BLOOD CULTURE SPECIMEN COLLECTION PRACTICES AMONG PATIENTS WITH SUSPECTED BLOODSTREAM INFECTIONS AT AN EMERGENCY DEPARTMENT OF A TERTIARY HOSPITAL IN JOHANNESBURG, 14-20 JUNE 2018

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Summary

Rapid diagnosis of bloodstream infections (BSIs) is critical to initiate appropriate treatment to reduce mortality and morbidity among patients. Blood culture remains the gold standard for diagnosis of BSIs and guidelines have been developed in order to optimise the benefits of this tool. Since the publication of the South African blood culture guidelines in 2010, few studies have evaluated healthcare workers' adherence to the recommended practices. The objectives of this study were to determine blood culture utilisation among healthcare workers in an emergency department, to quantify the contamination rates of blood cultures, and to assess the knowledge and practices of healthcare workers in a public-sector hospital in South Africa. A cross-sectional study was conducted at a Johannesburg tertiary hospital from 14-20 June 2018. The first fifty adult (≥17 years) patients admitted through the emergency department per day were screened for signs and symptoms of BSI/sepsis that qualify them for a blood culture, and the proportion that eventually received a blood culture was determined. Medical record reviews were conducted to collect demographic and clinical data, and laboratory information was obtained from the National Health Laboratory Service (NHLS) Central Data Warehouse. Knowledge, attitudes and practices of healthcare workers around recommended blood culture practices were assessed using a self-administered questionnaire. A total of 402 adult patients was admitted through the emergency department during the study period, and 165 (41%) of these were assessed for BSI/sepsis symptoms, including temperature of 38°C and above, or

tachycardia (abnormal heart rate), or tachypnoea (abnormally fast respiratory rate), or bradycardia (abnormally slow heart rate) or elevated white cell count. Of the 165 patients, 110 (67%) met the definition for suspected BSI/sepsis and were enrolled into our study, while 55 (33%) either had missing data or did not meet the inclusion definition. Among patients with suspected BSI/sepsis with available laboratory information (89), 25 (28%) had a blood culture done. Compared to patients who did not receive a blood culture, patients who had one done were more likely to be diagnosed with pulmonary conditions (36% versus 16%, p=0.031), infection-related conditions such as urinary tract infection, suspected sepsis, malaria, etc. (16% versus 5%, p=0.031), metabolic conditions (12% versus 8%, p=0.031), have abnormal white cell counts (57% versus 40%, p=0.179), be HIV-seropositive positive (73% versus 53%, p=0.296) and present with two or more BSI/sepsis signs and symptoms (70% versus 53%, p=0.144). Among 25 patients with blood cultures done, two (8%) had laboratory-confirmed BSI caused by *Escherichia coli* and *Proteus vulgaris*. Coagulase-negative *Staphylococcus* sp. (CNS) was isolated from two patients, yielding a contamination rate of 8%. We interviewed 56 healthcare workers, including 16 (29%) doctors, 32 (58%) professional nurses and 8 (14%) phlebotomists. Many (41%) healthcare workers had no knowledge of available blood culture guidelines and few (11%, 6/56) reported ever being trained on the 2010 guidelines above. There was varied knowledge on recommended practices such as appropriate hand antisepsis, volume of sample required and the effects of antibiotic administration prior to specimen collection. A majority of the doctors 87% (n=14) reported being satisfied with blood culture results and most reported that the reason was that results provided pathogen and susceptibility profiles that allow for targeted treatment. This study demonstrated that blood culture collection guidelines were not consistently adhered to leading to poor blood culture uptake at this facility. We also found poor and inconsistent knowledge of blood culture guidelines among healthcare workers. Periodic training to improve awareness of blood culture guidelines and blood culture practices is recommended.

Introduction

Bloodstream infections (BSIs) affect a substantial number of individuals worldwide, and without timely diagnosis, represent a medical emergency with high mortality rates.[1] Delayed diagnosis or treatment of BSIs may result in severe complications such as sepsis and septic shock, where invasion of microorganisms such as bacteria and fungi of the blood cause dysregulated inflammatory immune response, at times leading to multiple organ failure and death. A number of studies demonstrate the public health burden and impact of BSIs, with a major impact in low-income countries.[2–5] In 2011, BSIs accounted for about 19% of all healthcare-associated infections (HAIs) in low- and middle-income countries. African studies have reported case fatalities between 24% and 53% of children with bacteraemia.[4,5] South African studies have reported that HAIs form the majority of BSIs, accounting for 10% in a study of children and 73% in one adult study.[6,7] Furthermore, the overall cost impact of HAIs include additional hospitalisation days, antimicrobial use and additional laboratory investigations.[6]

Blood cultures are a gold standard laboratory-based diagnostic tool used by clinicians to diagnose and treat BSIs.[1,8] They allow for targeted treatment by providing clinicians with the pathogen identity as well as antimicrobial susceptibility patterns, and have been associated with a reduction in inappropriate antibiotic therapy and an improved reduction in 30-day mortality.[9,10] Despite the benefits of blood cultures, there is a lack of knowledge among healthcare workers on appropriate blood culture collection practices, which influence the diagnostic value of the methodology.[1,8,11–14] Good practice guidelines aimed at assisting clinicians to use blood cultures appropriately, such as identifying eligible patients and using the correct aseptic procedures to reduce contamination, have been published. In South Africa, guidelines aimed at optimizing blood culture yield and reducing contamination rates were published by clinicians and microbiologists in 2010.[15] In addition, the National Health Laboratory Service (NHLS), which provides laboratory diagnostic services for all public-sector hospitals in South Africa, has made available a handbook detailing standard operating procedures for blood culture sample collection.[16] However, available data in South Africa suggest that blood cultures are not used optimally and therefore their benefits are unlikely to be realised.

Several studies done among adults and children have shown a lack of universal implementation, and inconsistencies in blood culture practices as specified in guidelines.[6–8,11,17] For example, a study at a district hospital in Cape Town reported that indicators for performing blood cultures were diverse and inconsistent among clinicians, with fever and sepsis being the most common. In another study, some clinicians reported that they did not regard the above-mentioned 2010 guidelines nor the NHLS handbook as explicit guidelines for blood culture collection. Many studies also show lack of implementation of guidelines as demonstrated by high blood culture contamination rates, often exceeding the 3% recommended by the American Society of Microbiology.[8,11,17–19] In addition to delaying appropriate therapy, contaminants in blood cultures result in inappropriate therapy, which may lead to complications and ultimately death. Contaminants also increase the cost of healthcare, and are associated with 20% increased cost in subsequent laboratory charges, and 39% increased cost related to intravenous antibiotics.[20]

Although various studies have shown inappropriate or lack of use of blood culture guidelines, there is limited data on blood culture utility, and healthcare workers' blood culture practices and knowledge in hospitals in Gauteng. The first objective of this study was to determine whether clinicians at a tertiary hospital in Johannesburg collected blood culture specimens among all eligible patients as stipulated in available guidelines. The second objective was to quantify the contamination rates of blood culture specimens for patients who had a blood culture done. The third objective was to assess the knowledge and practices of blood cultures among healthcare workers.

Methods

Study design and setting: A cross-sectional study was conducted over a seven-day period (14-20 June 2018) at a tertiary hospital in Johannesburg, South Africa. This facility was selected firstly because it is a referral hospital that provides a variety of medical services to patients with multiple and complex medical conditions that makes them susceptible to BSIs. Secondly, it is an academic hospital with an onsite microbiology laboratory where blood cultures are routinely performed. This facility also provides 24-hour emergency services. After assessment or stabilisation, patients presenting at the emergency department are discharged or transferred to one of 21 in-patient wards. The hospital provides medical services to an urban population of

approximately one million people. For the first objective of the study, we identified and enrolled all patients that were eligible for a blood culture according to the 2010 guidelines and the NHLS handbook. On a daily basis, the first fifty patients admitted through the casualty service were screened for clinical criteria that qualified them for a blood culture, and the proportion that eventually received a blood culture was determined. In order to determine blood culture contamination rates among patients with blood cultures done, blood culture data from the NHLS Central Data Warehouse (CDW) were obtained. We then recruited healthcare workers who were on duty on any day during the study period to participate in a knowledge, attitudes and blood culture practices survey.

Study definitions: All eligible adults aged 17 years and above were included in the study. Suspected BSI was defined according to the Guideline for the optimal use of blood cultures, published in 2010.[15] Briefly, suspected BSI was defined as a temperature >38°C, or tachycardia (abnormal heart rate) of more than 90 beats per minute (bpm), or tachypnoea (abnormally fast respiratory rate) of more than 20 bpm, or $PaCO_2$<4.3 kPa (32 mmHg), or bradycardia (abnormally slow heart rate) of slower than 50 bpm, or white cell count (WCC) of more than 12 000 cells/mm^3 or >4-11x10^9 cells/L. Sepsis was defined as any patient with a documented infection who had a sequential organ failure assessment score (SOFA) of two or more points according to the Third International Consensus Definitions for Sepsis and Septic Shock (Sepsis-3).[21] Laboratory-confirmed BSI was defined as a positive blood culture result with a known pathogen that was not a common skin contaminant.[22] Known or recognized pathogens were defined according to the Centers for Disease Control and Prevention (CDC) National Healthcare Safety Network (NHSN) organisms list.[22] According to the Centers for Disease Control and Prevention (CDC) National Healthcare Safety Network (NHSN) organisms list, contamination was defined as isolation of microorganisms commonly found on the skin and which contaminated specimens during specimen collection.[22] Patients who did not meet the suspected BSI/sepsis definition, those who could not be traced in the wards, and those with missing demographic, clinical and laboratory data necessary for case ascertainment, were excluded from the analysis.

Data collection: The emergency department admission books were used to identify patients and medical records were reviewed to identify suspected cases of BSI/sepsis. Minimal demographic and clinical data, including type of ward, gender, diagnosis, and signs and symptoms related to BSI/sepsis such as fever, white cell count, and tachycardia were collected using a standard data collection form. Medical records and the NHLS laboratory data were used to ascertain blood culture specimen collection. Microbiological laboratory results for all blood cultures done during the study period were accessed from the NHLS CDW. The onsite NHLS laboratory used an automated blood culture system, BACT/ALERT 3D (bioMerieux. Inc. Durham, USA), for culture of organisms, and identification and susceptibility testing was done using the Vitek2 automated system (bioMerieux). Data on knowledge, attitudes and practices (KAPs) of recommended blood specimen collection practices among healthcare workers was collected using a self-administered questionnaire. Sixteen questions were used to assess level of knowledge and practices. Included questions assessed knowledge of the 2010 guidelines or NHLS handbook, prior training, signs and symptoms necessitating a blood culture, number of specimen collection bottles required in a standard blood culture, volume of blood required, temperature at which blood cultures are incubated, the effect of prior antibiotics use on blood cultures, etc. Trained field workers distributed a questionnaire to healthcare workers, including doctors, registered nurses and phlebotomists who were on duty across the hospital during the study period.

Data management and analysis: Patient information was captured electronically onto Epi-Info 7 statistical software. Data quality checks were conducted to ensure all data were complete and accurate. Where possible, missing or incorrect data were sought or rectified using patient records or laboratory reports. Data were analysed using the statistical package STATA version 15.1 (StataCorp LP, College Station, Texas, USA). Summary measures including proportions and medians and corresponding interquartile ranges (IQRs) were reported. The chi squared or Fisher's exact tests were used to compare categorical variables of patients who received a blood culture to patients who did not.

Ethics: Ethical clearance to conduct the study was obtained from the Faculty of Health Sciences Research Ethics Committee of the University of Pretoria (58/2018). Permissions were also obtained from the Gauteng Department of Health and the hospital's research committee and heads of departments. Permission to use the NHLS data was obtained from the NHLS Academic Affairs and Research Department. All healthcare workers were informed about the purpose of the study and gave informed consent before participating. Confidentiality for patients was ensured by assigning a study-specific identity number to protect each patient's identity. Identifying information was not collected for healthcare workers. A unique identifier was assigned to each participant. All data were stored electronically on encrypted devices and were only accessible to study investigators.

Results

A total of 402 patients was admitted through the general casualty service (includes the medical, trauma, orthopaedic, and surgery departments) during the study period, and of the 350 consecutive patients selected, medical files for eligibility screening were available for 165 (47%) (Figure 1). Due to a two-day lag in identifying and enrolling patients, some of the selected patients could not be traced within the hospital wards and some files could not be recovered. Of the 165 patients screened, 110 (67%) met the definition of suspected BSI/sepsis and were enrolled into the study. Fifty-five patients (33%) were excluded because they did not meet the case definition or had missing data. Among the 110 patients with suspected BSI/sepsis, blood culture information could only be retrieved for 89 (81%), and 64 (72%) of these did not receive a blood culture.

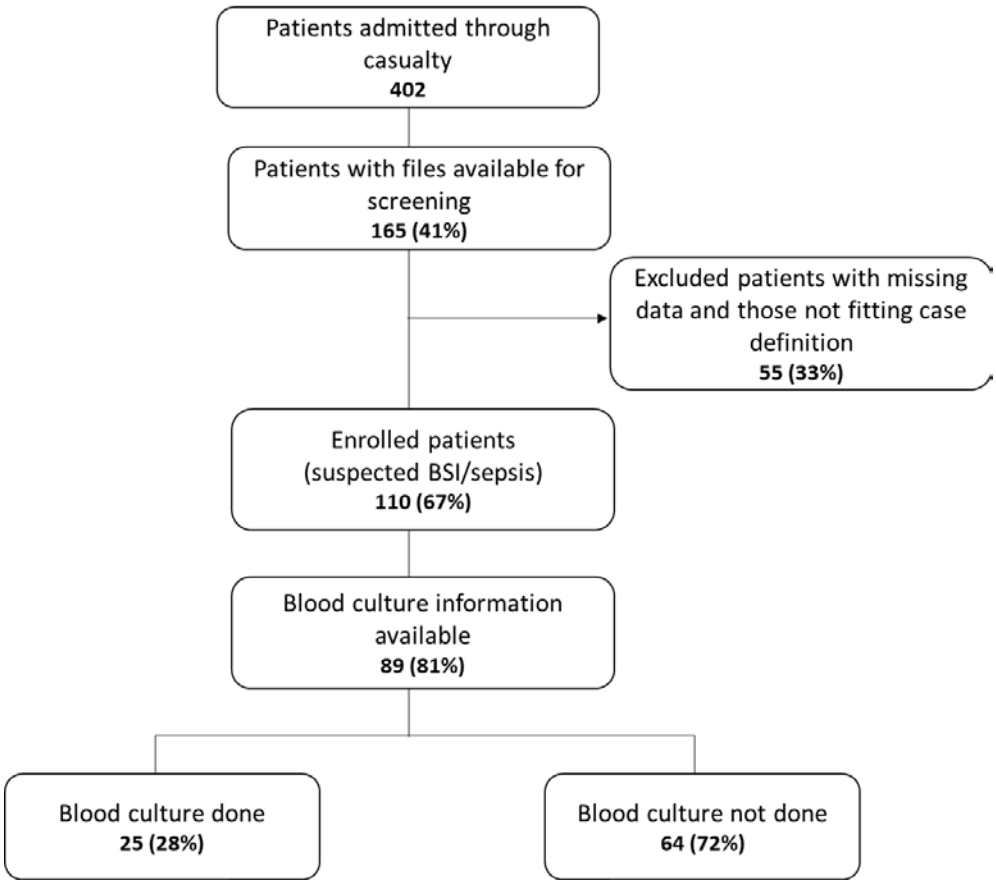

Figure 1. Study flow diagram. BSI = bloodstream infection

Enrolled patients were predominantly male (65/108 [60%]) and the median age was 44 years (IQR 34–61) (Table 1). The most common admission diagnoses (23% [25/106]) were pulmonary conditions such as pneumonia and respiratory failure. Trauma conditions such as vertebral fractures, gunshot wounds and motor-vehicle accidents accounted for 13% (14/106) of the diagnoses. Cardiac conditions such as hypertension and congestive cardiac failure, and infection-related conditions such as urinary tract infection and sepsis, each accounted for 10% (11/106) of the diagnoses. Skin and soft tissue infections accounted for 6% (6/106) of the conditions. Among patients with recorded HIV status, 26% (28/44) were HIV-seropositive. Most patients presented (58% [52/90]) with two or more symptoms related to BSI/sepsis. The median temperature was 36.5°C (IQR, 36°C–36.8°C) and three of the 71 patients with known information had fever (≥38°C). The median WCC was 8.88 x10^9 cells/L (IQR 6.81 – 13.49) and 42% (38/90) of patients had counts that were not within normal ranges. Most patients were transferred to medical units (64% [70/103]), followed by the surgical units (17% [14/103]), orthopaedic units (8% [9/103]) and intensive care units (2% [2/103]).

The proportion of male patients was not significantly higher among patients who had blood cultures done compared to those who did not (68% versus 51%, p=0.14). Compared to patients who did not receive a blood culture, those who had one done were more likely to be diagnosed with pulmonary conditions (36% versus 16.13%, p=0.03), infection related conditions (16% versus 5%, p=0.03), metabolic conditions (12% versus 8%, p=0.03), have abnormal white cell counts (57% versus 40%, p=0.18), and/or be HIV-seropositive (73% versus 53%, p=0.3). The proportion of patients presenting with two or more BSI/sepsis signs and symptoms was higher among those who received a blood culture compared to those who did not (70% versus 53%, p=0.14). Patients who did not receive a blood culture were more likely to have trauma conditions (23% versus 0%, p=0.03). The proportion of patients with fever (temperature ≥38°C) was higher among those who did not receive blood cultures (87% versus 100%, p=0.03). All patients in both groups with known information had tachycardia present. A higher proportion of patients who received blood cultures were given systemic antibiotics (100% versus 60%) and systemic antifungals (5% versus 2%) on admission. Sixty-five percent of patients with a blood culture received the broad-spectrum antibiotic amoxicillin-clavulanic acid (data not shown).

Table 1. Characteristics of patients with suspected blood stream infections (BSI)/sepsis (N=110) at a tertiary hospital in Johannesburg during the period 14-20 June 2018.

Characteristics	**All patients n=110**	**Blood culture done n=25**	**Blood culture not done n=64**	
	n (%)[b] or median (IQR)			**p value**
Age in years				
17-24	6 (5.50)	0 (0.0)	3 (4.7)	0.18
25-34	22 (20.2)	8 (32.0)	11 (17.2)	
35-44	28 (25.7)	9 (36.0)	13 (20.3)	
45-54	18 (16.5)	3 (12.0)	11 (17.2)	
55-64	15 (13.8)	1 (4.0)	12 (18.8)	
65+	20 (18.4)	4 (16.0)	14 (21.9)	
Sex				
Female	43 (39.8)	8 (32.0)	31 (49.2)	0.14
Male	65 (60.2)	17 (68.0)	32 (50.8)	
Ward type				
Medical unit	70 (68.0)	17 (70.8)	37 (59.7)	0.07
Surgical unit	19 (18.5)	3 (12.5)	16 (25.8)	
Orthopaedic unit	9 (8.7)	1 (4.2)	8 (12.9)	
Intensive care unit	3 (2.9)	2 (8.3)	0 (0.0)	
High care unit	2 (1.9)	1 (4.2)	1 (1.6)	

Admission diagnosis				
Pulmonary conditions	25 (23.4)	9 (36.0)	10 (16.1)	0.03
Trauma conditions	14 (13.1)	0 (0.0)	14 (22.6)	
Cardiac conditions	11 (10.3)	1 (4.0)	6 (9.7)	
Infectious diseases	11 (10.3)	4 (16.0)	3 (4.8)	
Metabolic conditions	9 (8.4)	3 (12.0)	5 (8.1)	
Skin and soft infections	6 (5.6)	2 (8.0)	4 (6.5)	
Neurological conditions	4 (3.7)	1 (4.0)	3 (4.8)	
Other conditions[a]	26 (24.3)	5 (20.0)	17 (27.4)	
HIV positive				
No	16 (36.4)	4 (26.7)	9 (47.4)	0.3
Yes	28 (63.6)	11 (73.3)	10 (52.6)	
Temperature (°C)	36.5 (36.0–36.8)	36.5 (36.0–37.0)	36.5 (36.1–36.7)	
Temperature ≥38°C	68 (95.8)	20 (87.0)	48 (100)	0.03
Temperature <38°C	3 (4.2)	3 (13.0)	0 (0.0)	
White cell count (10^9 cells/L)	8.9 (6.8–13.5)	8.4 (5.7–14.2)	9.1 (7.2–13.5)	
Within normal range	52 (57.8)	9 (42.9)	33 (60.0)	0.18
Above normal range	38 (42.2)	12 (57.1)	22 (40.0)	
Systolic blood pressure	126 (106–156)	126 (106–157)	125 (99–156)	
Tachycardia present	87 (100)	22 (100)	48 (100)	0.22
No tachycardia	0 (0.00)	0 (0.00)	0 (0.00)	
Respiratory rate	24 (22–28)	23 (21–29)	24 (22–26)	
Tachypnoea present	1 (3.0)	0 (0.0)	1 (5.0)	1.00
No Tachypnoea	32 (97.0)	6 (100)	19 (95.0)	
Number of BSI/sepsis				
One symptom	40 (43.5)	7 (30.4)	24 (47.1)	0.14
≥2 symptoms	52 (56.5)	16 (69.6)	27 (52.9)	
Antibiotics on admission				
No	25 (26.0)	0 (0.0)	22 (40.0)	0.001
Yes	71 (74.0)	22 (100.0)	33 (60.0)	
Antifungals on admission				
No	77 (96.3)	19 (95.0)	45 (97.8)	0.52
Yes	3 (3.7)	1 (5.0)	1 (2.1)	
Surgical treatment				
No	83 (80.6)	23 (95.8)	42 (70.0)	0.01
Yes	20 (19.4)	1 (4.2)	18 (30.0)	

IQR = interquartile range; [a]Other conditions include attempted suicide, systemic lupus erythematosus, etc. [b]Percentages may not sum to 100 due to rounding.

Among 25 patients for whom blood cultures were done, two (8% [2/25]) had laboratory-confirmed BSI due to *Escherichia coli* and *Proteus vulgaris*. Coagulase-negative *Staphylococcus* sp. (CNS) were isolated from two patients, yielding a contamination rate of 8%. No organism was isolated for 84% (21/25) of the patients who had blood cultures done. Both patients with a laboratory-confirmed BSI were above 60 years of age, had co-morbidities and had tachycardia as one of their enrolment criteria, and both received antimicrobial treatment on the day of

admission (data not shown). Overall, patients whose blood culture did not yield an organism had similar clinical characteristics (data not shown).

One hundred and seventy-four healthcare workers were approached and 56 consented to participate in the study, making the survey response rate 32%. The majority (77% [43/56]) of participants were females. Of the 56 healthcare workers, 29% (16) were doctors with a median age of 28 years (IQR, 25–31), 58% (32) were professional nurses with a median age of 36 years (IQR, 23–56), and 14% (8) were phlebotomists with a median age of 38 years (IQR,30–46]. The majority of the doctors (75%, n=12) worked in medical units and four (25%) worked in surgical units. Most nurses worked in the emergency department (31%), followed by surgical units (19%, n=6), high care units (19%, n=6), medical units (16%, n=5) and the orthopaedic unit (16%, n=5). When asked about knowledge of any currently available blood culture standard operating procedures (SOPs), 8 (100%) phlebotomists, 7 (44%) doctors and 3 (32%) nurses reported knowing about an SOP (p=0.04) (Table 3). Most doctors (19%, n=16), nurses (6%, n=2) and phlebotomists (13%, n=1) had not received training on blood culture practices according to the 2010 South African guidelines. All doctors reported that they sometimes make diagnoses that require a blood culture and 81% (n=13) reported taking a blood culture specimen each time it was required. Regarding procedures for specimen collection, 56% (n=9) of the doctors, 85% (n=23) of the nurses and 75% (n=6) of the phlebotomists reported using an appropriate antiseptic to prepare a venepuncture site (p=0.3). Most phlebotomists (75%, n=6) knew the minimum amount of blood required for a blood culture among adults compared to doctors (69%, n=11) and nurses (52%, n=14) (p=0.08). All phlebotomists, 88% (n=14) of the doctors and 50% (n=16) of the nurses knew that antibiotic use prior to specimen collection affects blood culture organism detection (p=0.04). A majority of the doctors (88%, n=14) reported taking a blood culture specimen if the patient was on antibiotics and specimen collection is still indicated. When asked if satisfied with the blood culture results, 87% (n=14) of the doctors and 53% (n=17) of the nurses reported being satisfied. Doctors' reasons (n=11) for satisfaction were that blood culture results provide pathogen and susceptibility profiles that allow for targeted treatment. One doctor (6%) reported not being satisfied with the results due to the high frequency of skin commensals isolation.

Discussion

This study shows that more than two-thirds of patients eligible for a blood culture did not have one done. Compared to the recommended standard, a higher blood culture contamination rate was found. This study however had a very small sample size. This study also found that familiarity with blood culture guidelines and blood culture procedure standards was low among healthcare workers, with phlebotomists generally having a greater awareness than doctors and nurses.

Diagnoses of BSI/sepsis is an important step in the treatment of patients and, consequently, reduction of community- and healthcare-associated infections through surveillance and antimicrobial stewardship. There are, however, limited studies that explore the extent to which healthcare workers use this diagnostic tool. This study found that an overwhelming majority of patients who qualified for blood culture according to available guidelines did not receive one. Among similar studies done in Canada and Denmark, variation in the use of blood cultures has been reported, with some studies showing high usage and some showing usage as low as 11%.[23,24] There is paucity of data regarding blood culture utilisation in our setting. Nonetheless, our study shows that in this Gauteng Province hospital, blood culture specimen collection practices were not in line with available guidelines. Whether this is a reflection of other hospitals in Gauteng Province or the whole of South Africa remains unclear. It is therefore recommended that hospitals assess blood culture utilisation in their own settings as this may improve diagnosis and treatment of BSI/sepsis.[25]

Blood culture guidelines and protocols have been developed so that healthcare workers have a guide on the most likely patients to have BSI/sepsis. The majority of patients with a blood culture investigation in our study had a pulmonary disease as an admission diagnosis, indicating that there may be a high index of suspicion of community-acquired pneumonia among casualty department clinicians. Inclusion of blood culture specimen collection recommendations in the current pneumonia management guidelines might have increased specimen collection among this group of patients.[26] No single symptom was strongly associated with blood culture specimen collection in our study. Instead, patients presenting with two or more BSI/sepsis symptoms were most likely to receive a blood culture. Although we did not ascertain this, clinicians in this study were likely to collect blood culture specimens when patients presented

with a combination of symptoms instead of one, likely due to prior experience with low yield of blood cultures among patients with only one symptom.[27,28]

Despite low blood culture specimen collection in this hospital, the yield of blood cultures was marginally below the generally reported rate of 10%, and similar to the 7.8% reported by a South African study conducted in the same setting.[25,28] There are several factors that affect blood culture yield, including blood volume and antibiotic use prior to specimen collection.[29,30] All patients in our study who received a blood culture were also treated with antibiotics, which may explain the low blood culture yield in this study. However, time stamps of blood culture collection and antibiotic administration were not available. We could therefore not ascertain whether specimens were collected prior to or post-antibiotic administration. Of note, two-thirds of patients who did not get a blood culture were given antibiotics on the day of admission. This is concerning as antimicrobial stewardship programs recommend that empirical treatment be given after taking specimens for microbial cultures and selecting the most appropriate narrow-spectrum antimicrobials based on invading pathogen and susceptibility testing. Antibiotic stewardship through dedicated programmes and infection control practice should be strengthened in this hospital in order to improve practices.[31]

According to The American Society of Microbiology, the proportion of contaminants in blood cultures should not exceed 3%.[19] Similar to what we found in this study, high rates of contamination have been reported in other South African studies.[6–8,11,17] One study conducted at peripheral hospitals reported decreased blood culture contamination rates, from 7-9% in 2006-2007 to 4.6% in 2010; however, the current rate was still higher than that recommended.[18] Taken together, these results suggests that blood culture procedures in South African hospitals are not optimally performed, necessitating widespread awareness and training on currently available guidelines. Such interventions have been shown to be effective at bringing about changes in blood culture practice and decreasing contamination rates.[32,33] Feedback on blood culture practice errors, contamination rates, adverse effects on patient outcomes and costs incurred because of guidelines and standard practice deviation, should be communicated to healthcare workers.

Best blood culture practices require a thorough understanding and knowledge of recommended guidelines such as appropriate indications for ordering and drawing of specimens, recommended drawing site, appropriate application of skin antiseptics and the blood collection process.[12,13,34,35] In this study, knowledge and practice of blood cultures among healthcare workers was unsatisfactory and suboptimal, although phlebotomists generally demonstrated better knowledge compared to other healthcare workers. Overall, these findings were similar to studies that reported a gap in knowledge, attitudes and practices among nursing staff, phlebotomists, patient care assistants and laboratory technicians.[12,34] One of the reasons for these findings is likely that a low proportion of healthcare workers surveyed were familiar with or had ever received training on available guidelines. Interestingly, nearly 90% of all doctors reported collecting blood culture specimens each time when indicated. This was contrary to a Nigerian study that reported that only 39.8% of doctors request a blood culture when indicated.[12] In addition, the high number of doctors in this study reporting specimen-taking did not match the low rates of blood cultures done among the study patients, indicating that blood culture practices among healthcare workers might be inappropriate. Furthermore, we found that a quarter of all healthcare workers did not know the minimum blood volume required for a blood culture among adults, and nearly 40% of doctors did not identify the correct hand antiseptic solution for use when collecting blood culture specimens. These findings indicate that some healthcare workers may not follow the recommended antiseptic techniques required, nor the volume of specimen needed, resulting in low yields of blood cultures and high rates of contamination.[33,34]

This study had several limitations, which limits interpretation and generalisation to other South African public-sector hospitals. Low utilisation of blood cultures was ascertained using information on the first day of admission, which means we might have missed additional blood cultures that were taken on subsequent hospital days as the conditions of the patients progressed. Only 47% of selected patients were screened for enrollment in the study and some of the medical records of enrolled patients had missing information, further limiting identification of patients with suspected BSI/sepsis who had a blood culture done, and resulting in data sparsity for statistical analysis. Furthermore, the short duration of our study likely did not account for periodic changes such as the type of diseases most prevalent during specific seasons, which may affect clinicians' decisions to do a blood culture. Additionally, variation in

blood culture practices may differ between sessional staff rotating in the emergency department. Although efforts were made to include as many healthcare workers in this survey as possible, the response rate was low, and therefore the findings of this survey may not be representative of the entire hospital. Lastly, blood cultures were collected by doctors working in the emergency department, none of whom participated in our survey, making it difficult to directly correlate survey findings to blood culture practices. Although this study was conducted at only one hospital, findings were in line with other studies done in South Africa. We therefore believe that these findings give an indication of knowledge and awareness among healthcare workers on blood culture guidelines, and the extent at which blood cultures are utilised at emergency departments of tertiary public-sector hospitals.

Conclusion

Low knowledge and adherence to blood culture guidelines among healthcare workers was evident from this study, with the exception of phlebotomists. Periodic training on blood culture guidelines is therefore recommended. Development of a blood culture task team and feedback system on blood culture practices and contamination rate could improve guideline adherence among all healthcare workers.[36,37]

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