International Journal of Medical Toxicology & Legal Medicine Volume 27, No. 2S, 2024
e-ISSN: 0974-4614
p-ISSN: 0972-0448

Assess of Quality of Blood Culture Testing - A Survey in Intensive Care Units and Microbiological Laboratories

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Received: 10.08.2024 Revised: 12.09.2024 Accepted: 21.10.2024

ABSTRACT

Background: Blood culture (BC) testing before starting antimicrobial therapy is an internationally recommended practice for sepsis management, essential for reducing ICU stays and a core component of antibiotic stewardship programs. However, BC testing faces limitations, including low pathogen detection rates and challenges in standardizing preanalytic procedures, which impact diagnostic accuracy and vary across healthcare systems.

Methods: This study conducted a qualitative survey across 138 interviews with ICU and microbiological laboratory (LAB) staff . The survey assessed current BC testing practices, including sepsis awareness, preanalytic procedures, sampling techniques, and result communication. Interviews were conducted via telephone by an independent agency, with data collected from ICU and LAB directors, residents, nurses, and managersthorough four hospital.

Results: Sepsis awareness was consistently high across countries, but BC testing practices varied significantly. In first hospital BC collection and transport were more streamlined, with LABs frequently open on weekends and ICU physicians responsible for sampling and antibiotic decisions. In contrast, another hospital reported notable preanalytic deficiencies, including delayed BC transport, insufficient blood volumes, and limited clinician responsiveness. The other two hospitals showed distinct procedural differences, with issues such as financial constraints impacting BC quality . Variability in blood volumes, transport times, and sample handling affected BC positivity rates and pathogen detection across the four countries.

Conclusion: This study reveals significant disparities in BC testing practices across different hospitals ICUs and microbiological laboratories. Improving BC test accuracy will require addressing preanalytic limitations through standardized protocols, optimized sampling procedures, and better communication between ICU and LAB staff. Enhanced awareness and training on preanalytic protocols may improve diagnostic yield and support more effective sepsis management.

Keywords: protocols, optimized, Variability, techniques

INTRODUCTION

Blood culture (BC) testing before the administration of antimicrobial therapy is considered a standard practice in international sepsis guidelines [1] and has been shown to shorten ICU stays [2-4]. Additionally, BC testing is a cornerstone of antibiotic stewardship programs, which help reduce unnecessary antibiotic use and lower healthcare costs for hospitalized patients [5,6].

Despite the benefits of BC testing, there are limitations, such as prior antibiotic or antifungal treatment, low pathogen detection rates in blood samples, and the presence of fastidious or non-cultivable organisms [7-9]. However, a high degree of standardization in laboratory (LAB) procedures ensures a blood culture positivity rate of about 30-40% in cases of severe sepsis or septic shock [10]. A recent large multicenter study from 3rd hospital[11] found that 33% of patients with severe sepsis or septic shock had confirmed bacteremia, while only 9.6% of patients in routine ICU practice had positive blood cultures outside of protocolized care [12]. This difference highlights deficiencies in preanalytic procedures, including improper skin antisepsis, sampling errors, access through intravenous catheters, insufficient blood volume, too few BC sets being drawn, and delays in incubation, all of which negatively impact diagnostic accuracy [13-15].

The number of BC sets processed per hospitalized patient is crucial. For hospitals with different case mixes, it is recommended that 100 to 200 BC sets be inoculated per 1,000 patient days [16,17]. However, this target is not

commonly met, especially in Germany, where a 2009 survey of 201 ICUs found only 55 BCs per 1,000 patient days, compared to 165 BCs in 2nd hospital [18]. The 2010 European Antimicrobial Resistance Surveillance Network (EARS-Net) annual report showed an even lower figure of 12.1 BCs per 1,000 patient days in 37 German hospitals, compared to 46.5 in 2nd hospital, 46.1 in the UK, and 70.7 in 4th hospital [19]. A study by the National Reference Centre for Hospital Infections (NRZ), using data from the German nosocomial infection surveillance system (KISS) from 2006, examined the correlation between BC frequency and rates of central venous catheter-associated bloodstream infections (CVC-BSI) in 223 ICUs [20]. The median number of BC sets taken was 60, but it ranged from 3.2 to 680 per 1,000 patient days. The study concluded that benchmarking CVC-BSI rates should be adjusted based on BC frequency.

Factors contributing to the underuse of BC testing include infrastructure limitations, as the detection of infections depends heavily on the proximity of LABs [12]. This suggests a need for standardized protocols and improved technical procedures in the preanalytic phase of BC testing. Additionally, the quality of BC testing may vary across countries due to differences in how clinical microbiology and infectious disease departments are structured, particularly in Germany, where clinical microbiology is often considered a subdiscipline of laboratory medicine [21].

This qualitative survey was designed to evaluate current practices in BC testing in ICUs and LABs across four hospitals, focusing on technical aspects of the preanalytic process and assessing the quality of these practices based on the perceptions of ICU and LAB staff and directors.

MATERIALS AND METHODS

138 interviews were conducted across 79 microbiological laboratories (LABs) and 59 intensive care units (ICUs) in four hospitals. Pediatric and neonatal ICUs were excluded from the survey. The interviewees included ICU directors, ICU residents, ICU nurses, LAB directors, and LAB managers. The survey was carried out by an international agency, AdventionBP ,on behalf of BD Diagnostics .To ensure a representative sample, the interview panel was selected to meet specific quotas, with 10 to 20 ICUs and microbiological laboratories per hospital. Additionally, the panel was balanced between customers of BD Diagnostics (49.5%) and bioMérieux (50.5%). Data were gathered using semi-structured methods, including in-depth personal telephone interviews. The interview guide covered a range of topics, such as sepsis awareness, indications for BC testing, preanalytic procedures, sample transport and preincubation, BC processing, and communication of results . The response rate was 100% due to the personal nature of the interviews, which tend to yield higher response rates compared to questionnaires [22]. Ethical approval was not required for the survey, according to the ethics committee

Table 1. Interviewees participating in the survey

Interviewees (n)	**Hospital 1**	**Hospital 2**	**Hospital 3**	**Hospital 4**	**Total**
Total (n)	39	32	30	37	138
ICUs (n)	16	13	17	13	59
LABs (n)	23	19	13	24	79
Type of structure (%):					
Private	10	37	0	0	12
Public	90	63	100	100	88
ICUs					
Private	0	23	0	0	5
Public	100	77	100	100	95
LABs					
Private	17	47	0	0	16
Public	83	53	100	100	84
Interviewee position (n):					
ICUs					
Head of ICU	3	6	0	0	9
Physician	7	7	12	12	38
Nurse	6	0	5	1	12
LABs					
LAB director	8	17	5	5	35
LAB manager	5	0	3	15	23
Microbiologist	10	2	5	4	21

LAB = microbiological laboratory.

RESULTS

Sepsis Awareness

In all countries surveyed, both Intensive Care Units (ICUs) and microbiological laboratories (LABs) prioritize sepsis and its timely diagnosis. Sepsis awareness is increasingly recognized as critical, with 46% of interviewees in the 1st hospital, 43% in 2nd hospital, and 30% in 3rd hospital emphasizing its importance due to its high incidence, mortality rate, and the crucial role early diagnosis plays in recovery. Medical staff across these nations reported heightened efforts to improve sepsis detection and treatment, with educational programs focused on infection control being implemented. In the 1st, critical care outreach teams have been set up to increase sepsis awareness among hospital staff.

Indication for Blood Culture (BC) Testing

All participants affirmed that BCs are collected and broad-spectrum antibiotics administered when sepsis is clinically suspected. Common criteria used to assess sepsis include fever or hypothermia, tachycardia, tachypnea, and abnormal white blood cell counts. The presence of any one suspicious sign, especially fever, typically triggers the collection of BCs. When multiple signs are present, further diagnostic workups, including additional standard cultures (urine, tracheal specimens, wound swabs, etc.), are regularly performed.

Preanalytic Procedures

Number of BCs Collected

ICUs generally collect between two and three sets of BCs per patient, with country-specific variations. In contrast, wards collect fewer BC sets, ranging from 1.3 in 3rdhospitalto 1.8 in 2nd hospital per patient. Only a small proportion of ICUs collect fewer than two BC sets. ICUs contribute significantly to the BC sets processed in LABs, accounting for between 15% (1st hospital) and 33% (2nd hospital) of the total.

Launch of BCs

Considerable variations exist between countries regarding the collection, transportation to the lab, and feedback procedures for BC results. While physicians typically decide when to order BCs, in the 1st hospital, they are generally responsible for blood sampling, while in 2nd hospital and 4th hospital, nurses perform this task. In 3rd hospital, both physicians and nurses collect samples.

Sampling Techniques

Blood collection methods vary across countries. In 3rd hospital and 4th hospital, fresh peripheral venipuncture is preferred, while in 2nd and 3rd hospital and the 1st hospital, blood is more often collected via an intravenous catheter. Both traditional (syringe and needle) and closed systems (winged sets, vacuum systems) are used, with closed systems predominating in 3rd hospital (71%). 2nd hospital has the highest use of syringes and needles (42%).

Blood Volumes Collected

The blood volume collected per bottle varies by country, from 8.3 ml in 2nd hospital to 11.5 ml in 4th hospital . Most ICUs collect between 8 and 12 ml per bottle, as recommended by the LABs. A significant majority (86%) of ICUs recognize that pathogen detection is directly related to the amount of blood taken.

Sample Transport and Preincubation

The time it takes for a BC to reach incubation depends on transportation time, LAB hours of operation, and BC management outside regular hours. Time-to-incubation can vary, ranging from 2 hours in the 1ST HOSPITAL to up to 20 hours in remote, non-resident LABs in Germany. Different countries have distinct methods for transporting BCs. In Germany, transportation is mainly done by vans, while in 4th hospital and the 1ST HOSPITAL , personnel handle transportation within the hospital. Pneumatic tube systems are used in about one-third of hospitals in 2nd hospital, Germany, and the 1ST HOSPITAL , but are not available in 4th hospital .

LABs generally close overnight across all countries, with about 40% offering weekend services, except in the 1ST HOSPITAL , where 62% remain open on weekends. Many LABs offer on-call services for emergencies, though this is rarely available for BC testing. In Germany, some ICUs have implemented local BC incubators to reduce incubation time, a measure supported by 88% of German and 86% of Italian ICUs. However, interest is lower in the 1ST HOSPITAL (0% in ICUs, 21% in LABs) and 2nd hospital (17% in ICUs, 22% in LABs).

BC Processing, Reporting, and Communication Strategies

On average, LABs process 50 BC sets daily, with 3rd hospitalprocessing the most (58) and the 1ST HOSPITAL the fewest (35), with a positivity rate of 12–13%. Not all positive cultures undergo identification and antibiotic susceptibility testing (ID/AST); this is done in only 9% of positive samples in 2nd hospital, 13% in 3rd hospital and 4th hospital , and 12% in the 1ST HOSPITAL . Positive culture results are usually communicated

by phone, but ID/AST results are only reported to physicians in the 1ST HOSPITAL ,2nd hospital , and 4th hospital . Negative results are typically reported in writing at the conclusion of the analysis.

The quality of interaction between LABs and ICUs is rated highly in most countries, except in Germany, where microbiologists report poor clinician responsiveness when discussing positive BC results, leading to delayed or incomplete communication. There are notable differences in how ICU physicians and LAB staff perceive BC testing challenges. While 42% of ICU physicians report no issues, 29% of LAB physicians identify several significant limitations, especially in Germany.

LABs highlight issues such as insufficient BC sets and blood volumes, the high rate of false positives due to improper skin antiseptics and intravenous catheter collection, and the financial pressures limiting the quantity and quality of BCs. The pressure to reduce costs is particularly noted in 4th hospital , where 41% of ICUs and 54% of LABs identify it as a limitation.

Delays in transporting BCs from ICUs to LABs are a significant issue, especially in 3rd hospitaland 4th hospital . 3rd hospitaland 2nd hospital also face high rates of insufficient BC sets and low blood volumes, contributing to false positives. In contrast, in the 1ST HOSPITAL , LABs play a prominent role in initiating antibiotic treatment, while in 2nd hospital and Germany, ICU physicians are more responsible for choosing antibiotics.

Table 2. Collection, transport and processing of BCs in four hospitals

Collection, Transport, and Processing of BCs in Four hospitals	**2nd hospital**	**3rd hospital**	**4th hospital**	**1ST HOSPITAL**
Sample Transport				
Time to Incubation (h)				
On-site LABs	3	2	4	2
Remote LABs	-	-	20	-
Cultures Incubated with a Delay of >8 h (%)				
On-site LABs	9	10	9	6
Remote LABs	-	>60	-	-
Modes of Transportation (%)				
Van	36	71	23	15
Porter	32	0	77	50
Pneumatic Tube	32	29	0	35
LAB Opening Hours (%)				
8 h 5 days per week	41	40	31	19
8 h 7 days per week	41	40	46	62
24 h 7 days per week	18	20	23	19
BC Management Outside LAB Opening Hours (%):				
Storage at room temperature (up to 12 h delay)	73	86	67	27
Access to BC system in the LAB (1 h delay)	27	0	33	73
Access to BC system in the ICU (no delay)	0	14	0	0
Interest in Relocation of BC Systems into ICU (%):				
LABs	22	47	33	21
ICUs	17	88	86	0
Decision to Launch BC (%):				
Physician	75	92	88	92
Nurse	25	8	12	8
Responsible for BC Collection (%):				
Physician	0	54	6	77
Nurse	100	46	94	23
Mode of BC Collection (%):				
Intravenous Catheter Only	33	8	0	23
Peripheral Venipuncture Only	20	42	76	23
Both	47	50	24	54

BC, blood culture; LAB, microbiological laboratory.

Table 3. Major challenges regarding BC testing in sepsis routine identified in 79 ICUs and 59 LABs across four hospitals

Major Challenges Regarding BC Testing in Sepsis Routine Identified in 79 ICUs and 59 LABs Across Four hospitals	**2nd hospital**	**3rd hospital**	**4th hospital**	**1ST HOSPITAL**
ICUs				
No challenges	50	62	18	38

Time constraints	19	15	41	8
Cost pressure	0	15	41	15
Insufficient training of personnel	0	0	18	31
Excessive time to transport	0	8	12	0
Poor communication with LAB	13	0	6	0
Other	25	0	6	8
LABs				
No challenges	19	31	18	46
Excessive time to transport	4	37	23	0
Insufficient incoming sample volumes/number of BC sets	43	42	0	21
Cost pressure	9	16	54	29
Mislabeling of BC bottles	13	0	23	4
Many false negatives	9	21	8	17
Many false positives due to				
Inappropriate taking of blood samples	61	53	0	38
Delayed transport to the LAB	9	0	8	0
Low reactivity of clinicians	0	11	0	4

BC = Blood Culture; LAB = Microbiological Laboratory.

DISCUSSION

Blood culture (BC) testing remains the definitive method for diagnosing sepsis in patients (24). Despite efforts in Europe to align with the US Clinical and Laboratory Standards Institute (CLSI) guidelines (17), our survey revealed varying perceptions regarding the execution of BC testing across four hospitals

The S2k guidelines of the German Sepsis Society (GSS) (25), 4th hospital 's Progetto LaSER (26), and the 1ST HOSPITAL 's Saving Lives (NHS) guidelines (27), along with the recent Surviving Sepsis Campaign (SSC) guidelines (1), all recommend taking at least two sets of BCs when sepsis is suspected. However, the French National Society of Anaesthesia and Intensive Care (SFAR) does not provide specific recommendations for BC testing.

Several challenges in BC testing were identified, including low rates of true positive results due to prior antibiotic treatment, insufficient blood volumes, inadequate numbers of BC bottles, and delays in incubation times.

In a French monocentric study, Vitrat-Hincky et al. found that only 45% of patients had an adequate number of BC sets, and only 13% had optimal sample volumes (≥10 ml per bottle) (28). Similarly, a Belgian study found that over one-third of BC bottles were improperly filled, regardless of the vial manufacturer (29).

Our survey revealed significant differences in the blood volumes collected for BC, with an average of less than 10 ml per bottle (8.3 ml in 2nd hospital, and 11.5 ml in 4th hospital as the exception). However, ICU staff were generally aware that BC positivity rates increase with larger blood volumes.

The variations in BC practices, including the number of sets and sample volumes, may stem from differing responsibilities among ICU staff. For instance, in the 1ST HOSPITAL , physicians primarily handle BC sampling, while in 2nd hospital and 4th hospital , nurses are more often responsible, and in Germany, both physicians and nurses are involved.

Regarding incubation times, the survey revealed a wide range: incubation occurred within 2 hours in the 1ST HOSPITAL , while it took up to 20 hours in remote laboratories in Germany. Kerremans et al. reported similar issues in the Netherlands, with 47% of cultures exceeding the recommended 4-hour transport window, especially on weekends or in hospitals located far from laboratories (30).

Delays in transport and storage before incubation were prominent in our survey, largely due to different transport methods (e.g., van, porter, or pneumatic tube) and varying infrastructure. In most cases, BCs were transported within 4 hours, but in Germany, blood was sometimes stored at room temperature for up to 12 hours before incubation, resulting in a total incubation delay of up to 20 hours. Some German ICUs have installed on-site BC incubation devices, which have been shown to improve turnaround times and antibiotic prescription practices (31).

Obtaining positive BC results is critical for patient management. Just as rapid pathological consultation during surgery ensures quick decision-making, BC results must be prioritized as urgent. Prompt notification of positive BC results to the appropriate clinical professional is essential for coordinating the next steps in patient care.

Since many patients are initially seen in the emergency department, it is the responsibility of the laboratory to track the patient's location once a BC becomes positive. According to our survey, most laboratories transmit preliminary results, such as Gram-staining findings, by phone to allow clinicians to adjust initial antibiotic treatments. Final results, including organism identification and susceptibility testing, are usually sent via fax or written report due to the complexity and cost of the information. Oral or face-to-face communication is used in

most countries, except in Germany. Enhancing the communication of BC results has been shown to reduce antibiotic use, particularly in neonatal ICUs (32). While telephone communication may involve minor errors, research by Howe et al. found only slight inaccuracies in transmission (33).

This study has several limitations. First, the discrepancies from the guidelines may reflect a broader issue in ICU practice, where adherence to recommendations is often overestimated by ICU directors (34). The survey was qualitative, using semi-structured interviews and open-ended questions, with respondents not being randomly selected. Thus, the findings may not fully represent current practices. We also lacked quantitative data on contamination rates, blood volumes, and post-collection procedures. Since our study was exploratory, we did not conduct a statistical analysis, and our results cannot be generalized. Nonetheless, the insights from this study offer valuable ideas for future quantitative research. Lastly, we did not assess ICU staff's knowledge and attitudes regarding the interpretation of BC results and their therapeutic implications. Following guideline-based practices for BC collection, processing, and reporting is essential for successful patient outcomes (35).

CONCLUSIONS

Effective, evidence-based blood culture (BC) testing is crucial for ICU patients suspected of sepsis. Identifying the causative agent (bacteria or fungi) and determining its susceptibility to antimicrobials allows clinicians to initiate the appropriate treatment and inform further diagnostic steps. While microbiological laboratory procedures are well standardized, deficiencies in preanalytic practices in the ICU—such as indications for testing, timing, blood volume, the number of sets, and collection techniques—can significantly impact diagnostic accuracy. To address this, strategies involving all ICU staff are necessary to bridge the gap between recommended best practices and national guidelines. Additionally, establishing the frequency of BC testing per 1,000 patient days should be considered a key quality indicator for ICU performance.

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