

Tackling the problem of blood culture contamination in the intensive care unit using an educational intervention

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SUMMARY

Blood culture contamination (BCC) has been associated with unnecessary antibiotic use, additional laboratory tests and increased length of hospital stay thus incurring significant extra hospital costs. We set out to assess the impact of a staff educational intervention programme on decreasing intensive care unit (ICU) BCC rates to <3% (American Society for Microbiology standard). BCC rates during the pre-intervention period (January 2006–May 2011) were compared with the intervention period (June 2011–December 2012) using run chart and regression analysis. Monthly ICU BCC rates during the intervention period were reduced to a mean of 3.7%, compared to 9.5% during the baseline period ($P < 0.001$) with an estimated potential annual cost savings of about £250 100. The approach used was simple in design, flexible in delivery and efficient in outcomes, and may encourage its translation into clinical practice in different healthcare settings.

Key words: Adequate clinical practice, blood culture, false positives, educational intervention.

INTRODUCTION

Sepsis, the systemic inflammatory response to infection, continues to be a major cause of morbidity and mortality in critically ill patients, resulting in frequent diagnostic testing, increased antibiotic administration and prolonged length of hospitalization [1, 2]. The

major health and economic impacts of bacteraemia highlight the importance of early detection and treatment of healthcare-acquired infections (HAIs), particularly in critically ill patients [1–3]. Blood cultures are the most important and most commonly performed tests used to identify the presence of bacteria in the bloodstream. When properly performed they enable therapy to be directed against the causative microorganism, helping to reduce mortality and the selection of multiresistant bacteria [4, 5]. However, blood culture contamination (BCC) leading to false-positive blood cultures, with microorganisms which

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were not actually present in the bloodstream can limit the value of this approach.

Rates of BCC vary widely between healthcare settings and have been estimated to range from 1.5% to >9% in several teaching hospital-based studies [6–10]. Although it has been recommended that target rates for BCC should not exceed 3% [11], in many institutions it actually exceeds 7% [11, 12]. Blood cultures are generally incubated for 5 days for bacterial growth but positive test results are usually available within 48 h. If culture results are negative, administering antibiotics may be unnecessary and other potential diagnoses can be considered [13]. When a positive culture is recognized as a likely contaminant, the usual practice is to obtain additional blood cultures which adds to costs and potentially delays targeted treatment of the patient [14, 15]. In the interests of patient safety, many physicians will treat patients once any growth in the blood culture is observed, with the potential for continuing empirical treatment, especially in immunocompromised or critically ill patients [16].

An earlier prospective case-control study at the Antrim Area Hospital to determine the clinical and economic impact of contaminated blood cultures showed increased lengths of hospital stay and total costs per patient of 5.4 days and £5002, respectively [17]. Moreover, the study showed a particularly high rate (13.6%) of false-positive cases in the intensive care unit (ICU). These findings provided the rationale for targeting the ICU to assess the impact of a staff educational intervention programme (a poster, DVD, monthly feedback of BCC rates) on decreasing BCC rates to a target value of <3% in the ICU at Antrim Area Hospital.

METHODS

The project was designed in the form of an audit of blood culture-taking practice within the hospital, as part of a continuing quality improvement programme. Approval was obtained from the Northern Health and Social Care Trust (NHSCT) research governance committee, and the study was registered within the Trust research and development department.

Study setting

The study was conducted in the ICU at the Antrim Area Hospital in Northern Ireland, a 426-bed district general teaching hospital serving a population of ~420 000. The hospital provides all acute, general

medical and surgical services, supports a range of out-patient facilities and acts as a centre for the coordination of health service provision throughout a defined geographical area in Northern Ireland. The ICU consists of eight beds (adult general medical and surgical), and admits about 35 patients per month.

Definitions

BCC was defined using a predictive model that is part of the standard operating procedure of the Microbiology Laboratory. The laboratory standard for blood cultures is a minimum draw of two sets of blood cultures from separate peripheral venous puncture sites in the same time-frame. For intravascular devices the standard is a minimum draw of two sets of blood cultures from separate peripheral venous puncture sites followed by drawing blood from each of the lumens of intravascular catheters in the same time-frame; in practice the laboratory usually only receives samples from a single catheter lumen. The multiple sets of blood cultures required by the standard is to increase the volume of blood cultured, thereby increasing the chance of recovering the pathogen as in adult bacteraemia there may be <1 organism/ml of blood sampled. In addition, the laboratory uses the multiple draws to establish the significance of any organism isolated. Bacteria and yeasts are classified into groups: (i) organisms that always or nearly always represent true infection ($\geq 90\%$) and (ii) common contaminants but which may be significant in specific clinical circumstances. The number of blood culture sets that grow a particular microorganism, when measured as a function of the total number of blood culture sets obtained is widely accepted to be a useful tool in the interpretation of the clinical significance of positive blood cultures. If organisms from the first group are isolated from any blood culture set they are considered to be clinically significant. However organisms from the second group are only considered to be clinically significant if they are isolated from a minimum of two blood culture sets and they yield organisms of the same biochemical profile and antibiogram; otherwise they are considered to be likely contaminants and reported as 'possible contamination please repeat if clinically indicated'. If the contamination rate is 3%, then the probability that identical organisms recovered from two sets of blood cultures from a patient are contaminants is <1/1000 ($0.03 \times 0.03 = 0.0009$) [4, 18, 19].

Time	Jan. 2006–May 2011	From June 2011	Sept. 2011	Nov. 2011	Dec. 2011–Dec. 2012
Intervention		Poster	DVD viewed	DVD viewed	Monthly feedback of BCC rates
BCC rate	BCC rate pre-intervention period 5 years and 5 months (all BC 5002 sets, BCC 451 sets) (1 Jan. 2006 to 31 May 2011)	BCC rate during the educational intervention period 19 months (all BC 451 sets, BCC 57 sets) (1 June 2011 to 31 Dec. 2012)			
Completion of BC request form	Completion of BC request form during pre-intervention 9 months (1 Sept. 2010 to 31 May 2011)	Completion of BC request form during the educational intervention 10 months (1 June 2011 to 31 Mar. 2012)			

Fig. 1. Study design. Impact of intervention on blood culture contamination (BCC) rate and completion of blood culture (BC) request forms timeline.

Data collection

In order to determine the BCC rate, the number of contaminated blood cultures and the total blood cultures taken in the ICU on a monthly basis were recorded through evaluation of microbiology laboratory records (i.e. retrospectively during the period from January 2006 to August 2010 and prospectively during the period from September 2010 to December 2012). This latter time period in the study includes evaluation of blood culture request form completion from September 2010 to March 2012 and the educational intervention from June 2011 to December 2012.

To assess the impact of the intervention on the appropriate completion, by staff, of the information requested on the blood culture request forms, the following details were recorded during the second period for each form completed: patient's name, gender, hospital number, date of birth, ward, time and date sample taken, clinical details, current antibiotic use, sample site and signature of person taking the sample, and expressed as the percentage of fully completed request forms.

Study design

The impact of the educational intervention on the BCC rate was evaluated by comparing the rate of BCC during the pre-intervention period (January 2006 to May 2011) with the rate during the educational intervention (i.e. June 2011 to December 2012; Fig. 1).

The educational intervention

The educational intervention was designed to increase the awareness of ICU clinical staff of BCC and the use of proper techniques for taking blood culture samples. This consisted of a poster (Supplementary Fig. S1), a

13-min structured DVD on blood culture sampling (produced by NHSCT Antimicrobial Management Team and Iskus Health; available at www.iskushealth.com) and the provision of monthly feedback to ICU staff via email on BCC rates with a run chart of the results which was displayed on the ward and updated on a monthly basis.

The DVD and poster were devised based on the Trust's policies and procedures for optimal blood culture collection practices. The poster was displayed on the main noticeboard in the ICU throughout the educational intervention from June 2011. A register of all ICU staff involved in taking blood cultures was established (16 physicians, 54 nurses), and each individual was requested to view the DVD in September 2011 or November 2011. The DVD focused on (a) the definition of BCC; (b) the targeted contamination rate (i.e. <3%); (c) the increased healthcare costs due to BCC; (d) the most common organisms involved in the contamination of blood cultures; and (e) the proper technique for taking blood culture samples. The latter was consistent with the seven steps outlined in the poster presentation, i.e. gather components; wash hands; wipe rubber septum with alcohol swab; decontaminate hands with alcohol gel; disinfect patient's skin with Chloraprep® (CareFusion, UK); transfer blood to the blood bottles; send labelled bottles with fully completed request form to laboratory. Feedback of results to ICU staff began in December 2011.

Economic evaluation

The estimated potential annual cost savings were determined based on the analysis previously published from this hospital [17] and included antibiotic, laboratory, and daily hospital costs ('hotel' charges) for each directorate in the hospital.

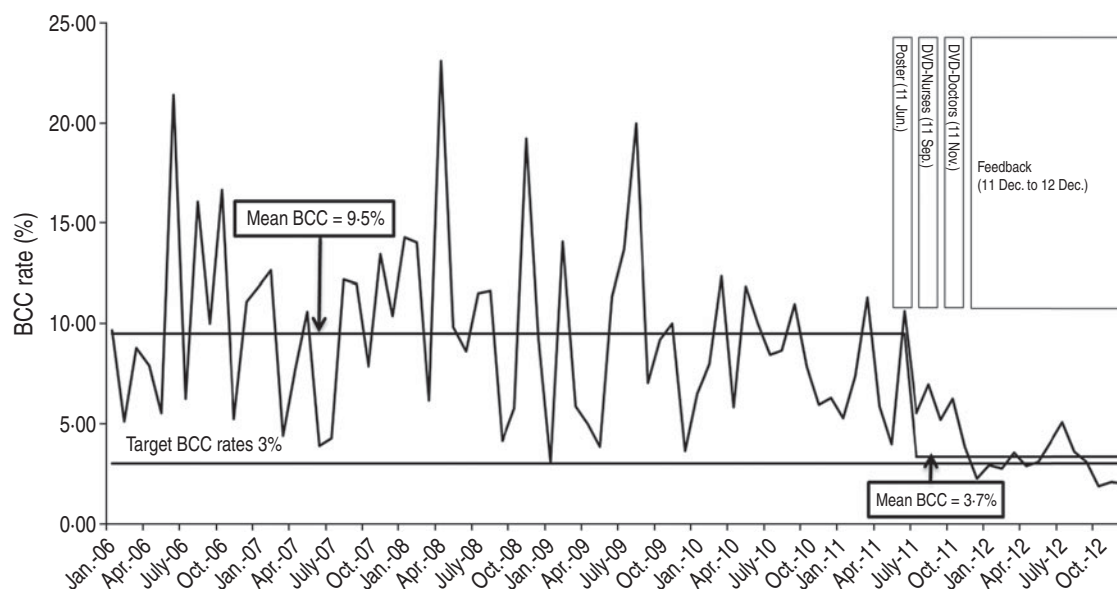


Fig. 2. Run chart of monthly blood culture contamination (BCC) rates over the whole study period (ICU; January 2006–December 2012), completion of blood culture request forms during pre- and educational intervention period (September 2010 to May 2011 and June 2011 to March 2012).

Statistical analysis

Non-normal distribution data were analysed using the Mann–Whitney U test with continuous variables expressed as medians and interquartile ranges (IQRs), and Pearson's χ^2 test with categorical variables expressed as percentages. A run chart was constructed showing the monthly BCC rate and the contamination rate was determined from the number of BCCs \times 100/number of total blood cultures taken. The impact of the implemented intervention was evaluated utilizing the analysis of segmented regression of an interrupted time-series [20]. This allowed the estimation of the intervention effect while taking account of time trend and autocorrelation existing in consecutive observations. Data for the period June 2011–December 2011 were omitted from the analysis as the full effect of the intervention was not present during this period. Data were coded as described elsewhere [20] (0, before educational intervention; 1, post-educational intervention), and a P value of <0.05 was considered to be statistically significant. All statistical analyses were performed using SPSS software v. 20.0 (SPSS Inc., USA).

RESULTS

During the whole period (i.e. both pre-intervention and during the educational intervention, January 2006 to December 2012) 6421 blood culture sets

were obtained from the ICU, of which 508 were categorized as contaminated. During the baseline phase (to May 2011), 5002 blood culture sets were obtained, of which 451 (9.0%) were categorized as contaminated. By contrast, during the intervention period (June 2011 to December 2012), 1419 blood culture sets were obtained, of which 57 (4.0%) were categorized as contaminated.

Impact of the intervention

The analysis of time series showed that the educational intervention ($R^2 = 0.27$) impacted upon the BCC rate, with a level change reduction (coefficient = -4.7 , $P = 0.034$) being observed 2 months post-intervention. The run chart (Fig. 2) shows a reduction in the monthly BCC rates during the educational intervention period to a mean of 3.7%, compared to 9.5% during the baseline period. There was no significant difference, using the Mann–Whitney U test, between the monthly number of blood culture sets obtained during the pre-intervention (median 72, IQR 61–84) and educational intervention (median 72, IQR 55–86) periods ($P = 0.63$).

Request form completion rates during the pre-intervention and educational intervention periods were almost identical for the following parameters: patient's name, gender, date of birth, hospital number, ward name, signature of person taking the sample, and

Table 1. Comparison of proper completion of blood culture request forms during pre-intervention and educational intervention period (September 2010 to May 2011 and June 2011 to March 2012)

Patient information	Pre-intervention period	Educational intervention period	<i>P</i> value*
Name	98.1	99.0	0.28
Gender	96.2	97.8	0.18
Date of birth	98.8	99.5	0.47
Hospital number	98.3	97.3	0.36
Ward recorded	94.3	96.3	0.16
Date sample taken	96.8	94.9	0.13
Time sample taken	95.1	93.9	0.47
Signature of person taking the sample	92.2	96.3	0.23
Sample site	65.3	73.3	0.008
Clinical details	44.6	52.0	0.006
Antibiotic use	47.0	61.2	<0.001

* Pearson's χ^2 test.

date and time sample taken. There was, however, a significant increase in the percentage of fully completed forms during the educational intervention period in relation to sample site, clinical details and current antibiotic use ($P = 0.008$, 0.006 , <0.001 , respectively). Absolute improvements in the completion of those variables were 8.0%, 7.4% and 14.2%, respectively, as shown in Table 1.

Sites associated with BCC

Data for this aspect of the study were collected over a 19-month period (September 2010 to March 2012). Of the 1509 blood culture sets obtained during this period, 619 (41.0%) were taken via peripheral venepuncture, 503 (33.3%) from a central venous catheter, 134 (8.9%) from a dialysis line, and 52 (3.4%) from an arterial line. A total of 201 (13.3%) sample sets did not have the site recorded. Among the false-positive blood culture results, the most common sample site was the central venous catheter (54.5%), while the least common site was the arterial line (3.4%). The peripheral venepuncture site was the most common site for both the true-positive and negative blood culture results (43.7% and 41.3%, respectively). Table 2 shows that blood cultures obtained via a central venous catheter yielded a contamination rate of 48/503 (9.5%), compared to 30/619 (4.8%) for peripheral venepuncture. Moreover, according to the odds ratio (OR) values, blood culture samples obtained through

a central venous catheter were more than twice as likely to be contaminated [OR 2.1, 95% confidence interval (CI) 1.3-3.3] than samples taken via peripheral venepuncture. Samples taken via a dialysis line and arterial lines showed no significant relationships with BCC (Table 2).

Economic analysis

Using data collected in the previous study in Antrim Area Hospital [17], it was found that patients with false-positive blood cultures had additional hospital costs of £5002 compared to the patients with negative blood cultures. A median of 72 blood cultures were taken in the ICU per month during the pre-intervention and educational intervention periods, and false positives before and after the intervention were 9.5% and 3.7%, respectively. Using these data the estimated potential annual cost saving was approximately £250 100 (Table 3).

DISCUSSION

The rate of contamination of blood cultures should not exceed 3% according to the standards of the American Society for Microbiology [11, 12]. Previously, in the study site hospital, the BCC rate was found to have a mean value of 4.7% [17], with a high percentage of the false-positive cases occurring in the ICU (BCC rate 13.6%).

The intervention put in place in the current study aimed to reduce the BCC rate in the ICU of the study site hospital to the recommended standard. It is a particular challenge to reduce BCC in an ICU as previous studies have demonstrated that BCC rates are generally higher in such units compared to general wards, due to the high workload of staff, high severity and urgency of illness, and poor vascular condition of patients [9, 21, 22]. Therefore, only a few studies have attempted to decrease BCC rates in adult ICUs through educational interventions [8, 12, 23]. The run chart approach was used in the present study to determine the effect of the educational intervention as it is considered to be of value for application in healthcare quality development [24].

Our findings indicate that the introduction of an educational intervention alone did significantly reduce BCC rates within an ICU in a typical medium-sized hospital in the UK. The rate of contaminated blood cultures was significantly reduced from 9.5% to 3.7%, and the rate fell below the 'gold standard' target

Table 2. Relationships between blood culture sample sites and BCC (September 2010 to March 2012).

Blood culture sites	Blood culture results			Relationships between blood culture sample sites and BCC	
	False positive <i>n</i> (%)	True positive <i>n</i> (%)	Negative <i>n</i> (%)	<i>P</i> value	OR (95% CI)
Peripheral venepuncture	30 (34.0)	28 (43.7)	561 (41.3)	0.009	1
Central venous catheter	48 (54.5)	24 (37.5)	431 (31.8)	0.003	2.1 (1.3–3.3)
Dialysis line	5 (5.7)	6 (9.4)	123 (9.1)	0.58	0.7 (0.29–1.99)
Arterial line	3 (3.5)	2 (3.1)	47 (3.4)	0.77	1.2 (0.35–4.1)
Not recorded	2 (2.3)	4 (6.3)	195 (14.4)		
Total	88	64	1357		

BCC, Blood culture contamination; OR, Odds ratio; CI, confidence interval.

Table 3. Estimated economic benefit flowing from the educational intervention

Item	Data
A	Median values of monthly blood culture sets taken in ICU at pre-intervention
B	Estimated annual number of blood cultures at pre-intervention (A × 12)
C	Blood culture contamination rate at pre-intervention
D	Estimated annual number of blood culture sets contaminated pre-intervention (B × C)
E	Estimated cost of one false-positive blood culture*
F	The estimated annual cost of contaminated blood culture at pre-intervention (D × E)
G	Median values of monthly blood culture sets taken in ICU at post-intervention
H	Estimated annual number of blood cultures at post-intervention (G × 12)
I	Blood culture contamination rate at post-intervention
J	Estimated annual number of blood culture sets contaminated at post-intervention of 3.7% (H × I)
K	Estimated annual cost of contaminated blood culture at post-intervention (J × E)
L	Impact of intervention on the estimated annual cost savings due to reduction in blood culture contamination (3.7% from 9.5%; F–K)

ICU, Intensive care unit.

* Based on a previous study in Antrim Area Hospital [17].

of 3% for a 7-month period during the 19-month educational intervention period. Moreover, the completion of the blood culture request forms was improved. As expected, it was found that the blood culture samples obtained via central venous catheters were more frequently associated with BCC.

The overall educational intervention, i.e. the poster, DVD and monthly feedback of BCC rates was developed and introduced to ensure there was minimal disruption to the work and staff in the ICU. The DVD was presented to the ICU staff for them to view at a time that suited them best and they were asked to sign a form to confirm that the DVD had indeed been viewed. This resulted in making the intervention more flexible and less costly, compared with other educational interventions, which often need to be performed on a one-to-one basis [25, 26]. Moreover, the educational intervention focused on improving staff

knowledge regarding the proper techniques for taking blood culture samples without changing hospital guidelines or patient services. Other previous studies, in combination with educational interventions, have sought to change guidelines for phlebotomy practice [12], introduce new disinfectants [8], or adopted new blood culture kits [5].

Two to three blood culture sets per episode is recommended for the optimal detection of bloodstream infection according to the blood culture standards of the Clinical and Laboratory Standards Institute (CLSI) [27]. A previous study aimed at reducing BCC rates through an educational intervention and the introduction of new blood culture collection kits, found that the BCC rate decreased, but this was coupled with a reduction in the total number of blood culture sets collected. The latter outcome was suggested to reflect the fear by junior physicians of

the possible consequences if they were held responsible for contamination [28]. The monthly blood culture numbers did not change over the study period. The blood culture request form in the study site hospital contains important information that may be used as an aid by the microbiologists in their interpretation of possible BCC (e.g. sample site, clinical details). Thus, completion of blood culture request forms was used as an indicator of the educational intervention on the awareness of the ICU staff and as such is, to date, the first study to document this outcome measure. Indeed, completion of the forms was found to have improved during the intervention.

The percentage of contaminated blood cultures obtained via central venous catheters (over a 19-month period), was almost double that via peripheral venepuncture (9.5% vs. 4.8%) which is consistent with data from other studies [14, 15, 29]. A recent study compared contamination rates of blood cultures obtained by central venous catheters with samples from peripheral venepuncture over 5.5 years in two ICUs (general and medical) and also found central venous catheter cultures to be more frequently contaminated than peripheral blood cultures (8% vs. 4%) [21]. The ICU is among the most expensive wards in hospitals and ICU patients may have long hospital stays. Contamination of blood cultures will increase this cost by extending length of stay inappropriately. We have demonstrated that a simple bespoke educational intervention to reduce BCC rates can result in significant cost savings (Table 3). In addition to the benefits of more appropriate use of resources, significant improvements in patient care and wellbeing are obtained through reductions in unnecessary antimicrobial usage and length of hospital stay, which reduce the risk of patients acquiring HAIs and the development of resistance.

This study has some limitations. First, the educational intervention was carried out in a single ICU and might have benefited if a multicentre trial had been possible. Second, there was no evaluation (e.g. a questionnaire survey) of staff awareness levels regarding adequate blood culture sampling techniques before and after the educational intervention. However, this was indirectly evaluated by documenting the percentage of blood culture request form details that had been comprehensively completed. Moreover, observation of the outcomes of blood culture sampling is considered a more effective method by which to evaluate staff awareness [25, 26]. Third, data on blood culture drawing sites, determined

before and after the intervention, was not available for analysis and it was not possible to assess differences in BCC rates accordingly. Last, although the evaluation of the impact of the intervention might have benefited from a longer follow-up period, the present analysis included sufficient numbers of observations post-intervention.

In conclusion, the educational intervention approach used in this study addressed the problem of false-positive blood cultures in hospital to a level that is consistent with best practice in the area. The observed decrease in BCC rates has important clinical and economic implications. Importantly, the approach was simple in design, flexible in delivery and efficient in outcome, and thus may encourage the translation of this approach into clinical practice in different healthcare settings.

SUPPLEMENTARY MATERIAL

For supplementary material accompanying this paper visit <http://dx.doi.org/10.1017/S0950268814003008>.

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DECLARATION OF INTEREST

Iskus Health Ltd partly contributed to the development of the DVD which was used as part of the overall educational intervention.

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