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Original article

Implementing a quality improvement plan to reduce the blood culture contamination rate in pediatric patients: A quasi-experimental study.

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ABSTRACT

Background: Blood culture contamination is a safety and quality indicator in the pediatric population. False positive blood culture negatively impacts pediatric patients' proper management, microbiology laboratories, healthcare facilities where blood cultures are ordered, and pharmacies. The study aims to appraise the blood culture contamination rate in an intensive care unit of an emergency department at an Egyptian tertiary care pediatric hospital, and accordingly design a quality improvement program to reduce it. **Methods:** A plan-do-study-act model is implemented over 8 consecutive months. All nursing staff members who enrolled in the study; participated in an educational program, afterward, they were assigned to collect blood samples for culture, following the instructions implemented and listed for improvement of the blood culture sampling practice. Then, blood culture samples were sent to the microbiology laboratory of this Egyptian tertiary care pediatric hospital for microbiological processing. **Results:** Our average contamination rate declined from the baseline of 12.6% to an average of 5.8%. **Conclusions:** According to our study, blood culture contamination rates can be significantly reduced when blood culture sampling is standardized.

Introduction

Blood culture (BC) remains the gold standard investigation for diagnosing bloodstream infections in infants and children [1]. The Clinical and Laboratory Standards Institute recommends a benchmark of 3% for the blood culture contamination rates (BCCR) [2]. However, BCCRs reported in the adults range from 0.6% to 17%, in the neonatal populations range from 2.6% to 18%, and in the pediatric population range between 1% and 15.2% [3-7].

BCC problem is not only widespread but also impactful to several stakeholders, BCC has a definite negative impact on clinical microbiology laboratories' practice, the involved institution, and the medical staff, with many economic ramifications, and, perhaps most significantly, the high probability of negative outcomes among patients from whom BCs are collected with the affection of proper management of sepsis-suspected cases [4].

Many key risks are associated with the presence of BCC, as it may lead to non-agreement between the test results and clinical symptoms and

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provide clinicians with a false basis for infection. Moreover, BCC leads to high microbiology laboratory costs, pharmacy costs, and indirect hospital costs [8], as faulty and delayed diagnosis may lead to repetition of diagnostic laboratory tests such as complete blood counts (CBCs), basic metabolic panels, more consultations for the patients [7][3], therapeutic drug monitoring, collecting another BCs, and diversion of the technologist's efforts away from critical samples.

In addition to the above, the workup of contaminated BCs increases the laboratories' staff workloads at a time when many microbiology labs are facing staffing shortages. There is also the issue of increased time spent in reporting false-positive blood cultures as rapid action values to healthcare providers [4].

More seriously, the falsely indicated use of antibiotics for the false positive blood culture can lead to disruption of the host microbiome that can lead to Clostridioides difficile infection [4]

BCs are frequently contaminated during the preanalytical phase of sampling [9].

Aim of our study is to appraise the blood culture contamination rate in an intensive care unit of an emergency department at an Egyptian tertiary care pediatric hospital, and accordingly design a quality improvement program to reduce it, in a trial to reach standard percentages.

Methodology

This Quasi-experimental study was conducted at a pediatric ICU of the Emergency Department at an Egyptian tertiary care pediatric hospital from January 2022; through August 2022. Registered nurses are responsible for blood culture sampling. Pediatric patients aged 28 days to 18 years admitted to the pediatric ICU with suspected bloodstream infections were enrolled while patients with no clinical suspicion of sepsis were excluded from the study.

Study Method

Based on the observed practices and the reported contamination rates in the pediatric ICU, it was decided that a quality improvement (QI) project must be warranted to ensure the achievement of the highest quality care. Although current guidelines recommend a contamination rate of less than 3%, evidence from the literature shows that rates of less than 2% can be reached with the use of an effective technique and commitment from the quality team [10-12].

The proposal for this QI project was approved by the head of the microbiology laboratory, the head of the pediatric ICU, and the head of the infection prevention and control team. This initiative did not involve new devices or products but only reinforced standard techniques for collecting blood culture samples [13].

A Plan-Do-Study-Act (PDSA) cycle was conducted during this project (Figure 1) [14]. PDSA is an effective method for QI programs that can be applied to clinical laboratory settings with remarkable outcomes [15].

A QI team consisted of the head of the microbiology laboratory, an infection prevention and control specialist, the head of the pediatric ICU, and two educational nurses of the ICU. The QI team discussed the problem of blood culture contamination, the most common attributable factors, and its negative impact on the patient's clinical outcome, the microbiology lab, the pharmacy, and the hospital. A QI program with a three-step PDSA cycle was conducted to assess the blood culture contamination rate, and educate the nurses responsible for blood culture collection, followed by an evaluation of the effectiveness of the QI program by comparing the blood culture results pre- and post-implementation.

The clinical data and findings of the patients were obtained from the electronic hospital records and included age, sex, laboratory findings including total leucocytic count (TLC), band cell count, C-reactive protein (CRP), and the blood culture results.

The PDSA cycle was classified as follows:

Plan step of (PDSA)

Observation of the sampling techniques was performed for three months to detect the common pitfalls of the sampling technique (Figure 2.) These pitfalls include:

- Inadequate swabbing of the skin by antiseptic solution [7]
- Insufficient time for the antiseptic to dry on the skin [7]
- Repalpation of the skin after the antiseptic solution was applied [16]
- Collection of suboptimal blood volume, from 1 to 3 mL of blood from all patients regardless of their weight and age [16]

- Lack of disinfection of the bottle top and/or touching it while inoculating the blood into the bottle [16]
- Placement of the syringe on a nonsterile surface before being injected into the bottle [16]
- Delayed delivery of the BC sample to the microbiology lab [16]

- Do step of (PDSA)

The QI team addressed the key driver of improving the blood culture sampling technique. The team then established and reviewed QI programs that had decreased blood culture contamination rates in similar settings [14].

A 15-item checklist covering all items of proper sampling was conducted in Table 1. The education of the responsible nurses was performed by the two educational nurses and the infection prevention and control specialist where the recorded blood culture collection pitfalls were discussed, and a simulation for standardized sampling technique steps was performed.

- Each trainee nurse was asked to simulate the steps twice, to ensure training competence; and then perform sampling from patients under the supervision of the educators, which was job training during their routine work
- A training video of performing the right steps of the sampling technique was recorded and it was available for all nurses to be a guide for them.
- Training the nurses was held every 15 days to achieve the most benefit of the QI program.
- The checklist was provided to all nurses and affixed to all phlebotomy carts to be visible and checked while sampling.
- Hand wash:

In our project, proper HH importance was discussed and handwash steps were done and repeated in front of the nurses, each was asked to do the steps, and all were asked to do the handwash for every BC withdrawn.

- Skin antisepsis:

For proper skin antiseptic technique to be achieved, the patient's skin was continuously cleaned using 70% isopropyl alcohol in a back-and-forth motion for at least 15 seconds, then tincture of iodine was applied and let to dry for 2 minutes, and the chosen site was allowed to dry for at least another 15 seconds before performing phlebotomy [7]. Skin antisepsis was done after locating the most appropriate vein, performing HH, and putting on gloves [7].

- BC bottle stoppers sterilization:

It was recommended to apply 70% isopropyl alcohol (the same used skin antiseptic) to the top of the blood culture bottle before the injection of the blood.

Blood Volume Collection

The nurses were instructed to collect adequate blood volume according to the weight-based volume chart (Table 2.) [18], with solitary aerobic BC collected at each set.

The samples were labeled and sent to the laboratory to be processed [7][19], where they were registered and incubated in BacT/ALERT and Bactec systems for five days. Positive bottles were submitted for direct Gram film examination [20]. Followed by subculture on blood, chocolate, and MacConkey agar plates and incubated at 35°C for 24 hours. Identification of the organisms' species was done by MALDI-TOF MS (bioMérieux, France). Antimicrobial susceptibility testing for the identified organism was performed by an automated VITEK 2 compact system (bioMérieux, France).

The identified organisms were categorized as either true pathogens or blood culture contaminants. [5] In cases where blood culture contamination was suspected, a discussion of the potential significance of the organism isolated with the assigned physician was conducted and the identified organisms were considered true pathogens or blood culture contaminants according to other laboratory marker results, including TLC, band cell count, and CRP, the microbiologist and clinician's judgment.[21]

- Study & Act step of (PDSA)

Observation of the sampling was performed for three months, and for every contamination event, ree-awareness was provided to the nurse who sampled the contaminated blood culture, affirming the negative consequences of blood culture contamination and emphasizing the QI team's goal of reducing its rate. Positive reinforcement was provided to the nurses who were performing well, and observational audits were held regularly to measure the effectiveness of the QI program intervention, which provided opportunities to discuss staff conflicts or concerns regarding practice changes and updates [7]

Evaluation of the effectiveness of the QI program was determined by comparing the blood

culture contamination rate before and after the program implementation [9][22][23].

The BCCR was calculated as percentages obtained from the following equation: (contaminated blood cultures divided by the total number of blood cultures collected) × 100. [21]

Statistical analysis.

Data were coded and entered using the statistical package for the Social Sciences (SPSS) version 28 (IBM Corp., Armonk, NY, USA). Data were summarized using the mean, standard deviation, median, minimum, and maximum for quantitative data and using the frequency (count) and relative frequency (percentage) for categorical data. Comparisons between quantitative variables were performed using the nonparametric Mann-Whitney test [24]. For comparing categorical data, the chi-square ($\chi 2$) test was performed. An Exact test was used instead when the expected frequency was less than 5 [25]. P values less than 0.05 were considered statistically significant.

Results

Demographic features of the study population

49 (47.6%) samples were collected from males and 54 (52.4%) were from females before the QI program implementation. Their age range was 1 to 180 months with a mean-/+ SD of 44.33-/+51.9 months.

After the QI program implementation, 57(55.3%) samples were collected from males and 46 (44.7%) were from females. Their age range was 1 to 168 months with mean-/+ SD 36.58-/+47.06 months**.**

Analysis of the phases of the QI program

1) Phase 1: Before the QI program implementation:

The most common pitfalls during BC sampling are shown in Table 3.

* Pitfall percentage was calculated from (number of observed pitfalls divided by the total number of blood cultures collected) × 100.

2) Phase 2: After the QI program implementation:

Table 4. shows the checklist items of proper sampling steps implemented through PDSA 2 and the assessment of the nurse's compliance with each step.

Table 5. shows a comparison between the compliance of nurses with the most important steps of blood culture collection before and after the QI program.

Laboratory findings:

1) Infection markers

Table 6. shows the 44 enrolled patients with positive BC results for whom we had data for every parameter under analysis (TLC, band count, CRP), with quantitative variables expressed as medians.

BCs with multiple organism results were excluded and were always considered BCC events.

2) Blood Culture Results

The rate of blood culture contamination decreased from 12.6% before the QI program to 5.8% after the QI program (p-value 0.092). The true pathogen prevalence was reported at 11.7% and 15.5% before and after the QI program implementation, respectively (P value 0.41)

Table 1. The checklist items of proper blood culture sampling technique [7, 14, 17]

1-	Obtain supplies (peds culture vial, Blood Culture sampling kit)
2-	Establish a clean work area
3-	Wear a mask
4-	Apply proper hand hygiene (HH)
5-	Set up supplies: open sterile glove packaging, and drop contents of the IV kit, syringes, and IV catheter.
6-	Open the bottle and clean the top with a 2% chlorhexidine pad for 15 seconds and allow to air dry
7-	Apply tourniquet
8-	Disinfect the skin in a circular direction from inside out with 70% isopropyl alcohol for at least 15 seconds**,** and then apply a tincture of 2% iodine for 2 minutes and let the skin air dry completely.
9-	Wear gloves
10-	Insert needle by no-touch technique.
11-	Withdraw blood according to the patient's weight chart.
12-	Remove tourniquet.
13-	Inoculate blood into the bottle.
14-	Dispose of the needle in a sharp container, label the specimen, and remove gloves.
15-	Perform proper hand hygiene.

Table 2. Volume of blood required per weight category: [18]

Weight in kilograms(kg)	**Blood volume in (ml)**
1.5-2.1	1.0
2.2-11.1	1.5
11.2-17.1	7.5
17.2-37.2	11.5
>37.3	16.5

Table 3. Common pitfalls during blood culture sampling practice before the Quality Improvement program implementation.

Type of Pitfall	**Pitfalls***	
	Count	**%**
1)Inadequate swabbing of the skin with antiseptic solution.	41	39.4%
2) Insufficient time to ensure disinfectant efficacy before sampling	45	43.3%
3) Lack of follow-up of no-touch technique	8	7.7%
4) The blood volume injected into a bottle was insufficient according to the patient's weight	46	44.2%
5) inappropriate disinfection of the stopper of the bottle /or touching it while inoculating into the bottle	62	59.6%
6) A blood sample was placed on a nonsterile surface before being injected into the bottle	6	5.8%
7) The sample was not sent to the microbiology laboratory within 1 hour of collection	4	3.8%

Table 4. Checklist for blood culture sampling steps and compliance of nurses to each step

	Count (n=103)	**%**
Obtain supplies (peds culture vial, BC sampling kit)	103	100%
2) Establish a clean work area	90	87.4%
3) Wear a mask	44	42.7%
4) Hand hygiene	33	32%
5) Set up supplies (open sterile gloves packaging) (drop contents of IV kit (syringes, IV catheter)	103	100%
6) Disinfect the top of the bottle with a chlorhexidine pad for 15 seconds, and allow it to air dry	50	48.5%
7) Apply tourniquet	97	94.2%
8) Wear gloves	103	100%
9) Apply skin antiseptic 70% isopropyl alcohol for at least 15 seconds, then apply a tincture of iodine for 2 minutes.	80	77.7%
10) Let air dry completely	86	83.5%
11) Insert needle by no touch technique	97	94.2%
12)Withdraw blood volume corresponding to the patient's weight	81	78.6%
13) Remove tourniquet	103	100%
14)Inoculate blood into the bottle	103	100%
15)Dispose needle in a sharps container, label the specimen, remove the gloves	103	100%
16) Hand hygiene	32	31.1%

Table 5. Compliance of nurses with the most important steps of blood culture collection before and after the QI program.

	Before the QI program (n=103)		After the QI program (n=103)		P value
	Count	%	Count	%	
Adequate swabbing of the skin by antiseptic	63	61.17%	80	77.6%	< 0.001
Sufficient time to ensure disinfectant efficacy before sampling	59	57.2%	86	83.5%	< 0.001
Follow up on the touch technique	88	85.43%	97	94.17%	0.004
Sufficient collected blood volume	58	56.3%	81	78.6%	< 0.001
Appropriate disinfection of the stopper of the bottle	42	40.77%	63	61.16%	< 0.001

Table 6. Infection markers of patients with true positive cultures versus patients with contaminated cultures.

Infection marker	**True positive BCs (n=28)**	**Contaminated BCs (n =16)**	**P value**
TLC (per mm3)	14650 (11000-19450)	9600 (8750-10500)	0.001
Band cells (per mm3)	12000 (9000-18000)	3000 (2000-4000)	<0.001
CRP (mg/l)	120.5 (57.25-166)	5.1 (2.85-11)	<0.001

Figure 1. The three-step conducted PDSA cycle throughout the whole study duration.

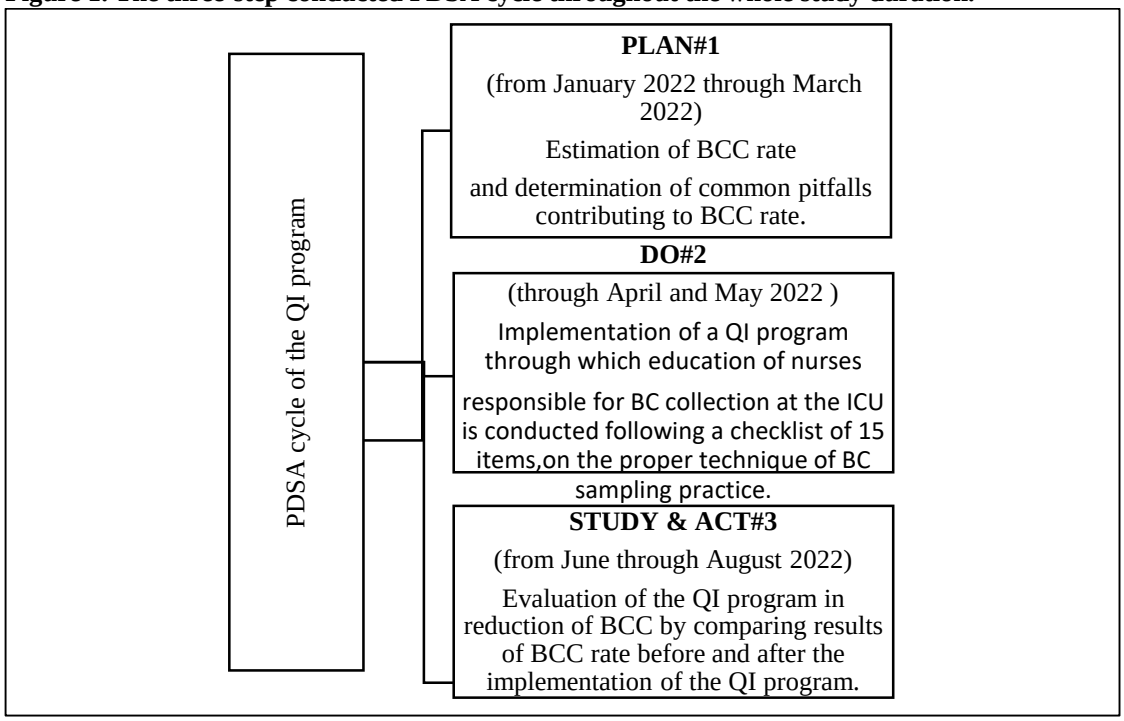
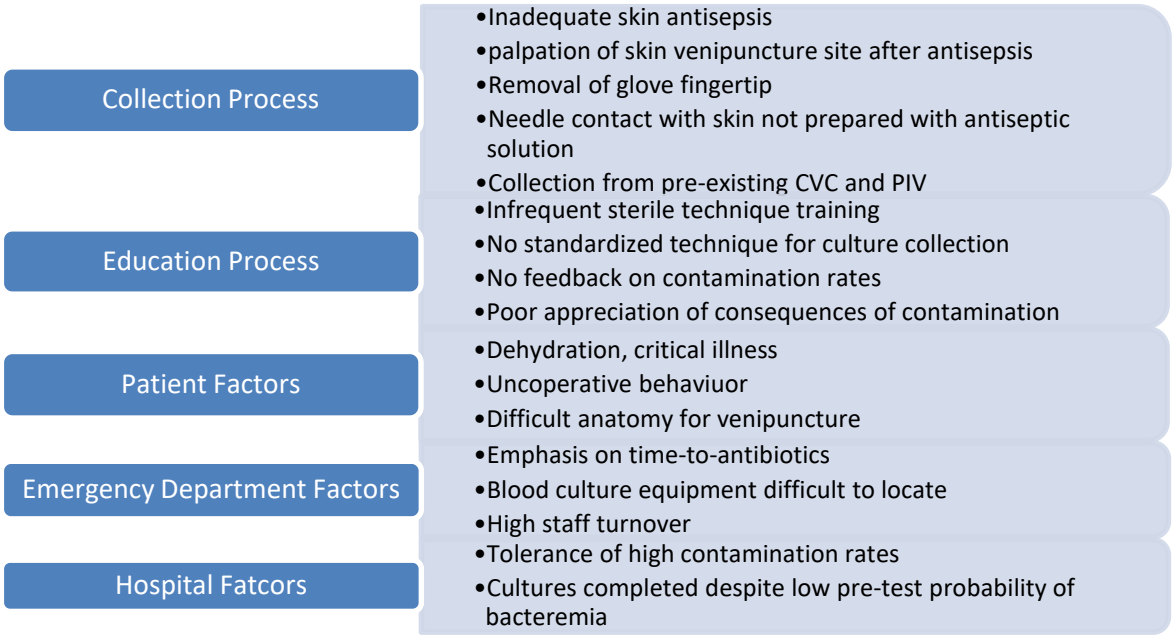


Figure 2. Common risk factors of BCC including collection process, education process, patient factors, Emergency Department factors, and hospital factors.



CVC: central venous catheter; PIV: peripheral intravenous catheter

Discussion

BC remains the gold standard test for diagnosing bacteremia or fungemia [26]. Microbiological laboratories are responsible for providing a value-based service that includes rapid, accurate, and clinically meaningful BC results that lead to improved and quick patient care while supporting their antimicrobial stewardship program [9] and reducing the BCCR to avoid its negative impacts on patients, microbiology laboratories, hospitals, and pharmacies [5].

However, despite its high accuracy results, blood culture contamination (BCC) is common and may occur at high rates [16]. According to our study,

out of 103 BC samples, the rate of BCC was 12.6% before the QI program implementation. Reports in the literature describing BCCRs are diverse and varied between the different patient age groups, in the adult population, roughly 20 to 56% of positive BC results may represent contamination [6], with overall contamination rates of from 0.6% to 17% [3], whereas in the pediatric population, BCs show contamination rates of 1% to 15.2% [5][6], BCCRs show an increase with patients of younger ages as well as fewer years of experience of the health care workers responsible for collecting the samples [17], higher rates of BCC are encountered in neonates and are reported be between 2.6% to18% [7].

The higher rates of BCC are found in younger children because of the technical challenges that may be present during BC sampling such as the small veins of the children, the small sample volumes, and decreased compliance [5].

BCCRs are often highest in Emergency Departments a recent study described a much higher rate of BCC (11.7 %) in an ED setting vs a BCCR of (2.5%) in other areas of the same hospital [27]. It was also reported that positive BC rates in EDs range only from 3.4% to 7.9% with high contamination rates of up to 7.9% [23]. Similarly, BCC rates are reportedly high in ICU settings ranging from 2.90% to 6.70% [28]

The reduction in BCCR in our study was a challenge due to several factors affecting the efficacy of BC collection. Like other institutes of the same work nature, our institute suffered from limited time, high turnover of healthcare workers, crowdedness, and many patients requiring critical care [9][19][29].

Several studies have reported varied interventions for the proper BC sampling procedures. Some studies described the use of dedicated phlebotomy teams, together with the following complete aseptic techniques during the collection of BCs [9]. Additionally, PDSA modules were conducted in different institutes, and the success of these QI plans was reported in literature reviews [9].

A Saudi study, performed in Najran Armed Forces Hospital, on blood cultures tested in the period from June 2019 to July 2020, reported that there was a statistically significant reduction in the contamination rate from 5.1% to 4.1%. The action plan simulates that in our study, affirming that blood culture is only requested by consultants, assuring that blood culture requests must include clinical indications, and previously used antibiotics with the rejection of blood culture requests if these items are not fulfilled. [30]

In agreement with our study findings of an assessment of BC collection technique, the study of EL Feghaly et al. (2018), conducted in a children's hospital in Kansas, concluded that the most common pitfalls that occurred during BC sampling were lack of adequate dry time for antiseptic use (62%), re-palpation of the vein after antisepsis (60%), collection of suboptimal blood volume (80%), lack of blood culture top cleansing (39%), and delay in transportation of the BC sample to the laboratory. Based on these observations, a QI program was identified to be designed to reduce the reported BCC rate, showing success in reducing the BCCR from 2.85% to 1.03% in two years [16].

In our hospital, our first quality improvement strategy involved spreading awareness about our local contamination problem and motivating the ICU nurses to change.

Therefore, an aseptic BC collection technique was developed to facilitate an efficient, standardized process following a checklist of 15 items that were tabulated to be available for nurses to review at any time.

Similarly, the study of Mullan, P. C. et al. (2018) in the ED of the Children's National Medical Centre showed the implementation of a QI program including 3 PDSA cycles. The study was to reduce the BCCR (3.2%) by 50% within 24 months of the project duration. In PDSA#1, a checklist of 30 items of aseptic sampling technique was conducted. The project's goal was achieved by reducing the BCC rate to 1.17% with a 61% relative decrease in the BCC rate [14].

Also, Allen et al. (2021), conducted a study in a southern Australian neonatal unit aiming at the reduction of BCCR, and showed the implementation of a QI program, by using 4 PDSA cycles, which led to an overall BCC rate decrease from 2.0% during the baseline period to 0.90% in the study period (>50% reduction) [7].

In reported literature reviews, nearly half of the conducted studies omitted the description of their contaminant results definition, with significant heterogeneity in the physicians' approaches to categorizing organisms as contaminants.

In our study, a multifactorial approach was conducted and followed for the differentiation

between true pathogens and BC contaminants, especially in cases of equivocal organisms with variable clinical significance, considering other laboratory marker results (TLC, band count, CRP), the judgment of the physicians, and the microbiology laboratory identification of the given positive organisms.

In accordance with our study, the study of Hernández-Bou et al conducted in a tertiary referral maternity and children's hospital in Spain assessed predictive factors of contamination in a BC with bacterial growth in an ED. These factors included fever, TLC, band count, CRP, TTP, and initial Gram stain result. The study found that the level of CRP was the most useful laboratory parameter for the early identification of a contaminated BC. Additionally, the TLC was significantly higher in the case of pathogens than of contaminants. Also, it was reported that the time to positivity of contaminants was considerably longer than that of pathogens. A Gram stain result suggestive of contamination stood out as the most useful individual parameter for the early identification of a contaminated BC in the Hernández-Bou et al study.[31]

In contrast to our study, the study of Tara L. Greenhow et al. (2012), conducted in Kaiser Permanente Northern California for infants, mentioned that the type of isolated bacteria was the only factor used to identify the three organisms *CONS*, *Micrococcus species*, and *diphtheroids* which were considered contaminants at every time of isolation. According to the above, an assessment of 4255 BCs results through a 5-year duration (2005-2009) was conducted, showing a total of 340 (8%) positive cultures, with only (93/4255) true pathogen cases (2% of all cases), whereas (247/4255) positive cultures were due to contaminants [32].

Different from our study, the study of Bonsu, B. K. et al. (2003) mentioned only the measurement of TLC for identifying true bacteremia in young infants. The results of this study showed that the rate of bacteremia was only 1% and that no threshold of the TLC count was found to have both good sensitivity and specificity, with TLC count being an inaccurate screening test for bacteremia, and if followed only in the diagnosis of bacteremia, more FPBC results will be yielded [33].

In general, as the internationally recommended benchmark of the BCCR is 2-3%, given the burden (physical and financial) of contaminated BCs placed on our pediatric patients, hospitals, HCWs, and pharmacies, it is essential to continue to minimize the BCCR. This can be done by conducting regular meetings with the ICU staff and nurses to discuss the ongoing problem of BCC, emphasizing the negative impacts of each BCC event, with the high probability of morbidities and mortalities being the most ramifications of BCC events, and with giving feedback on every BCC event to achieve the desired acceptable BCCR [20]. Additionally, preventive measures can be taken; to ensure the effectiveness of the quality indicators that are being monitored by accreditation bodies in microbiology [29] by notifying assigned personnel on every BCC event to achieve the acceptable BCCR.

Conclusions

BCCR evaluation is always recommended to improve patients' outcomes. Aspects of implementation of the QI plan were extracted to establish a list of key factors which contribute to successful intervention for the reduction of BCCR. We assume that there is a need for strict antisepsis and disinfection procedures hand in hand with regular training and monitoring of HCWs responsible for the collection of Blood cultures and that standardized BC sampling technique is mandatory to reduce BCCR. In our institute, it was successfully reduced from 12.6% to 5.8% affirming the importance of continual evaluation and consistent trials for the reduction of BCCR, in order to achieve the recommended benchmark which is 2-3%.

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