

# Blood culture practices and microbiological capacity for sepsis diagnostics in Europe (2021–2022): a cross-sectional analysis of the European Sepsis Care Survey



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## Summary

**Background** Blood cultures (BCs) are key diagnostic elements for sepsis patients. Accurate preanalytical procedures are substantial, and results should be available as soon as possible to guide adequate antimicrobial treatment. This study aimed to evaluate BC collection practices and diagnostic capacity across European hospitals.

**Methods** This cross-sectional survey investigated BC diagnostics in acute care hospitals across 37 European countries in the years 2021 and 2022. Analyses included BC guidelines, collection sites, number of BC sets in emergency departments (EDs), wards, and intensive care units (ICUs). We also examined transfer after collection, the use of on-site vs. external laboratories, opening hours, rapid testing capacity, and turn-around times of BCs processed in microbiology laboratories with different infrastructures.

**Findings** Responses were collected from 907 hospitals in Europe. BC guidelines were available in 84.4% (741/878) of the hospitals. BCs were preferably collected by multiple-site sampling in EDs (62.7%, 461/735), in wards (64.0%, 513/802) and ICUs (68.5%, 518/756). One BC set was preferred in EDs in 38.4% (270/704), in wards in 40.5% (314/775), and ICUs in 34.9% (261/748). Two BC sets were preferred in EDs in 31.0% (218/704), in wards in 28.1% (218/775), and ICUs in 39.2% (293/748). 48.0% (402/838) of hospitals used on-site and 52.0% (436/838) external microbiology laboratories. Around-the-clock microbiological services were available in 10.0% (91/907), and rapid pathogen identification in 43.7% (396/907) of hospitals. Infrastructure with around-the-clock microbiological service and rapid testing was available in 7.4% (62/840) of hospitals, and probability of a final microbiological result within two days was highest in these hospitals compared to hospitals with limited microbiology service (for BC collected on wards: 19.6% vs. 52.7%, Odds Ratio 4.59 [95% CI 2.50–7.79],  $p < 0.0001$ ).

**Interpretation** Despite the availability of BC guidelines in many hospitals, current recommendations for BC collection were often neglected. Rapid testing capacity was limited in most microbiological laboratories, and around-the-clock service for BCs was very rare. As delay in results may have a detrimental impact on patient outcomes, strategies to improve these processes are urgently needed.

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**Keywords:** Sepsis; Blood cultures; Diagnostics; Infrastructure; Turn-around time; Opening hours; Rapid testing; Single-site sampling; Multiple-site sampling; Number of blood cultures sets; Clinical practice; Pre-analytical practice; Blood culture analysis

## Research in context

### Evidence before this study

Blood culture collection is a key element in sepsis diagnostics, as it supports the identification of the pathogen causing the infection. Appropriate preanalytical practices and rapid processing of blood cultures are essential to provide clinicians with valid microbiological results as promptly as possible. We conducted a PubMed search for studies published between January 2000, and September 2025 that reported on preanalytical practices of blood culture collection in patients with sepsis and/or on the infrastructure and capacity of microbiological laboratories processing blood cultures. We used the search terms “(“blood culture”) AND (“practice” OR “infrastructure” OR “capacity” OR “microbiological diagnostics”), and limited the search to multi-centre studies describing practices and infrastructure at the level of countries. Up to now, there was one study in 2013 that investigated 79 microbiological laboratories and 59 ICUs across four European countries. This study revealed considerable differences in the quality of blood culture testing. In particular, time to incubation was a considerable problem, largely due to the increasing number of remote laboratories. A 2017 study from Germany involving 706 medical doctors and final-year medical students suggests that there are substantial deficits in blood culture ordering and in the application of guidelines for blood culture practice. The largest study, published in 2019, collected data from 209 laboratories across 25 European countries on microbiological diagnostics of bloodstream infections at the laboratory level. This study demonstrated that laboratories have begun to use novel methods for rapid identification and antimicrobial susceptibility testing. However, this improvement was hampered by limited operating hours, meaning that current practices of blood culture diagnostics in Europe only partially meet the requirements for optimal management of bloodstream infections. A 2022 study from Nordic countries investigated blood culture diagnostics in 49 clinical microbiology laboratories in Denmark, Finland, Iceland, Norway and Sweden. The study reported limited opening hours and restricted availability of clinical microbiologists. Overall, there is little comparative information on the practice of blood culture diagnostics in

Europe, taking into account the clinical aspects, the processes and the available laboratory infrastructure.

### Added value of this study

Compared to previous studies, we extended the analyses to include both blood culture processing in microbiology laboratories and preanalytical practices of blood culture collection in hospitals, differentiating between emergency departments, wards, and intensive care units. We increased the number of countries studied and included a substantial sample of European hospitals of all sizes and types. This study provided a comprehensive analysis of blood culture diagnostics including preanalytical aspects, transportation, as well as infrastructure of microbiology diagnostics and its availability. The differences in laboratory infrastructure observed were contextualized with the reported turn-around times of blood cultures. This approach allowed us to demonstrate the impact of microbiology laboratories providing 24/7 service and using rapid testing on turn-around times, in contrast to laboratories with limited capacity.

### Implications of all the available evidence

In this study, involving a large sample of European hospitals of all categories, preanalytical practices of blood culture collection were often not in accordance with current recommendations. Particularly the recommended number of blood culture sets was frequently not followed. Shipping to laboratories was often delayed, and most laboratories had limited opening hours. The results of our study, along with previous research on these aspects, provide convincing evidence that there is substantial room for improvement at preanalytical stages of blood culture diagnostics. Additionally, there is potential for enhancing the capacity of microbiology laboratories, including extending opening hours and implementing rapid testing. These findings are important because delays in time to result may have a detrimental impact on patient outcomes. Urgent measures at national and international levels are needed to ensure timely and effective care for patients with sepsis.

## Introduction

Blood cultures (BC) are the gold standard for detecting bloodstream infections, especially in patients with sepsis. They are important for identifying the causative pathogens and support the correct choice of antimicrobials.<sup>1</sup> Although broad-spectrum antibiotics are in most cases part of the initial treatment of sepsis, in a substantial number of cases, antibiotic prescriptions have gaps in coverage or encounter pathogens resistant to the administered agents, resulting in inadequate treatment.<sup>2,3</sup> The BC findings inform management,

guide clinicians to tailor antimicrobial therapy for optimal efficacy, and allow de-escalation of antimicrobials to minimize collateral damage.<sup>4,5</sup> There are several practice guidelines about how to collect a BC,<sup>6–11</sup> but many aspects related to the process of taking BCs are subject of intensive research and scientific debate. This includes, for example, the collection site, the number of punctures (single-site vs. multiple-site sampling), the optimal number of BC sets and blood volume.<sup>1,12–25</sup> BC analysis is a complex process, involving multiple steps that require considerable time and expertise. There are

only limited data regarding BC sampling strategies, microbiological handling of BCs, laboratory operating hours, and the use of rapid testing for BCs in European countries.<sup>26–29</sup> Overall, there is little comparative information on the practice of blood culture diagnostics in Europe, taking into account the clinical aspects, the processes and the available laboratory infrastructure.

However, such organizational and infrastructural aspects are essential for the optimal management of sepsis patients.<sup>1,26,30</sup>

In this study, we aimed to evaluate practices in BC collection and diagnostic capacity across European hospitals and examine their relationship with diagnostic turnaround time.

## Methods

### Design and population

The European Sepsis Care Survey (ESCS) was a cross-sectional survey project investigating sepsis care in acute care hospitals in a convenience sample. A self-reported 94-item questionnaire (see [Supplemental Material](#)), harmonized by a multiprofessional steering committee led by the European Sepsis Alliance and peer-reviewed by the scientific committees of four European professional scientific societies (see [Supplemental Material](#)) was distributed to health-care professionals working in acute care hospitals in 69 countries. Participants registered online and completed the survey via a web-based platform (LamaPoll Platin Edition, Germany) using a hospital-specific, unique access link. They were encouraged to obtain the necessary details from other services or departments within the hospital. Each hospital was permitted to submit only one entry, including sections for the emergency department, wards, and intensive care units. The data were collected in 2021 and 2022, and were handled confidentially. The questionnaire contained questions about sepsis screening and sepsis management, as well as BC collection practices and the diagnostic capacity of microbiology laboratories. The general part of the ESCS was published previously.<sup>31</sup> Here, we report the analysis of ESCS data regarding BC collection practices and microbiological diagnostics. The study protocol received ethical approval from the ethics committee of University Medicine Greifswald, Germany (BB 124/21), where data were stored and processed. Written consent from the participants was not required. The ESCS complied with the EQUATOR network reporting guidelines CHERRIES<sup>32</sup> and CROSS<sup>33</sup> and was registered at [ClinicalTrials.gov](https://clinicaltrials.gov) (Identifier: NCT05059808). For this analysis we used data from acute care hospitals located in 37 countries in Europe, including Albania, Austria, Belarus, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, North

Macedonia, Norway, Poland, Portugal, Republic of Moldova, Romania, Russian Federation, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Türkiye, Ukraine and United Kingdom. Data from countries outside the European continent were excluded due to fundamental differences in procedures used in European and non-European countries.

### Variables of interest

The following aspects were analysed: availability of a hospital protocol or guideline for the collection of BCs, BC collecting staff, BC sampling sites including single-site vs. multiple-site sampling, the number of BC sets per collection and surveillance of the number of BCs. We further investigated the processing of BC after collection, the availability of on-site or external microbiology, transfer priority to the microbiology, and the availability of around-the-clock microbiological service. Around-the-clock service was defined as including BC incubation, pathogen identification, antimicrobial susceptibility testing (AST) and result reporting. We also assessed the availability of rapid testing, i.e., rapid pathogen identification by PCR, direct MALDI-TOF MS, or MALDI-TOF MS after short incubation, and rapid AST directly from positive blood cultures, as well as BC tracking and reporting systems. Turn-around-times (TAT) to preliminary results (e.g., Gram stain) and TAT to final microbiological result (including pathogen identification and AST) reported by the participants were analysed.

### Statistical analyses

Analyses were performed by using Excel Version 16, RStudio and Datawrapper. Due to the lack of standardised information on the total number of hospitals in the individual countries and therefore the impossibility of making a statement on the response rate, representativity per country was calculated based on number of beds in the included hospitals divided by total bed capacity per country according to Organisation for Economic Co-operation and Development (OECD) and European Statistics Office (Eurostat) data ([Supplemental Table S2](#)). Only definitive answers (yes/ no) were used to calculate proportions. Responses of the category “I don’t know” were not considered since they could shift the results in either direction. Since not all questions were mandatory, the number of participants included in each analysis varied. Results were presented as numbers and proportions. To avoid biased representation from countries with only a few participating hospitals, we presented country-specific results only if a country contributed at least 10% of its total hospital bed capacity, or at least 10 hospitals.

In a second step, we put the available diagnostic infrastructure and capacities in context with the BC TAT. The TAT of different settings (with and without around-the-clock BC processing; with and without rapid

testing) were compared. Odds ratios with 95% confidence intervals were calculated for the probability of having a microbiological result within two days. Hospitals without 24/7 microbiology service and without rapid testing were set as reference. The Chi-squared test was used to compare contingency tables. *p*-values below an alpha level of 0.05 were considered statistically significant. Due to the multiple comparisons, a Bonferroni correction was performed to adjust all *p*-values.

### Role of the funding source

The study was supported by a grant from Becton Dickinson SA for technical realisation of the study. Becton Dickinson SA was not involved in the study design or recruitment or in writing, reviewing, or submission of the manuscript. This article represents the views of the named authors only.

## Results

The original ESCS included 1023 hospitals worldwide. The present study analysed only European data including 907 hospitals from 37 European countries (713 hospitals from 26 countries within the European Union and 194 hospitals from 11 non-EU countries). Participants were hospital directors (6.0%, 54/907), head or deputy head of departments (44.4%, 403/907), consultants (38.6%, 350/907) and other (i.e., doctors, residents, nurses) (11.0%, 100/907). Details about the positions and specialties are provided in the [Supplemental Material \(Table S1\)](#).

The study included 312 (34.4%) university and 595 (65.6%) non-university hospitals. We included 260 hospitals with less than 250 beds, 268 hospitals with 251–500 beds, 140 hospitals with 501–750 beds, and 239 hospitals with more than 750 beds ([Supplemental Table S3](#)). Based on data from the OECD on hospital bed capacity, the study covered 13.9% of all acute care beds in the included countries. In the European Union, the sample covered 23.1% (388,574 out of 1,681,334) of all acute care beds in the 26 European Union countries and 6.2% of the capacity in the non-European Union countries ([Supplemental Figure S1 and Table S2](#)).

### Blood culture guidelines

Information about the availability of a guideline or protocol for the collection of BCs was reported from 878 hospitals. 84.4% (741/878) of the hospitals reported to have a BC guideline or protocol. In individual countries, implementation of such guiding documents varied between 55.6% and 100% ([Fig. 1](#)). BC guidelines were available in 93.3% (42/45) of private hospitals, followed by university hospitals (87.5%, 265/303), and general or community hospitals (81.9%, 434/530) (*p* = 0.61). The hospital bed size had no significant influence on the availability of guidelines (*p* > 0.99).

### Blood culture collection practices

BCs were predominantly collected by nurses (emergency departments (EDs) 78.4% (576/735), wards 72.4% (581/802), intensive care units (ICUs) 79.8% (639/801), respectively), with a higher proportion of BC collecting by nurses in EDs and on ICUs (*p* = 0.029). Physicians collected BCs in EDs in 33.3% (245/735), on wards in 35.5% (285/802), and on ICUs in 40.2% (322/801), respectively (*p* = 0.41). Specialized phlebotomy teams were rarely utilized ([Fig. 2A](#)).

Direct venipuncture at two different sites (multiple-site sampling) was the preferred method of taking blood cultures in EDs (62.7%, 461/735), on wards (64.0%, 513/802), and ICUs (68.5%, 518/756). Venipuncture at one site (single-site sampling) was the preferred technique in 35.4% (260/735) of the EDs, 33.5% (269/802) of the wards and 26.2% (198/756) of the ICUs. In case of suspected catheter infection, BCs were taken from more than 24 h old catheters in 43.9% (323/735) of the EDs, in 40.0% (321/802) of the wards, and in 49.5% (374/756) of the ICUs. Other preferred sites for BC collection are presented on [Fig. 2B](#) and alternative sites in the [Supplemental Table S4](#). Responders indicated that they preferred a specific number of BC sets to be taken but acknowledged that this was not always achieved ([Fig. 2C](#)). Collection of only one BC set was reported from wards in 40.5% (314/775), from EDs in 38.4% (270/704), and ICUs in 34.4% (261/748) (*p* > 0.99). Collection of always two BC sets was reported from EDs in 31.0% (218/704), from wards in 28.1% (218/775), and from ICUs in 39.2% (293/748) (*p* = 0.0002). Sampling of three and more BC sets was less frequently reported ([Fig. 2C](#) and [Supplemental Table S5](#)).

### Blood culture transfer, tracking, result reporting and quality indicators

Among the hospitals, 838 provided information about the location of their microbiology laboratory, 48.0% (402/838) used on-site microbiology laboratory and 52.0% (436/838) used external microbiological services to process BCs (*p* > 0.99). The ratio of on-site and external laboratories in individual countries and hospital sizes varied and is shown in [Fig. 3A](#) and [Supplemental Material Table S7](#). Responders reported that BCs were sent to the microbiology laboratory immediately after collection from the EDs (69.7%, 495/710), from the wards (67.7%, 525/775), and from the ICUs (76.9%, 575/748) (*p* = 0.14). In smaller proportions, BCs were sent at set times throughout the day, were sent irrespective of collection time, or were stored in the department where they had been taken and collected by personnel from the laboratory depending on availability ([Supplemental Table S6](#)). Immediate transfer of BCs to the laboratory was reported more frequently in hospitals with on-site microbiology

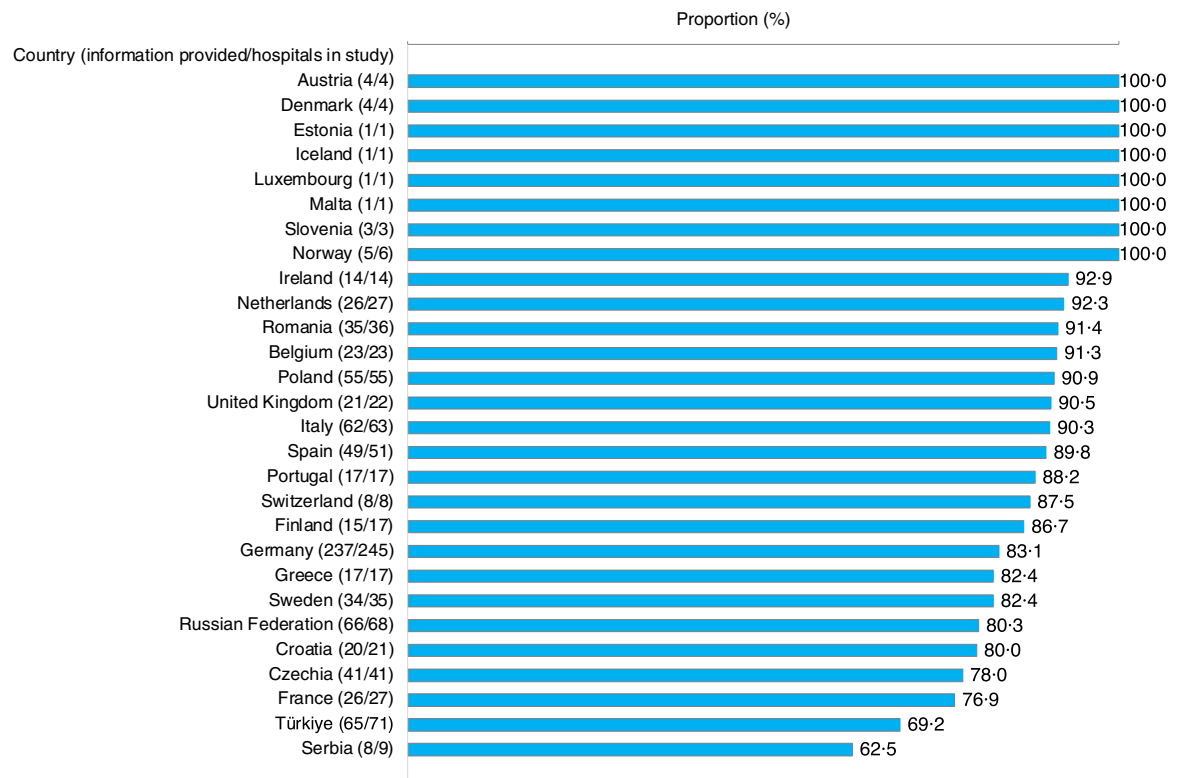


**Fig. 1: Availability of blood culture guidelines or protocols by country.** The figure shows only countries that contributed at least 10% of the country's hospital bed capacity, or at least 10 hospitals of the country. Due to this threshold, data from Bulgaria, Cyprus, Hungary, Slovakia, Belarus, Ukraine, Republic of Moldova, North Macedonia and Albania are not presented in the figure. Proportions were calculated on definitive answers (yes/no). The numbers in brackets present the "number of hospitals that provided information/total number of hospitals in the study".

compared to hospitals with external microbiology (EDs 76.5% (250/327) vs. 64.0% (245/383),  $p = 0.008$ ); wards (74.7% (277/371) vs. 61.4% (248/404),  $p = 0.002$ ); and ICUs (82.7% (296/358) vs. 71.5% (279/390),  $p = 0.008$ ) (Fig. 3B).

The actual state of the BC processing could be tracked in 22.6% (189/837) of hospitals in the hospital information system in real-time, in 46.5% (389/837) of hospitals with delay, and 19.2% (161/837) had no system for BC tracking (Fig. 3C). The first finding (e.g., microscopy result or species identification) was reported by direct calls from the laboratory and via clinical IT systems; there were also notifications via paper and fax or by other ways (Fig. 3D).

In 47.5% (393/828) of hospitals, the number of BCs was systematically measured as quality indicator. Contamination rates within their hospitals were only reported by 15.3% (139/907) of the responders with a median contamination rate of 10% (IQR 5–18).

#### Microbiological infrastructure and diagnostic capabilities

Around-the-clock microbiological services for blood culture incubation, pathogen identification and result

reporting were available for 10.0% (91/907) of the hospitals. Larger hospitals with more than 500 beds had unlimited 24/7 service in 13.5% (51/379) compared to smaller hospitals with less than 500 beds (7.6%, 40/528) ( $p = 0.09$ ) (Fig. 4). There were no significant differences in the availability of 24/7 microbiological laboratory service between university (10.3% (32/312) and non-university hospitals (9.9% (59/595) ( $p > 0.99$ ), and not between on-site microbiology (9.6% (42/436) and external microbiology (10.4%, 49/471) ( $p > 0.99$ ). The availability of 24/7 service in individual countries is shown in Fig. 4.

Rapid pathogen identification from positive BCs was available in 43.7% (396/907) of hospitals. AST directly from positive BCs was available in 23.9% (217/907) of hospitals. Both rapid pathogen identification and AST were available in 14.4% (131/907) of hospitals. The availability of rapid testing varied between hospitals of different sizes and across countries (Fig. 5). University hospitals compared to non-university hospitals had more rapid testing for pathogen identification (63.5%, [198/312] vs. 33.3% [198/595],  $p < 0.0001$ ), AST (35.3%, [110/312] vs. 18.0% [107/595],  $p < 0.0001$ ) and both, pathogen identification and AST (24.0% [75/312] vs.

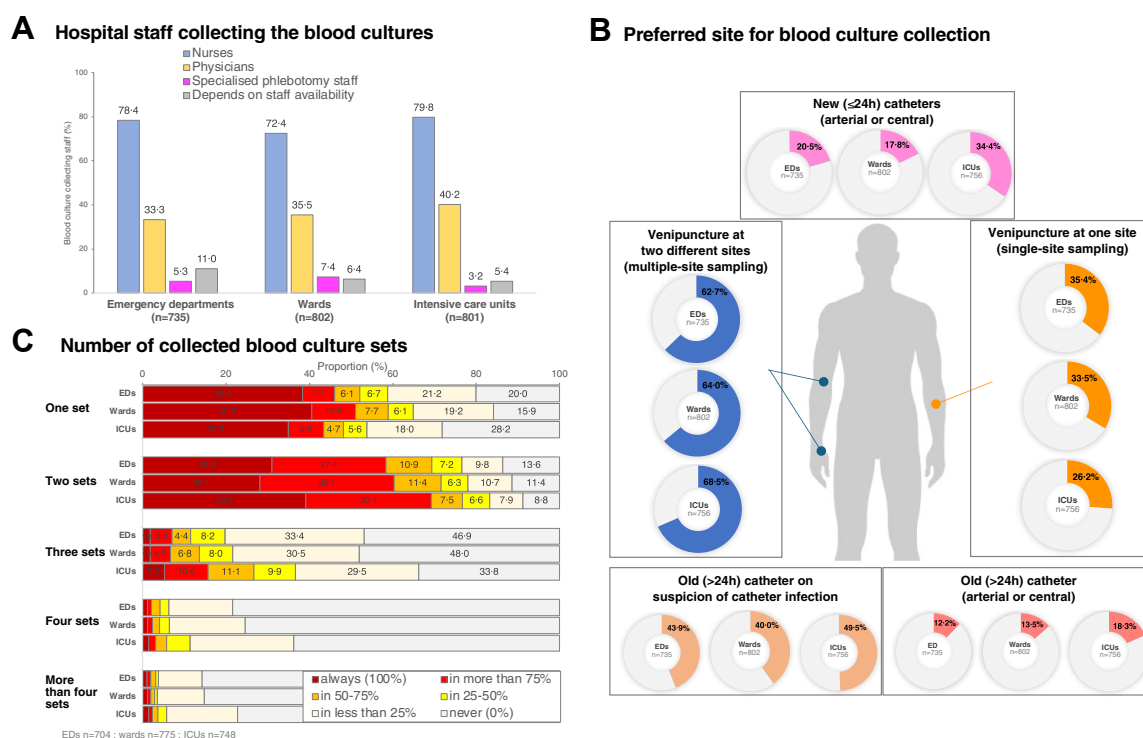


**Fig. 2: Blood culture collection practice in case of sepsis.** (A) The majority of BCs were collected by nurses. (B) Preferred site for BC collection was a multiple-site approach. In case of suspected catheter infection, a collection from more than 24 h old catheters was also frequently reported. Alternative collection sites for BCs are presented in the [Supplemental Table S4](#). (C) In emergency departments (EDs), on wards, and intensive care units (ICUs), one or two blood culture sets were collected in most cases. More information about the number of BCs sets is presented in the [Supplemental Table S5](#).

9.4% [56/595],  $p < 0.0001$ ). Detailed information about the overall infrastructure (opening hours and rapid testing) was provided by 840 hospitals ([Fig. 6](#)). Only 7.4% (62/840) of the hospitals had both, rapid testing and 24/7 microbiological service ([Fig. 6A](#)). On-site microbiology used more rapid testing for pathogen identification (50.5%, [238/471] vs. 36.2% [158/436],  $p = 0.0004$ ), and AST (28.5% [134/471] vs. 19.0% [83/436],  $p = 0.02$ ).

### Blood culture turn-around times

Participants reported how long it usually took to receive a preliminary (e.g., Gram stain microscopy) and the final BC result, including pathogen identification and AST. The majority had a final result within 3 days, on wards 69.0% (535/775) and on ICUs 72.4% (535/739) ([Supplemental Figure S2](#)).

Depending on the available infrastructure, a higher proportion of final BC results were available within two days when BCs were processed in microbiology laboratories offering around-the-clock service (24/7) and rapid testing compared to hospitals with limited service and without rapid testing (52.7% [29/55] vs. 19.6% [54/276],  $p < 0.0001$ ) ([Fig. 6B](#)). The proportion of hospitals with around-the-clock microbiological service and rapid testing was only 7.4% (62/840), but the likelihood for a

final microbiological BC result within two days was highest in these hospitals (wards: odd ratio 4.59 [95% CI 2.50–7.79], ICUs: odds ratio 4.21 [95% CI 2.27–7.22]). The risk of a delayed final BC result was highest in hospitals with limited microbiological services and no rapid testing, of which there were 40.2% (338/840) of hospitals ([Fig. 6](#)).

When participants were asked “How could your microbiological diagnostic service improve?”, 64.4% (584/907) answered “Microbiological diagnostics of sepsis should be more rapid”, 47.4% (430/907) felt that 24/7 microbiological service was needed, 30.5% (277/907) wanted more specific advice (e.g., on antibiotic choice, dosage, duration), 26.5% (240/907) stated that microbiological diagnostics of sepsis should be more precise, and 16.1% (146/907) were satisfied with the microbiology service.

### Discussion

This study presents a comprehensive picture of BC collection practices and microbiological capacity for BC diagnostics in Europe. In total, responses from 907 hospitals in 37 countries were analysed. With 83.0% (753/907) of participants being heads or deputy heads of departments or consultants ([Supplemental Material](#),

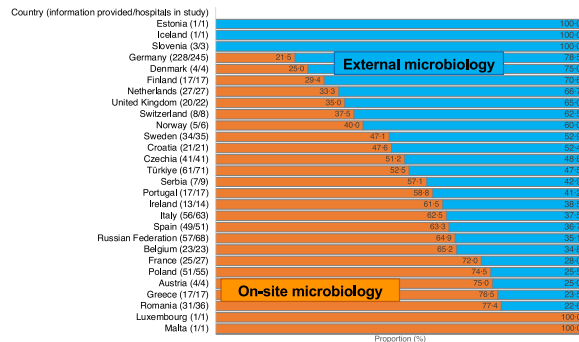
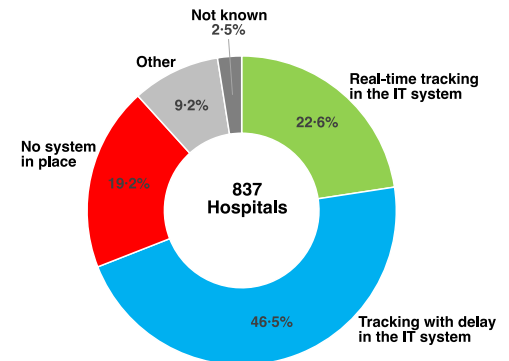
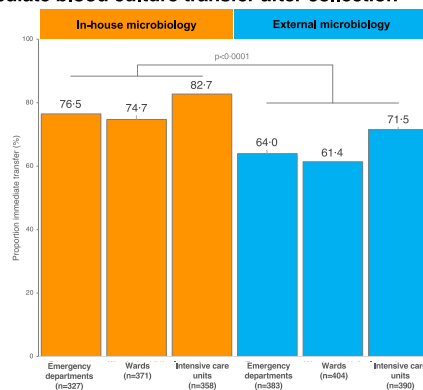
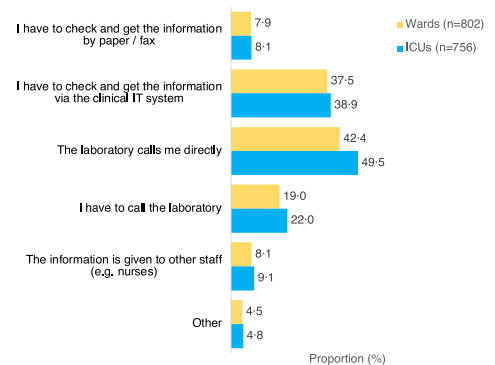
**A** Distribution of on-site and external microbiology**C** Blood culture tracking systems**B** Immediate blood culture transfer after collection**D** Notification about the first finding

**Fig. 3: Blood culture transfer, tracking and reporting.** (A) Distribution of on-site and external microbiology laboratories providing service for hospitals in different countries. (B) Transfer priority of blood cultures to the microbiology after collection. Displayed are the proportions with immediate transfer. In other cases, blood cultures were transported with delay. For more information see [Supplemental Table S5](#). (C) Availability of blood culture tracking systems to view the status of blood cultures. (D) Communication of information regarding the first microbiological finding to a clinician. Figure (A) shows countries that contributed at least 10% of the country's hospital bed capacity, or at least 10 hospitals of the country. Due to this threshold, data from Bulgaria, Cyprus, Hungary, Slovakia, Belarus, Ukraine, Republic of Moldova, North Macedonia and Albania are not presented in the figure. Proportions were calculated on definitive answers (yes/no). The numbers in brackets present the "number of hospitals that provided information/total number of hospitals in the study".

[Table S1](#)), the data in this study predominantly reflects input from senior professionals, supporting its validity. Until now, there has been little cross-border and comparable information on the practice of BC diagnostics. Some studies pointed to significant weaknesses that could have a relevant impact on patient safety.<sup>26–29</sup>

In our study, guidelines or protocols for BC collection were available in more than 80% of hospitals, but current recommendations were often neglected and not followed. A study from Germany in 2017 already reported low adherence to the guideline recommendation of taking at least two BC sets (whereby one BC set consists of one aerobic and one anaerobic bottle).<sup>29,34</sup> Also in our study there was a high proportion of EDs, wards and also ICUs, who usually collected less than two BC sets, a practice that is deviating from current recommendations,<sup>7</sup> but also from recommendations that have been in place for many years.<sup>35,36</sup> Interestingly,

the guideline recommendation to take at least two BC sets disappeared in the latest version of the sepsis guidelines,<sup>37,38</sup> which now does not clarify the needed number of BC sets.<sup>1,13,17,39</sup> A potential issue of collecting only one BC set is to miss detection of bloodstream infections due to reduced blood volume and that it is challenging to differentiate contamination from true pathogen.<sup>23,39–43</sup> Despite available evidence supporting single-site sampling, more hospitals were using multiple-site sampling, which has also been shown to increase the risk of contamination.<sup>14–16,41,44</sup> Our survey revealed contamination rates (10%) higher than those recommended by the Clinical and Laboratory Standards Institute.<sup>7</sup> CLSI currently recommends a contamination rate of <3% of all BCs collected. However, previous publications have reported actual overall BC contamination rates ranging from 0.6 to 12.5%.<sup>45,46</sup> Only a small proportion of respondents (15.3%) were able to

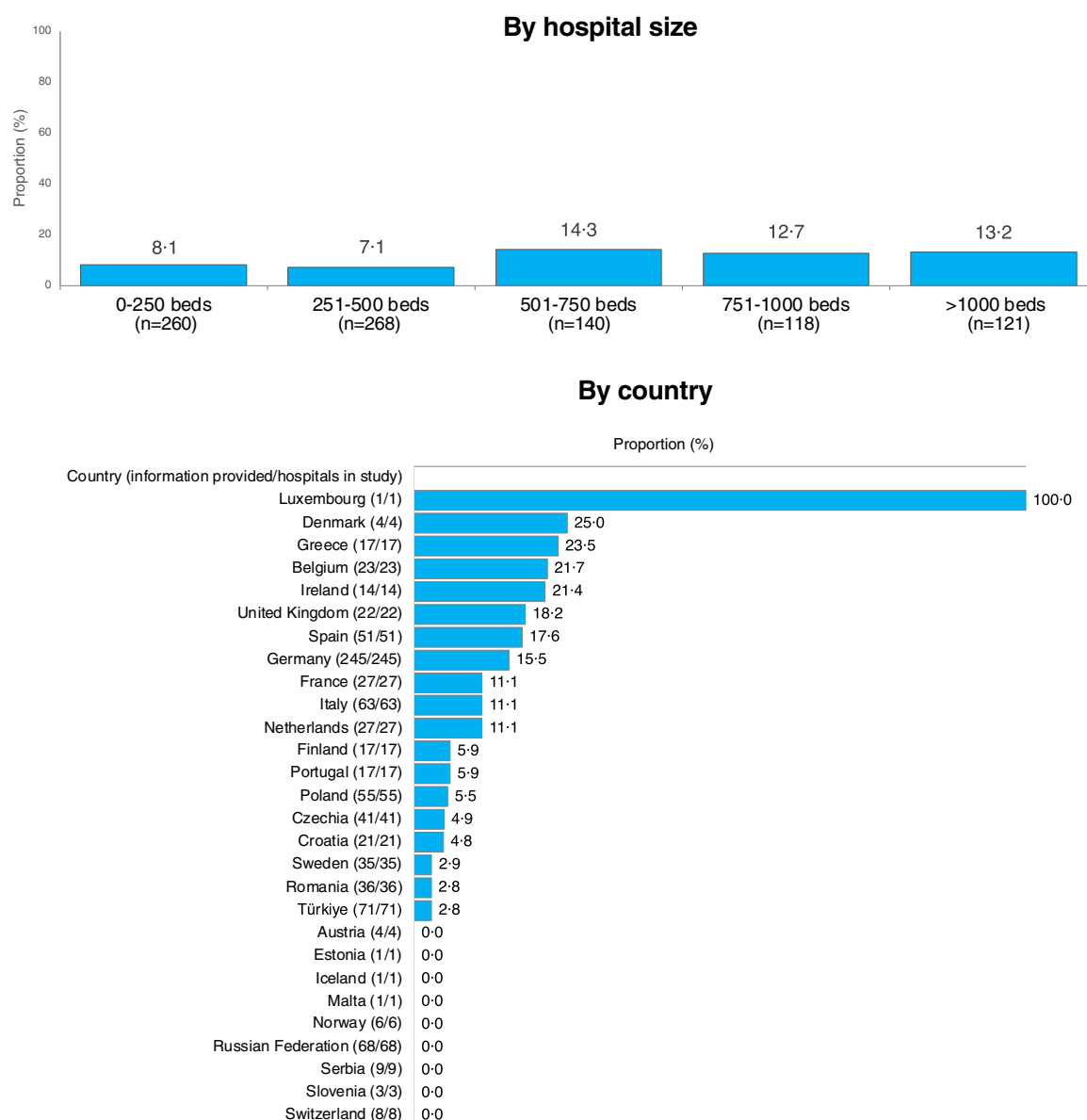


**Fig. 4: Availability of around-the clock microbiology service.** Availability of timely unlimited (24/7) microbiological service for blood culture analysis in hospitals of different sizes and countries. Around-the-clock service had to include blood culture incubation, pathogen identification, antimicrobial susceptibility testing, and result reporting. The country figure shows only countries that contributed at least 10% of the country's hospital bed capacity, or at least 10 hospitals of the country. Due to this threshold, data from Bulgaria, Cyprus, Hungary, Slovakia, Belarus, Ukraine, Republic of Moldova, North Macedonia and Albania are not presented in the figure. Proportions were calculated on definitive answers (yes/no). The numbers in brackets present the "number of hospitals that provided information/total number of hospitals in the study".

provide information on contamination rates, indicating that such data are not routinely documented in many hospitals. High contamination rates are clinically significant, as they may lead to unnecessary antibiotic use, prolonged hospital stays, and increased healthcare costs, highlighting the need for systematic monitoring

and targeted interventions to reduce contamination and improve patient care.<sup>27,40,42,45-49</sup>

A previous study in four European countries reported delayed BC incubation due to transportation to remote labs.<sup>27</sup> Our study confirmed delayed transfer due to transport to external laboratories, but there was

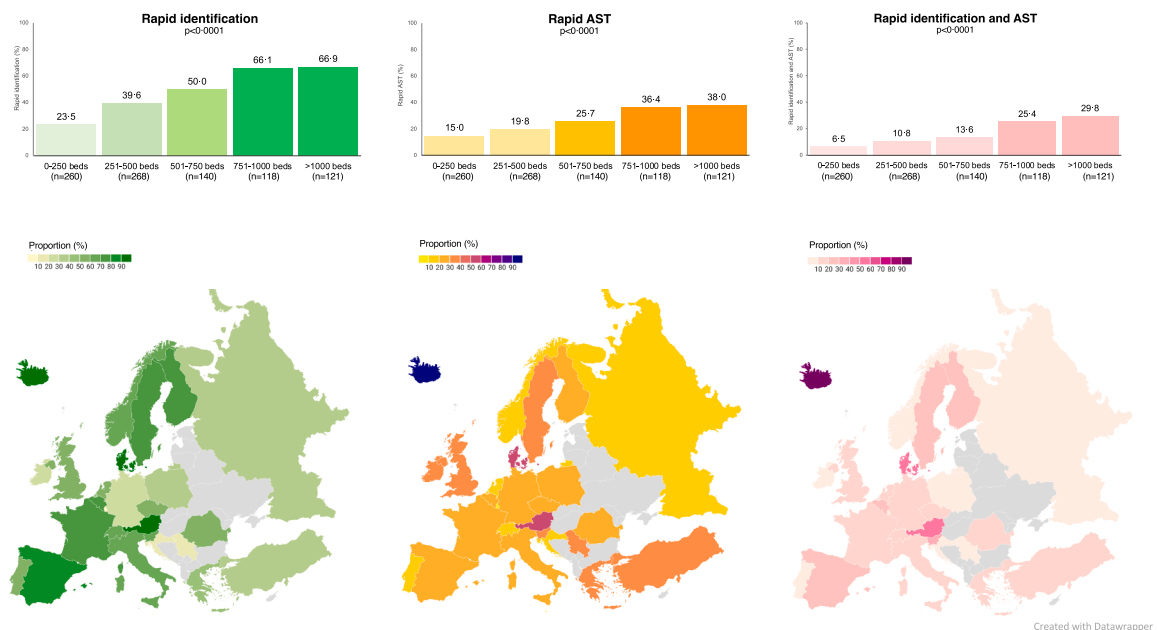


**Fig. 5: Rapid testing capacity.** Availability of rapid pathogen identification (by PCR, direct MALDI-TOF MS, or MALDI-TOF MS after short incubation) and rapid antimicrobial susceptibility testing (AST) directly from positive blood cultures in hospitals of different size. The country maps show only countries that contributed at least 10% of the country's hospital bed capacity, or at least 10 hospitals of the country. Due to this threshold, data from Bulgaria, Cyprus, Hungary, Slovakia, Belarus, Ukraine, Republic of Moldova, North Macedonia and Albania are not shown on the maps.

also significantly delayed transfer to on-site microbiological laboratories. A large survey study investigating 209 microbiological laboratories in Europe reported the use of rapid technologies in two thirds of laboratories,

but only 13% had established a 24 h service to start immediate processing of positive blood cultures and only 4.7% of laboratories validated and transmitted the results of identification and AST to clinicians around-

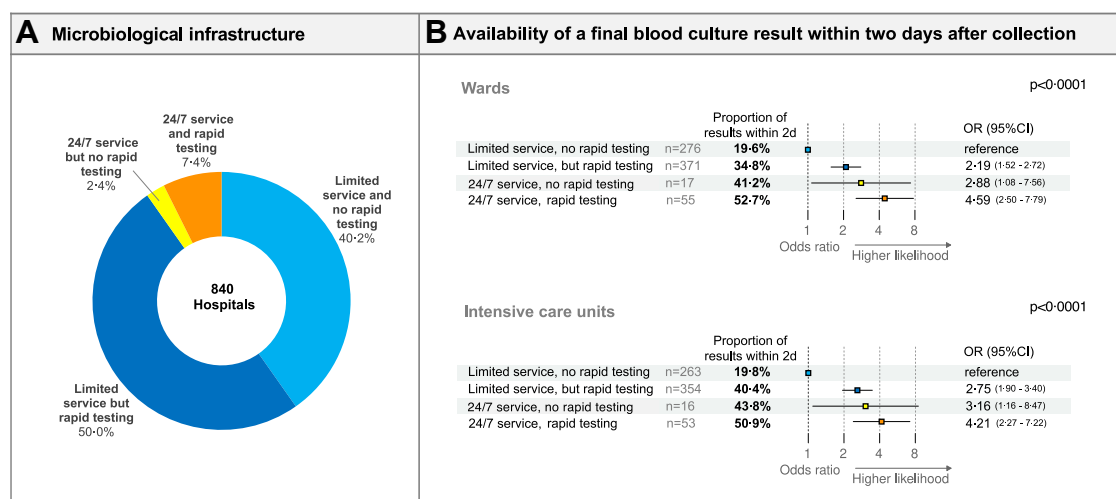


**Fig. 6: Distribution of microbiological infrastructure and capacity for blood culture analysis and time-to-result.** (A) Distribution of microbiological infrastructure was calculated on the basis of all hospitals with complete information about around-the-clock service and rapid testing. Hospitals with partial information were not considered. (B) The first 48 h after blood culture collection were considered for the comparison of different infrastructure and capacity.

the-clock.<sup>26</sup> A study in five Nordic countries in 2022 investigated 49 microbiological laboratories and confirmed limited opening hours confining the potential of satellite incubators and rapid testing.<sup>28</sup> The very low number of around-the-clock microbiological service was confirmed in our study involving more countries and a larger number of hospitals. In addition, we observed an important association between the available microbiological capacity (opening hours and availability of rapid testing) and the TAT of BCs.

Hospitals with rapid testing or around-the-clock microbiological service reported significantly faster TAT compared to hospitals without these infrastructures, confirming the importance of each component. Hospitals that had both around-the-clock microbiological service for blood cultures and rapid testing reported the most accelerated TAT. The risk of a final microbiological result not being available within two days was highest in hospitals with limited microbiological opening hours and no rapid testing. This underlines the urgent need for more extensive microbiological service to provide clinicians as fast as possible with BC results to empower them to adjust antimicrobial therapy as soon as possible.<sup>4,50,51</sup> This becomes more important since several studies have highlighted the increased mortality with inadequate treatment and even more importantly, the high proportion of initial inadequate antimicrobial treatment in patients with life-threatening infections.<sup>2,52–56</sup> The time to receiving adequate antimicrobial treatment is an essential factor to successful therapy and is associated with mortality.<sup>3,54</sup> It underlines the importance of extensive microbiological infrastructure, which means availability of around-the-clock microbiological service and the broad use of rapid testing for BC analysis in critically ill patients.

This study has limitations that should be taken into account when interpreting the findings. Although the data represent a broad range of European hospitals, the use of convenience sampling and voluntary participation introduces the possibility of selection bias. This study was based on a survey, not on a site audit. Therefore, responses were not validated. Not all questions were definitely answered by all respondents. If questions were answered with “I don't know” these responses were excluded from the analyses. The reality can therefore differ in either direction. As with any survey, responses may reflect more favorable or less favorable views. Information about the probability of a final microbiological BC result within two days, turn-around times, and all other data were based on the replies and estimations of the respondents and should be interpreted with appropriate caution.

## Conclusion

Although BC guidelines were available in many hospitals, current recommendations for BC

collection were frequently disregarded, potentially leading to missed microbiological findings. In most hospitals, microbiology laboratories offered limited rapid testing and rarely provided 24-h BC services. Furthermore, we observed a significant association between microbiological capacity and reported BC turn-around times. These findings highlight an urgent need to improve pathogen diagnostics in patients with sepsis.

## Contributors

CSS, KR, RF, EAI, MG contributed to the conceptualisation. CSS, DF, AL, RF, AA, SL, MO (Ostermann), MG, EGB, EAI, KR contributed to the study design and harmonised the questionnaire. DF, AL, EAI, ATA, MGS, KL JS, MG, MO (Ostermann) translated and checked the survey. CSS and national coordinators (see below) verified the data, CSS and MV had access to raw data. CSS and MV analysed the data. CSS wrote the first draft of the manuscript and produced the tables and figures.

CSS, EAI, EGB, DA, VC, MS, KZ, MO (Ostermann), MiO(Osthoff), JH, MM, MG, JM, KD, RF and RCR revised the Article.

RF, DA, AA, ATA, GB, HRB, VC, RCR, MG, KD, JH, KL, JM, MM, GM, MO (Ostermann), MiO (Osthoff), JAP, MS, JS, SL, MGS, ATL, NV and KZ contributed as national coordinators or representatives of scientific societies to survey dissemination, were responsible for hospital recruitment and checked participants.

All authors contributed to data interpretation, provided substantial feedback on the article, and approved the submitted version.

CSS and EAI had the final responsibility for the decision to submit for publication.

## Data sharing statement

The data used for this analysis can be made available upon reasonable request for up to five years. For further information, please contact the corresponding author.

## Editor note

The Lancet Group takes a neutral position with respect to territorial claims in published maps and institutional affiliations.

## Declaration of interests

**Christian S. Scheer** discloses funding from European Sepsis Alliance for conducting the European Sepsis Care Survey and funding from Becton and Dickinson for technical realisation of the project. He received honoraria from BD for scientific lectures.

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**Abdullah Tarik Aslan** has nothing to disclose.

**Gabriella Bottari** discloses her position as unpaid deputy chair of the infection systemic inflammation and sepsis section of the European Society of Pediatric and Neonatal Intensive Care.

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**Renata Curic Radivojević** has nothing to disclose.

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**Johanna Hästbacka** discloses a steering board membership of CRIC (Collaboration for Research in Intensive Care, unpaid Chairperson of the Finnish Sepsis Society and minor stock options of Orion Pharma).

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**Konrad Reinhart** discloses holding shares from InflaRx NV, which is based in Jena, Germany and listed at NASDAQ; he is the Founding

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**Adam Linder** has nothing to disclose.

**Daniela Filipescu** is Deputy chair of the European Sepsis Alliance (ESA) and representative of the European Society of Anaesthesiology and Intensive Care (ESAIC) to the ESA, both unpaid, she is president of the World Federation of Societies of Anaesthesiologists (WFSA) and discloses a grant from CSL Vifor paid to the WFSA and honoraria from CSL Behring paid to the WFSA and travel support from CSL Behring, she is scientific coordinator of the national congress of the Romanian Society of Anaesthesiology and Intensive Care.

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Livia Vladouiu, Lorena Forcelledo Espina, Ludger Kämmerling, Luigi Bonavina, Luis Ensenat, Lukas Barnas, Lukas Lörinc, Łukasz Olendrzyński, Łukasz Rak, Lupe Coronel, Lutz Pfeiffer, M. Gryskova, M. Schüler, Maarit Hult, Maciej Gawor, Magdalena Miulescu, Magdalena Wujtewicz, Magnus von Seth, Maja Karaman Ilic, Malgorzata Mikaszewska-Sokoleiwc, Malte Morisse, Matthias Meyer-Barner, Manelli Filippo, Manfred Hoefler, Manfred Nuscheler, Corina-Cecilia, Manole-Palivan, Mary Nicoleta Lupu, Marc Beckers, Marc Bota, Marco Barchetti, Marco Ingrosso, Marco Ripa, Maria Andersson, Maria De Marco, Maria Fortofoiu, Maria Galiana Ivars, María José Pérez Pedrero, María Juliana Hernández Benito, Maria Slocker Barrio, Maria Zach, Mariana Anghel, Mario Guarino, Mariola Maciaszek, Mariola Talaaj, Marisa Ann Capaldi, Marius Papurica, Mark Neufang, Markus Bressler, Markus Eller, Markus Kestler, Markus Kredel, Markus Rudnick, Markus Teipel, Marta Valcarcel Rodriguez, Martijn van Telling, Martin Beiderlinden, Martin Bier, Martin Cermak, Martin Ebert, Martin Helan, Martin Kahl, Martin Metelka, Martin Reichert, Martin Schütz, Martin Spångfors, Martin Wagner, Martina Čehulić, Martina Pavletić, Marton Gyenge, Mary Bedding, Marzouk Mehdi, Maša Biberić, Mateusz Mischczyszyn, Mathias Fischer, Mathias Sprenger, Matija Belavić, Matija Jurjević, Matjaž Groznik, Matthias Gründling, Matthias Huck, Matthias Lutze, Matthias Menzel, Matthias Schmauß, Matthias Weiß, Maurizio Mazzoni, Max Müller, Jochen Souquet, Maximilian Ragaller, Mercedes Ibarz Villamayor, Michael Booke, Michael Buerke, Michael Dalager-Pedersen, Michael Dolch, Michael Fries, Michael Habenicht, Michael Kremer, Michael Meisner, Michael Meyer, Michael Pogatschnigg, Michael Schütz, Michael Stofkoper, Michal Holub, Michal Pelíšek, Michal Sitina, Michał Śpiewak, Michał Ziółkowski, Michelle Behan, Miguel Castelo-Branco Sousa, Mihaela Blaj, Mihaela Conci, Mihaela Lupse, Mika Valtonen, Mikael Moriconi, Dagmar Minafiková, Miroslav Zajicek, Mirza Aun Muhammad Baig, Mitre Ioan Remus, Modesto Martinez Pillado, Mohamed Hasaballah, Monique van der Lugt, Moritz Unglaube, Natacha Mrozek, Nádia Guimarães, Nahema Issa, Nathalie Layios, Naya Bellaubi Pallarés, Nelson Barros, Nieves Carbonell Monleón, Nicolas Belaube, Nicolas Mongardon, Nicolas Serck, Nikolaas Verbeke, Nikolas Lambiris, Nicoletta Rovina, Nils Haake, Nina Polze, Nina Sulen, Noelia María Muñoz Guillen, Nora Bruns, Noud Buenen, Ojan Assadian, Ole Broch, Olena Oliwa, Olga Klementová, Oliver Beck, Oliver Habler, Oliver Hensel, Oliver Kunitz, Oliver Schmid, Olof Blivik, Ondrej Zika, Onnen Mörer, Orestis Ioannidis, Oskar Ljungquist, Pablo Vidal Cortés, Paola Rodari, Papa Raffaella, Pär Lindgren, Pascal Stammel, Pasquale Minchella, Patricia Patricio, Patrik Gille-Johnson, Patrizia Petricci, Paula Pestana, Paula Vera, Pavel Dostal, Pavel Malina, Pavel Sedláč, Pedro Castro Rebollo, Pedro Rascado Sedes, Peter Brand, Peter Neumann, Petr Hubacek, Petr Stepanek, Petr Uhlig, Petra Wegermann, Philipp Tsafoulis, Pierre Fillatre, Pierre Gregoire Guinot, Pierre Tattevin, Pio Faust, Piotr Czempik, Piotr Smuszkiewicz, Piotr Staniewski, Plinio Calligaro, Polychronis Tassioudis, Přemysl Dörr, Przemysław Michalski, R. Klimaschewski, R. Schnabel, Radek Cihlár, Rafael Leon Lopez, Rafał Gahuszka, Rafał Wójtowicz, Rainer Haas, Ralf Walper, Ralph Budnik, Ralph Sander, Raphael Gukasjan, Reiner Sitzler, Reinoud Cartuyvels, Renata Szmigielska, Renate Koch, René Verbeek, Ricard Ferrer, Ricardo Castelbón, Rob Wilting, Robert Bock, Robert Janda, Roberta Moretti, Roelie Wösten-van Asperen, Romain Jouffroy, Romaric Larcher, Ronald Seidel, Rosario Cristoforo Puleo, Rouven-Alexander von Holten, Roxana Ungurean, Rüdiger Albrecht, Rüdiger Lott, Rui Terras, Rute Fernandes Alves, Ruth Müller, Ryszard Tokarczuk, Salla Kumpulainen, Sami Mäenpää, Sandra Müller, Sandra O Donovan, Sanna Pohjanpaju, Sara Cajander, Sascha Ussat, Rouven Angela, Sebastian Brandt, Sebastian Casu, Sebastian Hafner, Sebastian Hammerich, Sebastian Rehberg, Sebastian Tranca, Selena Knoth, Shahram Mashayekhi, Shona Fitzgerald, Silvana Pilia, Silvia Carbajo Azabal, Silvia De Rosa, Simo-Pekka Koivisto, Simon Oelsner, Simon Schäfer, Simona Barnini, Simona Viola, Simu Tudor, Sinead O'Neill, Stanisław Iwańczak, Söhnke Boye, Sonja Krofak, Spadaro Savino, Staffan Tveell, Stefan Angermair, Stefan Bergt, Stefan Markoff, Stefan Ostmeier, Stefan Otto, Stefan P. Wirtz, Stefan Rußwurm, Stefan Schroeder, Stefan Staar, Stefanie Vandervelden, Stefano Trapassi,

Steffen Volkert, Stepani Bendel, Stephan Baumann, Stephan Blache, Stephanie Koster, Stephanie Mifsud, Sulamita Carvalho Brugger, Sunil Jagoda, Sven Ackermann, Sybille Glöckl, T. Dormans, Tajana Milanovic Robina, Talvikki Koskue, Tatiana Ciomartan, Teresa Tomasa, Theodoros Aslanidis, Thessa VerNeverst, Thomas Eckermann, Thomas Grau, Thomas Hahn, Thomas Kiss, Thomas Libuda, Thomas Melzer, Thomas Rösel, Thomas Uhlig, Thomas Volk, Thomas Weidemann, Thorsten Keil, Tim Bruckmoser, Tim Piepho, Timmermans Mark, Tina Frolo, Tina Tomić Mahečić, Toamas Gabrhelik, Tobias Gropp, Tobias Klöpfer, Tobias Lahmer, Tobias Leipold, Tomáš Málek, Tomáš Tajč, Tomas Urbina, Tomas Vymazal, Tomasz Musiuk, Tomasz Siegel, Tomasz Skalec, Torsten Fricke, Udo Gottschaldt, Ulf Linstedt, Ulrich Blumenthal, Ulrich Katt, Ulrich Plog, Ulrich Ronellenfisch, Ursula George, Ute Brüggemann, Uwe Treue, Václava Adámková, Valeria Caramello, Vasileios Kaldis, Vasileios Nolas, Vasilios Papaioannou, Verena Plötz, Vesna Degoricija, Viktor Švigelj, Ville Jalkanen, Vincenzo Francesco Tripodi, Vladimír Zemánek, Volker Ostermoor, W. Alexander Osthau, W. Joost Wiersinga, W.B. Huiszoon, Wahid Altaf, Waldemar Sobolewski, Walravens Stig, Walter Stadlmeyer, Wiktorina Mizak, Witold Wasiak, Wojciech Dabrowski, Wolfgang Heinke, Wolfgang Zink, Xavier Muschart, Yuriy Bunin, Yvo Boué, Yvonne Young, Zdenek Kos, Zdenko Povšić-Čevra, Zrinka Safaric Oremus, Zuzanna Górska.

#### Appendix A. Supplementary data

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.janepe.2025.101570>.

#### References

- Lamy B, Sundqvist M, Idelevich EA. Escmid Study Group for Bloodstream Infections E, Sepsis. Bloodstream infections - standard and progress in pathogen diagnostics. *Clin Microbiol Infect*. 2020;26(2):142–150.
- Kadri SS, Lai YL, Warner S, et al. Inappropriate empirical antibiotic therapy for bloodstream infections based on discordant in-vitro susceptibilities: a retrospective cohort analysis of prevalence, predictors, and mortality risk in US hospitals. *Lancet Infect Dis*. 2021;21(2):241–251.
- Van Heuverswyn J, Valik JK, Desiree van der Werff S, Hedberg P, Giske C, Nacler P. Association between time to appropriate antimicrobial treatment and 30-day mortality in patients with bloodstream infections: a retrospective cohort Study. *Clin Infect Dis*. 2023;76(3):469–478.
- De Waele JJ, Schouten J, Beovic B, Tabah A, Leone M. Antimicrobial de-escalation as part of antimicrobial stewardship in intensive care: no simple answers to simple questions-a viewpoint of experts. *Intensive Care Med*. 2020;46(2):236–244.
- Arulkumaran N, Routledge M, Schlebusch S, Lipman J, Conway Morris A. Antimicrobial-associated harm in critical care: a narrative review. *Intensive Care Med*. 2020;46(2):225–235.
- Irish Guideline for the Investigation of Blood Culture Samples. CDI015/2021. Version 3 ed. Irish Society of Clinical Microbiologists Blood Culture Guideline Development Group. Health Service Executive (HSE) <https://www.hse.ie/eng/about/who/cspd/lsr/resources/irish-guideline-for-blood-cultures.pdf>; 2021.
- CLSI. *Principles and Procedures for Blood Cultures*. 2nd ed. CLSI guideline M47. Clinical and Laboratory Standards Institute; 2022.
- NHS England. *Improving the blood culture pathway A national review of blood culture pathway processes to support better antimicrobial stewardship and improved patient safety*. 2023.
- Miller JM, Binnicker MJ, Campbell S, et al. Guide to utilization of the microbiology laboratory for diagnosis of infectious diseases: 2024 update by the infectious diseases society of America (IDSA) and the American Society for Microbiology (ASM). *Clin Infect Dis*. 2024;ciae104. <https://doi.org/10.1093/cid/ciae104>.
- WHO. *WHO guidelines on drawing blood: best practices in phlebotomy*. World Health Organization; 2010.
- UKHSA. *Sepsis and systemic or disseminated infections. UK Standards for Microbiology Investigations*. UK Health Security Agency; 2025.
- Andersson Norlen E, Widerstrom M, Lindam A, Olsson J, Ryding U. Blood cultures with one venipuncture instead of two: a prospective clinical comparative single-center study including patients in the ICU, haematology, and infectious diseases departments. *Infect Dis (Lond)*. 2023;55(9):591–598.
- Lamy B, Dargere S, Arendrup MC, Parienti JJ, Tattévin P. How to optimize the use of blood cultures for the diagnosis of bloodstream infections? A state-of-the art. *Front Microbiol*. 2016;7:697.
- Yu D, Larsson A, Parke A, et al. Single-sampling strategy vs. multi-sampling strategy for blood cultures in sepsis: a prospective non-inferiority study. *Front Microbiol*. 2020;11:1639.
- Ekwall-Larson A, Yu D, Dinné P, Nordqvist H, Özenci V. Single-site sampling versus multisite sampling for blood cultures: a retrospective clinical study. *J Clin Microbiol*. 2022;60(2):e01935-21.
- Leyssene D, Gardes S, Vilquin P, Flandrois JP, Carret G, Lamy B. Species-driven interpretation guidelines in case of a single-sampling strategy for blood culture. *Eur J Clin Microbiol Infect Dis*. 2011;30(12):1537–1541.
- Cockerill FR III, Wilson JW, Vetter EA, et al. Optimal testing parameters for blood cultures. *Clin Infect Dis*. 2004;38(15):1724–1730.
- Jindai K, Strerath MS, Hess T, Safdar N. Is a single positive blood culture for *Enterococcus* species representative of infection or contamination? *Eur J Clin Microbiol Infect Dis*. 2014;33(11):1995–2003.
- Suleyman G, Moore NM, Palavecino E, et al. *Blood culture bottle inventory management and clinical conservation during supply shortages Endorsed by the Society for Healthcare Epidemiology of America (SHEA)*. American Society for Microbiology; 2025. <https://asm.org>.
- Isaacman DJ, Karasic RB, Reynolds EA, Kost SI. Effect of number of blood cultures and volume of blood on detection of bacteremia in children. *J Pediatr*. 1996;128(2).
- Hashimoto T, Shiojiri D, Ohmagari N. A retrospective study of the optimal number of blood cultures at a hospital in Japan. *Tohoku J Exp Med*. 2021;253(4):233–239.
- Arendrup M, Jensen IP, Justesen T. Diagnosing bacteremia at a Danish hospital using one early large blood volume for culture. *Scand J Infect Dis*. 1996;28(6):609–614.
- Collazos-Blanco A, Perez-Garcia F, Sanchez-Carrillo C, de Egea V, Munoz P, Bouza E. Estimation of missed bloodstream infections without the third blood culture set: a retrospective observational single-centre study. *Clin Microbiol Infect*. 2019;25(4):469–473.
- Mirrett S, Weinstein MP, Reimer LG, Wilson ML, Reller LB. Relevance of the number of positive bottles in determining clinical significance of coagulase-negative staphylococci in blood cultures. *J Clin Microbiol*. 2001;39(9):3279–3281.
- Vashti A, Mullan J, Nitzberg M. Single-site sampling strategy versus multisite sampling strategy in blood culture collection within the hospital setting: a systematic review. *Am J Infect Control*. 2025;53(10):1113–1120. <https://doi.org/10.1016/j.ajic.2025.07.010>.
- Idelevich EA, Seifert H, Sundqvist M, et al. Microbiological diagnostics of bloodstream infections in Europe-an ESGBIES survey. *Clin Microbiol Infect*. 2019;25(11):1399–1407.
- Schmitz RP, Keller P, Baier M, Hagel S, Pletz M, Brunkhorst F. Quality of blood culture testing - a survey in intensive care units and microbiological laboratories across four European countries. *Crit Care*. 2013;17:R248.
- Akerlund A, Petropoulos A, Malmros K, Tangden T, Giske CG. Blood culture diagnostics: a Nordic multicentre survey comparison of practices in clinical microbiology laboratories. *Clin Microbiol Infect*. 2022;28(5):731.e1–731.e7.
- Raupach-Rosin H, Duddeck A, Gehrlich M, et al. Deficits in knowledge, attitude, and practice towards blood culture sampling: results of a nationwide mixed-methods study among inpatient care physicians in Germany. *Infection*. 2017;45(4):433–441.
- Blondeau JM, Idelevich EA. The 24-h clinical microbiology service is essential for patient management. *Future Microbiol*. 2018;13(15):1625–1628.
- Scheer CS, Giamarellos-Bourboulis EJ, Ferrer R, et al. Status of sepsis care in European hospitals: results from an international cross-sectional survey. *Am J Respir Crit Care Med*. 2025;211(4):587–599.
- Eysenbach G. Improving the quality of web surveys: the Checklist for Reporting Results of Internet E-Surveys (CHERRIES). *J Med Internet Res*. 2004;6(3):e34.
- Sharma A, Minh Duc NT, Luu Lam Thang T, et al. A consensus-based Checklist for Reporting of Survey Studies (CROSS). *J Gen Intern Med*. 2021;36(10):3179–3187.
- Ransom E, Burnham C. Routine use of anaerobic blood culture bottles for specimens collected from adults and children enhances

- microorganism recovery and improves time to positivity. *J Clin Microbiol.* 2022;60(9).
- 35 Rhodes A, Evans LE, Alhazzani W, et al. Surviving sepsis campaign: international guidelines for management of sepsis and septic shock: 2016. *Intensive Care Med.* 2017;43(3):304–377.
  - 36 Dellinger RP, Levy MM, Rhodes A, et al. Surviving sepsis campaign: international guidelines for management of severe sepsis and septic shock: 2012. *Crit Care Med.* 2013;41(2):580–637.
  - 37 Evans L, Rhodes A, Alhazzani W, et al. Surviving sepsis campaign: international guidelines for management of sepsis and septic shock 2021. *Intensive Care Med.* 2021;47(11):1181–1247.
  - 38 Scheer C, Grundling M, Kuhn SO. Do not forget the blood cultures. *Intensive Care Med.* 2022;48(4):509–510.
  - 39 Lee A, Mirrett S, Reller LB, Weinstein MP. Detection of blood-stream infections in adults: how many blood cultures are needed? *J Clin Microbiol.* 2007;45(11):3546–3548.
  - 40 Dargere S, Cormier H, Verdon R. Contaminants in blood cultures: importance, implications, interpretation and prevention. *Clin Microbiol Infect.* 2018;24(9):964–969.
  - 41 Lamy B. What is the relevance of obtaining multiple blood samples for culture? A comprehensive model to optimize the strategy for diagnosing bacteremia. 2002.
  - 42 Blood culture contamination: an overview for infection control and antibiotic stewardship programs working with the clinical laboratory. U. S. Department of Health and Human Services Centers for Disease Control and Prevention; 2022. <https://stacks.cdc.gov/view/cdc/123257>.
  - 43 Gonsalves WI, Cornish N, Moore M, Chen A, Varman M. Effects of volume and site of blood draw on blood culture results. *J Clin Microbiol.* 2009;47(11):3482–3485.
  - 44 Goehring F, Soudant M, Alauzet C, et al. Single- versus multiple-sampling strategy for blood cultures in the diagnosis of infective endocarditis: the prospective multicenter UniEndo study. *Clin Infect Dis.* 2025;81(4):756–765. <https://doi.org/10.1093/cid/ciaf163>.
  - 45 Doern GV, Carroll KC, Diekema DJ, et al. Practical guidance for clinical microbiology laboratories: a comprehensive update on the problem of blood culture contamination and a discussion of methods for addressing the problem. *Clin Microbiol Rev.* 2019;33(1).
  - 46 Koroki T, Fujii M, Kotani Y, et al. Contamination of blood cultures drawn from arterial catheters versus venipuncture or venous catheters in critically ill patients: a systematic review and meta-analysis. *Clin Infect Dis.* 2025;ciaf260. <https://doi.org/10.1093/cid/ciaf260>.
  - 47 Dawson S. Blood culture contaminants. *J Hosp Infect.* 2014;87(1):1–10.
  - 48 Ferrer R, Gonzalez Del Castillo J, Martinez-Martinez M, Plata-Menchaca EP, Larrosa MN. Time to decision in sepsis. *Rev Esp Quimioter.* 2023;36(1):82–87.
  - 49 Bunn JD, Cornish NE. Blood culture contamination and diagnostic stewardship: from a clinical laboratory quality monitor to a national patient safety measure. *J Appl Lab Med.* 2025;10(1):162–170.
  - 50 Dickinson JD, Kollef MH. Early and adequate antibiotic therapy in the treatment of severe sepsis and septic shock. *Curr Infect Dis Rep.* 2011;13(5):399–405.
  - 51 Garnacho-Montero J, Gutierrez-Pizarra A, Escobedo-Ortega A, et al. De-escalation of empirical therapy is associated with lower mortality in patients with severe sepsis and septic shock. *Intensive Care Med.* 2014;40(1):32–40.
  - 52 Ibrahim EH, Sherman G, Ward S, Fraser VJ, Kollef MH. The influence of inadequate antimicrobial treatment of bloodstream infections on patient outcomes in the ICU setting. *Chest.* 2000;118(1):146–155.
  - 53 Marquet K, Liesenborgs A, Bergs J, Vleugels A, Claes N. Incidence and outcome of inappropriate in-hospital empiric antibiotics for severe infection: a systematic review and meta-analysis. *Crit Care.* 2015;19(1):63.
  - 54 Stoneking LR, Patanwala AE, Winkler JP, et al. Would earlier microbe identification alter antibiotic therapy in bacteremic emergency department patients? *J Emerg Med.* 2013;44(1):1–8.
  - 55 Suberviola Canas B, Jauregui R, Ballesteros MA, Leizaola O, Gonzalez-Castro A, Castellanos-Ortega A. Effects of antibiotic administration delay and inadequacy upon the survival of septic shock patients. *Med Intensiva.* 2015;39(8):459–466.
  - 56 Garnacho-Montero J, Gutierrez-Pizarra A, Escobedo-Ortega A, Fernandez-Delgado E, Lopez-Sanchez JM. Adequate antibiotic therapy prior to ICU admission in patients with severe sepsis and septic shock reduces hospital mortality. *Crit Care.* 2015;19(1):302.