC collection is often found to have fallacies inappropriate skin asepsis (leading to frequent contamination), or are collected in insufficient volume, inadequate number of BC bottles, or collected after institution of antimicrobials.[7-9] The preanalytical errors in BC collection result in several detrimental outcomes such as delay in identification of bacteremia and initiation of pathogen-directed therapy, ordering of more investigations resulting in increased financial burden, and increased morbidity and mortality.[10-12]

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Although errors in BC collection have been reported in all areas of the hospital, it is more profound in the emergency department (ED). Several studies documented BC contamination as a significant problem in ED.[1,3,12] This may be due to various reasons such as heterogeneity of the health-care workers (HCWs) posted, high staff turnover, lack of awareness, emergency collection, or increased work pressure.[13] Therefore, this quality improvement study was undertaken in the ED, in collaboration with the clinical microbiology team; aiming to reduce the BC contamination rate following a multimodal intervention.[3] The study also aimed to achieve a significant improvement in the compliance of clinicians to follow the correct BC collection protocol (e.g. appropriate volume, and adequate bottle numbers) and to fill various essential information/parameters in the BC requisition form following the multimodal intervention.[8]

Methods

The study was conducted in ED at a tertiary care teaching hospital, which is also an institution of national importance under the Ministry of Health and Family Welfare, Government of India, located in Southern India. The ED included in the study caters only adult age group patients. There is a separate pediatric emergency in the facility which was not included in the present study. The ethical clearance for this study was obtained from the Institute Ethics Committee (IEC), which approved a waiver of informed consent. The study design was an interventional type of quality improvement study, conducted for a total duration of 1 year (November 19 to October 20), which was further divided into two phases of 6 months each: Preintervention phase and intervention phase. BC specimens collected from the patients clinically presenting with signs and symptoms suggestive of BSI and/or sepsis in the ED were included during the study period. This study comprised of two components: (i) development and implementation of a multimodal intervention for BC collection in ED, (ii) evaluation of the effectiveness of this intervention by assessing the reduction in the BC contamination rate and improvement in the compliance of the clinical team of the ED to the BC collection protocol and filling of the various parameters in the BC requisition form.[3]

Preintervention phase

During the preintervention phase (November 19–April 20), a task force comprised of consultants (both microbiology and clinical), microbiology senior resident, and postgraduate students was formed for the development of a multimodal intervention. The task force studied the process of BC collection in the ED through direct observation of BC collection and also by conducting surveys and structured interviews of the HCWs involved in the collection. Subsequently, a fishbone diagram was drawn line listing the risk factors which contributed to a high BC contamination and irrational filling of requisition forms in ED [Figure 1].

It was observed that the nonuniformity of the protocol used for BC collection technique and lack of knowledge of staff involved in sample collection were the key risk factors and therefore chosen as the target of intervention. The BC specimens were collected by the intern doctors and emergency medicine technician (EMT) students, who were posted in ED on a weekly rotation. Samples were sent to the microbiology laboratory along with requisition forms raised online in laboratory information system (LIS). There was significant variation in the practice of BC collection. Some of the key defects identified in the collection process were – practice of one step decontamination, use of nonsterile gloves, inadequate contact time after applying disinfectant, applying a tourniquet, and palpating vein after applying the disinfectant and not

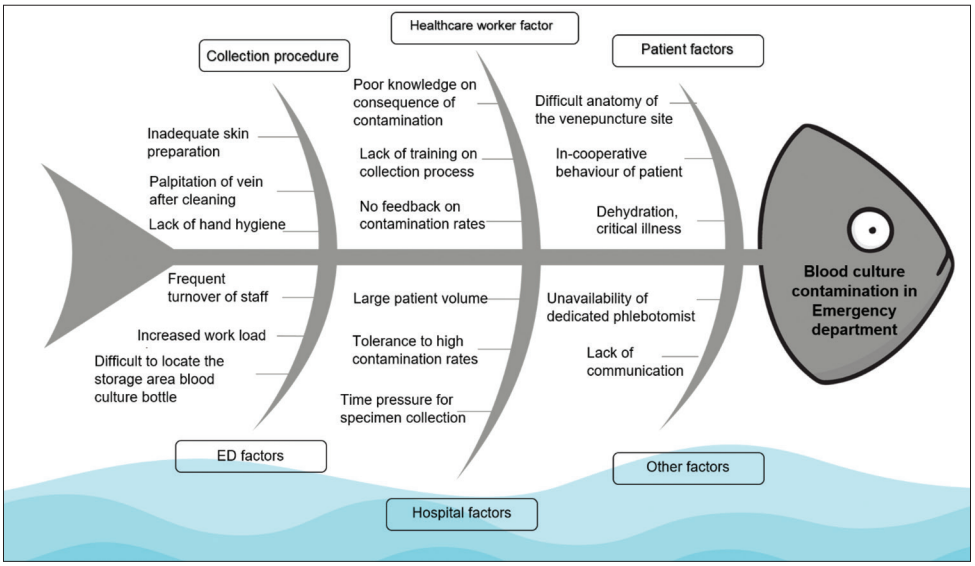

Figure 1: Fishbone diagram depicting the risk factors which contributed to a high blood culture contamination and irrational filling of requisition form in emergency department

cleaning the BC bottle cap with alcohol wipes before inserting the needle.

Intervention phase

Guided by the fishbone diagram [Figure 1] depicting risk factors identified in the preintervention phase, a multimodal intervention was designed, which included the following:

Standard protocol for blood culture collection

A standard protocol for BC collection was developed. The key changes introduced were – two-step decontamination (70% alcohol, followed by 0.5% w/v chlorhexidine based antiseptics), use of sterile glove, adequate contact time (30 s to 1 min), after applying antiseptics, applying tourniquet, and palpating vein before applying the antiseptics and cleaning the BC bottle cap with alcohol wipes before inserting the needle.[14]

Educational and training sessions

Educational and training sessions were conducted for the staff involved in BC collection such as intern doctors and technician students ("regular group") posted in the ED. Training on standard protocol for BC collection and filling of requisition form was given through interactive sessions, posters, PowerPoint presentations, and video-graphic methods. The HCWs were also made aware of the importance of appropriate blood volume collected in each BC bottle (8–10 mL and 1–3 mL for adult and pediatric BC bottle respectively) and the culture of cultures (i.e., BC collection before start of antibiotics or before next dose of ongoing antibiotics).[15] Frequent sessions were conducted at regular intervals as the staff were posted on the rotation basis in ED.

Dedicated phlebotomists

The studies in the existing literature depict that the BC contamination can drastically be reduced if trained phlebotomists are engaged in collection.[16,1,17] In our setting, the blood collection was performed by intern doctors and EMT students who were posted on a rotation basis in ED; which was found as one of the major detrimental factors for increased BC contamination. Due to a lack of resources, dedicated phlebotomists could not be posted in ED round the clock. However, as a part of the pilot intervention, the hospital administration approved to post a separate set of dedicated phlebotomists in ED for a limited period of time in a day during the intervention phase, who were exclusively trained on the BC collection protocol.

Data collection and analysis

The data on BC collection and the parameters filled in the online requisition form were collected through the hospital's LIS for all the three groups – the preintervention, intervention, and dedicated phlebotomist groups. The effectiveness of the multimodal intervention was evaluated by comparing the BC contamination rate and the compliance to filling of the parameters in the BC requisition form between the preintervention and intervention groups using appropriate statistical test (Chi-square test). Two-sided $P < 0.05$ was considered statistically significant. A subgroup analysis was carried out to evaluate the differences in the impact of this multimodal intervention between dedicated phlebotomist group and intervention group.

The demographics of the patients, for example, age have been recorded. The study group involved adults only, the pediatric age group was excluded from the study. However, age-specific BC contamination among the adult patients was not evaluated in the present study. BC was classified as contaminated if one or more of the following organisms grew: Coagulase-negative Coagulase-negative *Staphylococcus* (CoNS) species except *S. lugdunensis*, aerobic spore bearers (*Bacillus* species except *B. anthracis*), diphtheroids (*Corynebacterium* species, except *C. diphtheriae*), *Micrococcus* species, α-hemolytic *Streptococcus,* and *Aerococcus* species, All positive cultures not classified as contaminated were considered true-positives (pathogen).[5,10]

Statistics

All data were analyzed using the Statistical Package for the Social Sciences (SPSS) software computer program version 22 (IBM Corp. Armonk, NY, USA). A value of $P < 0.005$ was considered as significant, and $P < 0.01$ was considered statistically significant.

Results

During the 12-month study period, a total of 1465 BC bottles were collected from 920 patients from ED – 630 bottles from 460 patients during the preintervention (6 months) and 835 bottles from 460 patients all through the intervention period (6 months). During the intervention period, 741 bottles from 410 patients were collected by the "regular group" (i.e., intern doctors and technician students) and 94 bottles from 50 patients were drawn by the "phlebotomist group." The BC specimen was collected in single bottle in 63.5%, 20.5%, and 14% of patients from the preintervention, regular, and phlebotomist groups, respectively. For the remaining patients, the BC specimens were collected in pair, except for a minority of patients where BC were collected in triplets [Table 1].

Figure 2 represents the outcome of BC investigations. In the preintervention group, 13.7% (86/630) of specimens were reported as contaminant grown, whereas 11.9% (75/630) and 74.4% (469/630) of specimens were reported as pathogen grown and sterile, respectively. On the contrary, during the intervention period, 4.2% (31/741), 17.9% (133/741), and 77.9% (577/741) of specimens were reported as contaminant grown, pathogen grown, and sterile, respectively, in the regular group. In phlebotomist group, the contamination rate was further reduced to 3.2% (3/94), whereas the pathogen isolation rate and sterility rate were found to be 19.1% (18/94) and 77.7% (73/94), respectively. The frequency distribution of organisms isolated in the contaminated specimens is depicted in Figure 3. The majority of the contaminants were CoNS (80.5%), followed by aerobic sporebearers (14.4%), *Micrococcus* (3.4%), and diphtheroids (1.7%) Figure 3.

The compliance of HCWs to various elements of BC collection protocol is illustrated in Figure 4. A total of 36.5% (168/460) of BCs were drawn in pairs in preintervention group, which was increased to 79.5% (326/410) and 86.0% (43/50) in regular and phlebotomist groups, respectively. There was also an increase in the compliance rate of BCs sent in appropriate volume from 35.9% (226/630) in preintervention group to 39.1% (290/741) and 71.2% (67/94) in regular and phlebotomist groups, respectively. The compliance to the concept of culture of culture (i.e., culture needs to be collected before the start of antibiotics) is found to be 81.7% (376/460), 90.5% (371/410), and 94.0% (47/94) in preintervention, regular, and phlebotomist groups, respectively.

Figure 5 depicts the compliance to fill various parameters in the BC requisition form. It was found that there was an improvement in the compliance rate to form filling such as mentioning of clinician's details, provisional clinical diagnosis, and source of collected blood for both regular group (99.7%, 99.7%, and 92.9%) and phlebotomist group (100%, 100%, and 85.1%) as compared to the preintervention group (91.1%, 77.1%, and 88.5%).

Discussion

BCs are an indispensable diagnostic tool for the management of BSIs and sepsis, which accounts for a significant cause of morbidity and mortality.[8] The treatment of BSIs requires the rapid and accurate identification of the etiological agent. For any investigation of BC carried out in a laboratory, the quality of the final result report depends on various factors that attribute to the quality of the workflow during the preanalytical phase.[4] Of note, factors such as a technique of specimen collection, volume of blood collected, number of BCs drawn, time of collection with respect to antibiotic administration and transport time, etc., play crucial roles in determining the outcome of BC investigation.[3,7] The ED is particularly vulnerable to an increased risk of noncompliance to these preanalytical factors of BC investigation, which may be due to various reasons such as high staff turnover, increased patient load, and simultaneously managing many critically ill patients at the same time, leading to high work pressure.[1,3,10] Therefore, this study was carried out to develop a multimodal intervention and subsequently to evaluate its effectiveness to improve BC collection practices in the ED.[1]

Blood culture contamination

In the present study, the BC contamination was found to be significantly reduced in intervention phase (i.e. both regular group [4.2%] and phlebotomist group [3.2%]) compared to preintervention group (13.7%) ($P < 0.001$). The contamination rate was further reduced to 3.2% in phlebotomist group as compared to regular group (4.2%). The standard guidelines such as Clinical and Laboratory Standards Institute (CLSI) recommend that institutions should aim for acceptable limit of <3% contamination rate for the BC collected.[18] The literature depicts a divergence in the BC contamination rates among studies, with reported figures between 3% and 12%.[19-22] Such variation in contamination rates may be partly due to the type of interventions implemented and also because of the criteria used by the studies to define contaminant.

The different studies used different interventions to reduce BC contamination – informational responses (e.g., regular E-mails mentioning the monthly contamination rates),

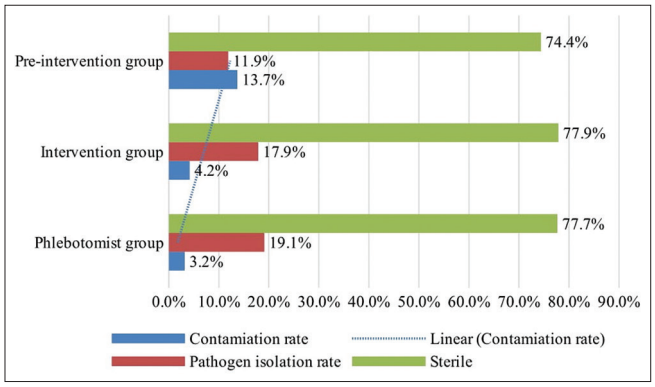

Figure 2: Outcome of blood culture investigations depicting the contamination rate, pathogen isolation rate and sterility rate in pre-intervention, intervention, and phlebotomist groups

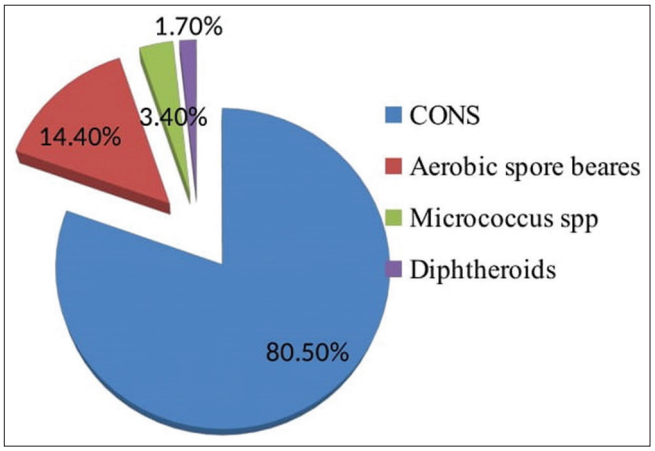

Figure 3: Organism frequency distribution in the contaminated specimens

Table 1: Total samples collected by pre-intervention group, regular group and phlebotomists group

	Total episodes	Total BC bottles	Single BC bottle	Paired (set of 2 + set of 3)
Preintervention group*	460	630	63.5% (292)	36.5% (166+2)
Regular group*	410	741	20.5% (84)	79.5% (321+5)
Phlebotomist group	50	94	14.0% (7)	86.0% (42+1)

*Both preintervention and regular group the BC were collected by intern doctors and technician students. BC: Blood cultures

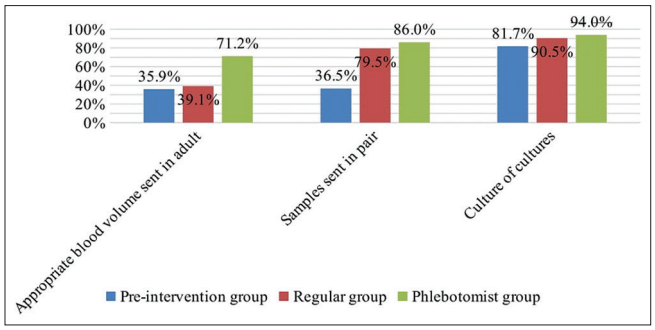

Figure 4: Compliance to various elements of blood culture collection protocol

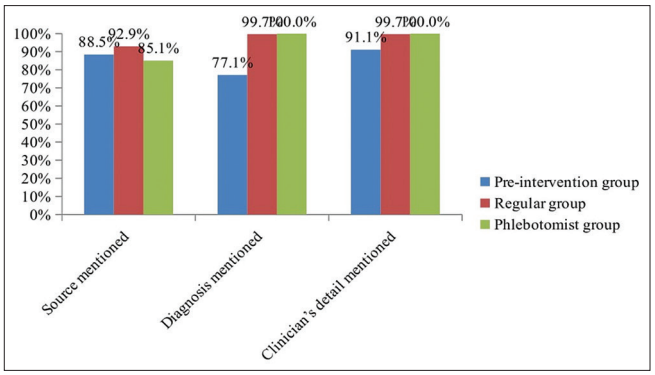

Figure 5: Compliance to filling of various parameters in the blood culture requisition form

change of skin antiseptics (e.g. chlorhexidine swabs), use of specialised BC collection set, individual feedback on rates of contamination and technique, educational intervention, and posting of dedicated phlebotomists.[11,13,17] Our study involved a multimodal intervention comprising educational intervention and implementing a standard protocol for BC collection. As a result, there was drastic reduction in the contamination rate of regular group as well as dedicated phlebotomist group. The rotational and shift-based posting of intern and resident doctors in our EDs was found as the most detrimental barrier to reduce BC contamination further.[12] Therefore, we carried out a pilot intervention, where a separate set of dedicated phlebotomists were posted in ED for a limited period of time during the intervention phase, who were exclusively trained on the BC collection protocol.[16] The subgroup analysis of dedicated phlebotomist group revealed that the contamination rate was further reduced to 3.2%. In concordance to this observation, various other studies in the literature also depicted that the collection of BCs through dedicated phlebotomists as the most effective intervention to reduce the contamination rate to below the CLSIs acceptable limit of <3%.[16,23,24] Aseptic collection of BC is a multifaceted skill that requires special training, expertise and knowledge; therefore, use of trained phlebotomists has been associated with a significant decrease in the BC contamination rate.[23] Similar to our study, there are also few other studies where higher BC contamination rates were reported in teaching hospitals, especially in EDs.[1,3,10,12,13,16]

The studies with varied in BC contamination rate differ among each other in the criteria used to define "contaminant," which in turn is due to the reporting practice of the laboratories. While some laboratories directly report the BC result as "contaminant" based on a list of common contaminant organisms (according to NHSN guideline) isolated in BC.[8] some other laboratories report the organism name and ask the clinicians to decide whether to consider it as a pathogen or contaminant based on clinical correlation.[11,15] The CLSI defines contamination as a "microorganism isolated from a BC during specimen collection or processing (and was) not pathogenic for the patient from whom the blood was collected."[18] Contamination rates provide a significant metric of the quality of a health-care facility and should be maintained at the lowest possible rate regardless of the reporting practices of the laboratories.[16]

In the intervention phase, we observed that with the reduction of contamination rate, there was a concordance increase in the percentage of BCs reported as "true positive (pathogen)" and "sterile." BC contamination frequently leads to increase in the incidence of false-positive and false-negative results.[16] False-positive result occurs when actually the BC is sterile, but it becomes contaminated with skin commensal/colonizers during collection.[15] False-positive BCs may impulse the clinical team to intitiate treatment based on the reports (especially if the laboratory mentions on the report as "correlate clinically"), and it may have harmful effects to the patient, the healthcare facility and also to antimicrobial stewardship efforts.[17] Such false-positive BCs may result in unnecessary prolongation of antimicrobial therapy to the patient, extended hospital stay, and augmented financial burden.[16] At the same time, release of false-negative BCs (i.e., contaminants overgrowing or supressing the isolation of pathogens) also has detrimental effect on the patient due to delay in both diagnosis and initiation of appropriate pathogen-directed therapy.[17]

Source of blood culture contamination

Analysis of the frequency distribution of organisms in the contaminated specimens revealed that CoNS accounted for the majority of the contaminants, followed by aerobic spore bearers, micrococci, and diphtheroids In concordance, several other studies also revealed that CoNS and aerobic spore bearers were the predominant contaminant isolated in the BCs.[25] Isolation of these organisms in BCs indicate that the source of BC contamination is either, – (i) patient's own skin flora (due to inappropriate skin decontamination during collection), or (ii) from HCWs' hands (due to inadequate hand disinfection), or (iii) very rarely from the hospital environment.[22,25]

Compliance to blood culture collection protocol

We also evaluated the compliance of HCWs to the BC collection protocol. Compared to preintervention group, both in regular and phlebotomist groups of intervention phase, there was a significant improvement in the compliance of HCWs to draw BCs in pairs ([36.5% vs. 79.5% and 86.0%] [$P \leq 0.01$]).

Various studies showed that the collection of paired or multiple BCs result in improvement in pathogen isolation and also helps in differentiating contaminants from pathogens.[15-17] In our study also, we noted that there was an improvement in pathogen isolation rate, both in regular and phlebotomist groups, which may be partly attributed to the increase in compliance of HCWs to draw BCs in pairs.

The compliance of HCWs to collect appropriate blood volume was also significantly increased from 35.9% in preintervention group to 39.1% and 71.2% in regular and phlebotomist groups, respectively ($P < 0.001$). Collection of an appropriate amount of blood is crucial in optimizing the pathogen detection in BCs.[15] In this context, whenever possible, 8–10 mL of blood per BC bottle should be obtained for adult patients suspected of having BSI. Both underfilling and overfilling BC vials have been associated with delay in time-to-positivity, increased contamination, false-negative, and/or false-positive results.[15-17]

Following the multimodal intervention, there was an increase in the compliance of HCW to collect the BCs before the administration of antibiotics, from 81.7% in preintervention group to 90.5% and 94% in regular and phlebotomist groups, respectively. The concept of culture of culture is extremely important in order to achieve a better yield of pathogen isolation in culture.[11,13] Collection of culture afters the antibiotic start is found to be associated with poor recovery of the organism from the clinical specimen.[15] The improvement in pathogen isolation rate both in intervention and phlebotomist groups in our study could be partly attributed to increase in the compliance of HCWs to collect BCs before antibiotic start.[16]

Compliance to filling of various parameters in the blood culture requisition form

During the preintervention phase, it was often found that there was irregularities in the filling of various parameters in the BC requisition form such as clinician's details, diagnosis, and source of blood collection.[19] Information on these clinical and patient-related parameters is critical for the clinical microbiological reporting of BC investigations and susceptibility testing reports by the laboratory.[11] Through the educational interventions, we found that there was an improvement in filling of all the above-mentioned parameters of the BC requisition form by our clinical team.[19] Adequate provision of the clinical team detail and the in-hospital location of the patient help in fostering effective communication between the laboratory and the clinical team.[10] When the clinical diagnosis is indicated in the requisition form, it helps the laboratory to ascertain the site-specific pathogenicity of the organisms and thereafter including appropriate site-specific antimicrobials for antimicrobial susceptibility testing.[6] Mentioning the source of collection of blood (central line or venepuncture) will guide the laboratory to differentiate between colonizers and pathogens, and also to ascertain the microbiological diagnosis of catheter-related blood stream infection.[14]

Conclusions

Although BCs have been a potentially life-saving diagnostic test for decades, yet the problem pertaining to the collection procedures of BC still persist, which results in increased contamination that in turn leads to unintended consequences to patients such as prolonged antibiotic exposure, increased diagnostic testing, and prolonged periods of hospital stay and increased morbidity and mortality.[1] In this study, we found that implementation of a comprehensive multimodal intervention resulted in a drastic reduction in BC contamination and improvement in compliance to BC collection protocol and filling of various parameters in the BC requisition form and thus improving the overall effectiveness of BC testing.[19] We also observed that the contamination rate was further reduced to within the acceptable limit of CLSIs recommendation by implementing a dedicated trained phlebotomist for BC collection.[16] We, therefore, conclude that the clinical microbiology laboratory should be preemptive in instituting policies and providing direction to the clinical team with respect to optimizing the BC collection protocol.[24]

Research Quality and Ethics Statement

This study was approved by the Institutional Review Board/ Ethics Committee JIPMER/IEC/2019/400. The authors followed applicable EQUATOR Network ("http:// www.equator-network.org/) guidelines during the conduct of this research project.

Acknowledgment

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Nil.

Conflicts of interest

There are no conflicts of interest.

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