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Systematic Review

Performance of Automated Versus Manual Blood Culture Systems in Detecting Bloodstream Infections; Systematic Review

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Abstract

Background: Bloodstream infections (BSIs) are a major cause of morbidity and mortality worldwide, which require accurate diagnosis for effective management. Blood culture is the gold standard for detecting BSIs, and the choice between automated and manual systems is a challenge, mainly in resource-limited settings. In this systematic review we aim to compare the diagnostic performance of automated versus manual blood culture systems in detecting bloodstream infections, focusing on yield, time to detection, and clinical impact.

Methods: Our review identified relevant studies which compare automated and manual blood culture systems. The review was conducted according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Data were extracted and synthesized from 5 studies. Outcomes assessed included detection rate, contamination rate, time to detection (TTD), and pathogen identification efficiency.

Results: Automated systems show higher detection rates, shorter TTD, and improved pathogen identification. These systems improved clinical decision making and supported antimicrobial management through faster organism recovery. Manual systems is widely used in low and middle income countries due to cost and infrastructure limitations.

Conclusion: Automated blood culture systems better manual methods in most diagnostic metrics, but implementation in low resource settings need strategies to address the barriers.

Keywords: Bloodstream Infections; Blood Culture; Automated Systems; Manual Systems; Diagnostic Yield; Time to Detection

Abbreviations

BSI: Bloodstream Infection; TTD: Time to Detection; LMICs: Low- and Middle-Income Countries; AST: Antimicrobial Susceptibility Testing; AMR: Antimicrobial Resistance; CRBSI: Catheter-Related Bloodstream Infection; MALDI-TOF MS: Matrix-Assisted Laser Desorption Ionization–Time of Flight Mass Spectrometry; CMBC: Continuous Monitoring Blood Culture; IDSA: Infectious Diseases Society of America; qSOFA: Quick Sequential Organ Failure Assessment; BC-GP: Gram-Positive Blood Culture Panel; BC-GN: Gram-Negative Blood Culture Panel; WHO: World Health Organization; ASP: Antimicrobial Stewardship Program.

Introduction

Bloodstream infections (BSIs) is a significant global health concern, which contribute to morbidity and mortality, mainly in critically ill and immunocompromised patients. Early and accurate detection of BSIs is essential to guide appropriate antimicrobial therapy and reduce adverse outcomes [1]. Blood cultures acted as the gold standard for diagnosing BSIs, but the process is hampered by prolonged times and limited sensitivity, mainly in settings where manual methods are the norm [2].

Manual blood culture systems more accessible in low-resource environments, are frequently limited by prolonged incubation periods, higher contamination rates, and delayed organism identification [3]. Automated blood culture systems provide significant improvements, continuous monitoring, reduced TTD, and higher pathogen recovery rates. These systems developed since the 1990s, with modern platforms integrating advanced detection technologies and enhanced culture media to optimize clinical performance [4].

Recent studies shown that automated systems outperform manual methods in yield and speed. This is critical in intensive care settings, where delays in diagnosis lead to septic shock or death. The use of automated systems was associated with improved antimicrobial treatment by enabling earlier organism identification and susceptibility testing, facilitating timely and targeted therapy [1]. Their implementation in low and middle income countries (LMICs) is challenging due to high costs, infrastructure requirements, and supply chain limitations [2].

The shift toward rapid molecular diagnostics, multiplexed nucleic acid tests indicate the need to evaluate conventional and automated culture systems in different clinical settings. BSIs continue to pose a large burden on healthcare systems, a comparison of automated versus manual blood culture systems is needed to inform future diagnostic strategies and health policies [5].

Methodology

This study compare the performance of automated versus manual blood culture systems in detecting bloodstream infections (BSIs). The review was conducted according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

A search strategy was developed in electronic databases (PubMed, Scopus, Web of Science, and Google Scholar). The search was conducted to identify studies published from 2020 to 2025. Keywords and MeSH terms were used (automated blood culture, manual blood culture, conventional blood culture, bloodstream infections, diagnostic accuracy, and time to detection) were used in various Boolean combinations. The reference lists of included articles were searched manually to capture relevant studies that were missed in the database search.

We include studied compared automated blood culture systems (BacT/ALERT or BACTEC) with manual methods. Eligible studies reported at least one diagnostic outcome (detection rate, time to detection, contamination rate, or overall diagnostic yield). Only full-text articles written in English were considered. We exclude review articles, conference abstracts, case reports, *in vitro* or animal studies.

Screening and selection of studies were done independently by two reviewers who assessed titles and abstracts for relevance. Full texts of potentially eligible studies were retrieved and evaluated against the inclusion criteria. Discrepancies in selection were resolved by discussion. Five studies met the eligibility criteria and were included in this review.

Data were extracted using a standardized form that collect (study citation, study design, setting, population demographics, type of infection evaluated, blood culture systems used, key

findings, and reported clinical or operational outcomes). The extracted information was summarized and tabulated to facilitate comparison within studies.

To assess the methodological quality of the included studies, the Joanna Briggs Institute (JBI) Critical Appraisal Checklists were employed (Table 1). Diagnostic accuracy studies [6,7] were evaluated using the JBI checklist for diagnostic studies. Cross-sectional and retrospective studies [8-10] were appraised using the JBI checklist for analytical cross-sectional studies. We assessed clarity of inclusion criteria, validity of outcome measurement, identification and management of confounding variables, and appropriateness of statistical analysis.

Citation	Year	Sample Size	Study Design	Setting	Country	Patient Group	Outcomes Measured	TTD (Hours)
Qin., *et al.*	2024	1772	Comparative evaluation study	Various hospital wards including ICU	China	Adults (≥16 years)	Detection rate, TTD, organism sensitivity	14 (Virtuo) vs 16 (BACTEC)
Halperin., *et al.*	2022	9957	Prospective crossover diagnostic clinical trial	Tertiary care hospital	Spain	Adults (>16 years)	TTD, TAT, impact of prior antimicrobial therapy	15.2 (Virtuo) vs 16.3 (BACTEC)
Rizvi., *et al.*	2020	553 (214 manual, 339 automated)	Retrospective cross-sectional study	Cardiology Institute	Pakistan	Mixed (ICU and ED patients)	Detection yield (manual vs automated)	Manual system: 10.3% Automated system: 15.3%
Isaac., *et al.*	2022	6445 (5276 manual, 1169 automated)	Retrospective analysis	Federal Teaching Hospital	Nigeria	Pediatric (0–18 years)	Detection rate, isolate spectrum, Gram type	9.7% were culture-positive. 45.9% were positive in automated
Chowdhury et al.	2021	178	Cross-sectional study	NICUs of CMCH and CMOSHMC	Bangladesh	Neonates	Detection rate, TTD, unique isolate recovery	26.4 (Automated) vs 46.3 (Manual)

Table 1: Characteristics of the included studies.

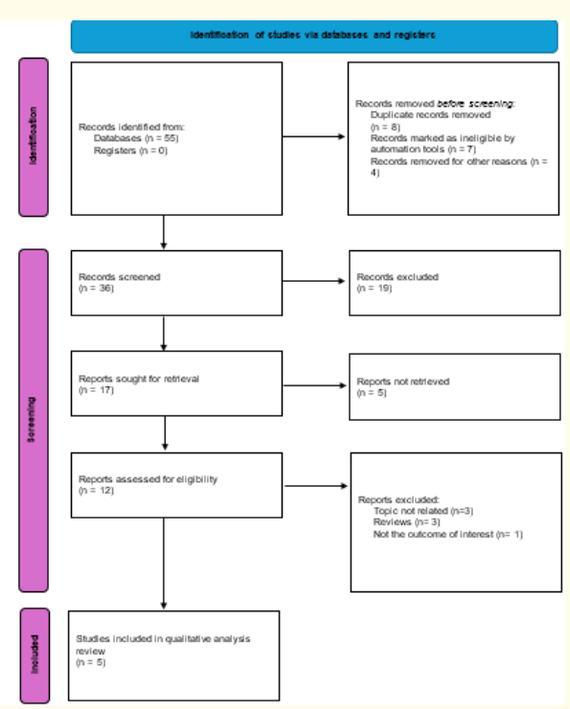

Figure 1: PRISMA consort chart.

Results

The comparison of automated and manual blood culture systems show advantage in diagnostic performance for the automated systems in all included studies. In different clinical settings and patient populations, automated systems showed higher detection rates, reduced time to detection, and better support for clinical decision making.

One study compared the BacT/ALERT VIRTUO and BACTEC FX400 systems using blood samples from patients with suspected bloodstream infections. The automated VIRTUO system showed better performance, with a higher detection rate for anaerobic and Gram-positive organisms. It also had a shorter median time to detection (TTD), which give faster diagnoses and therapeutic decisions (Qin., *et al.* 2024). Characteristics of the included studies presented in (Table 2).

Study	Design	Clear inclusion criteria	Reliable measurement of exposure/ intervention	Standard criteria for condition measurement	Identified confounding factors	Strategies to deal with confounders	Valid and reliable outcome measurement	Appropriate statistical analysis	Clear reporting of results
Qin., *et al*. 2024	Diagnostic comparison	Yes	Yes	Yes	No	No	Yes	Yes	Yes
Halperin., *et al*. 2022	Diagnostic clinical trial	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Syed., *et al*. 2020	Cross-sectional	Yes	Yes	Unclear	No	No	Yes	Unclear	Yes
Isaac., *et al*. 2022	Retrospective analysis	Yes	Yes	Unclear	No	No	Yes	Yes	Yes
Chowdhury., *et al*. 2021	Cross-sectional	Yes	Yes	Yes	No	No	Yes	Yes	Yes

Table 2: JBI methodological assessment of included studies.

A large clinical trial examined 9,957 samples (Table 3) compare the performance of Virtuo and Bactec FX automated systems. The Virtuo system show lower median TTD and shorter turnaround time (TAT) for Gram stain results. These benefits amplified in patients who received prior antimicrobial therapy, where earlier detection allowed clinicians to modify treatments, and improve antimicrobial stewardship (Halperin., *et al*. 2022).

Citation	Study Design	Duration	Inclusion Criteria	Culture Methods	Study Aim	Methodology
Qin., *et al*. 2024	Comparative evaluation study	Not specified	Patients ≥16 yrs suspected of sepsis in various wards (ICU, internal medicine, etc.)	BacT/ALERT VIRTUO vs. BACTEC FX400	Compare diagnostic performance of two automated systems	Parallel blood cultures from same patients processed in both systems
Halperin., *et al*. 2022	Prospective crossover diagnostic clinical trial	6 months	Patients >16 yrs with suspected bacteremia/ fungemia	Virtuo vs. Bactec FX	Compare time to detection (TTD) and turnaround time (TAT)	9,957 samples processed alternately in both systems over biweekly periods
Syed., *et al*. 2020	Retrospective cross-sectional	2018–2019	All ICU and emergency department samples at CPEIC	Manual vs. BacT/ ALERT	Compare detection rate between manual and automated methods	214 manual and 339 automated cultures analyzed

Isaac., *et al*. 2022	Retrospective analysis	CM: 2008–2012, ABCS: 2015–2020	Pediatric patients (0–18 yrs) with suspected BSIs	Conventional vs. Bactec	Compare yield and isolate types between manual and automated methods	Lab register data of pediatric blood cultures compared
Chowdhury., *et al*. 2021	Cross-sectional	January–December 2018	Neonates with clinically suspected sepsis at NICUs of CMCH and CMOSHMC	Manual vs. BACTEC FX40	Compare diagnostic efficiency and time to detection	Parallel cultures using 1 ml samples in both systems, bedside inoculation

Table 3: Studies comparing automated vs. manual blood culture systems.

In a retrospective study conducted at a tertiary care cardiology hospital, manual and automated blood culture systems were evaluated over a one-year period. The automated system (BacT/ALERT) had a 15.3% detection rate compared to 10.3% for manual methods. This significant increase in detection rate underscored the greater sensitivity of automated systems and encourage authors to its routine use in high volume tertiary hospitals (Rizvi., *et al*. 2020). In pediatric populations, a retrospective analysis comparing conventional methods and the Bactec automated system show a five times higher blood culture detection rate with the automated method. The study also how that automated methods were more effective in detecting Gram positive pathogens (Staphylococcus aureus) and had a broader spectrum of isolate detection. These findings support the adoption of automated blood culture systems in pediatric settings to ensure accurate diagnosis of bloodstream infections [9].

A cross sectional study on neonates admitted to intensive care units compared conventional and automated systems using parallel blood cultures. Both methods showed similar yield in overall positivity, and the mean time to isolate pathogens was shorter in the automated group (26.4 hours) compared to the manual group (46.3 hours). Automated systems detected all isolates identified during the study period, and manual cultures failed to detect 10.2% of them (Table 4). The time efficiency and accuracy of automated systems were shown as improtant factors to optimize neonatal sepsis management [10].

Citation	Demographic Characteristics	Infection Type	Main Findings	Outcomes
Qin., *et al*. 2024	Patients ≥16 yrs from ICU and internal medicine wards	Suspected bloodstream infections (BSIs)	VIRTUO system had higher detection rates, especially for anaerobic and Gram-positive bacteria, and shorter median TTD	Enhanced detection, faster diagnosis, better support for clinical decisions
Halperin., *et al*. 2022	Patients >16 yrs, 9,957 samples analyzed, mixed ED and inpatient population	Suspected bacteremia/fungemia	Virtuo had significantly shorter TTD and TAT compared to Bactec FX	Faster reporting led to earlier clinical intervention and improved antimicrobial stewardship
Syed., *et al*. 2020	Samples from ICU and emergency department	Suspected sepsis	Positive yield was 15.3% with automated vs. 10.3% with manual system	Recommendation for using automated system in tertiary hospitals
Isaac., *et al*. 2022	Children aged 0–18 years	Bloodstream infections in children	Positive cultures: 45.9% in automated vs. 9.7% in manual system; significantly higher detection rate with Bactec	Automated system recommended for pediatric BSIs due to higher sensitivity and reliability
Chowdhury., *et al*. 2021	Neonates in NICUs at CMCH and CMOSHMC	Neonatal septicemia	Mean time to isolate: 26.4h in automated vs. 46.3h in manual; automated detected all isolates, manual missed 10.2%	Automated system significantly reduces time to diagnosis and improves pathogen recovery

Table 4: Detailed study outcomes: automated vs. manual blood culture systems.

Discussion

This systematic review show the better diagnostic performance of automated blood culture systems compared to manual methods in clinical settings. Included studies show higher detection rates and shorter TTD with automated systems, which allow early intervention and improved patient outcomes. Our findings are supported by recent literature showing the importance of rapid and accurate infection diagnosis to guide antimicrobial therapy [11].

BacT/ALERT VIRTUO and BACTEC FX offer operational advantages. *In vitro* evaluations show that VIRTUO detects microbial growth faster than both BACTEC and BacT/ALERT 3D systems, mainly in simulated adult and pediatric blood samples [12]. The Mindray TDR system show comparable action to BacT/ALERT 3D in terms of TTD, with better detection for yeast at low concentrations [13]. Newer automated systems enhance the speed and accuracy of pathogen detection in settings with diverse pathogen profiles and samples.

Early and appropriate therapy guided by early culture results, is important to reduce mortality in critically ill patients with BSI, it's important to control and optimized dosing of antimicrobials, in ICU populations where delays lead to septic shock and death [11]. The ability to perform differential time to detection using automated systems improves the identification of catheter related infections, as shown by Stewart., *et al*. (2023) [14] and make clinical decisions more accurate.

In pediatric setting BSI diagnosis is complicated by low blood volume and non-specific symptoms, so automated systems show significant diagnostic advantages. Isaac., *et al*. (2022) and Chowdhury., *et al*. (2021) showed higher detection rates and faster detection in neonates using automated methods. This is in line with previous findings that neonatal sepsis is commonly caused by Klebsiella and Staphylococcus species, and early diagnosis is important due to high resistance patterns and mortality [15,16].

Studies examined the potential of oral antimicrobial therapy in selected BSI cases, showing the role of rapid diagnostic systems in facilitating transitions. Al-Hasan and Rac (2019) [17] show that early switch to oral therapy is safe in uncomplicated Gram-negative BSIs and some Gram-positive infections, provided culture results are available. Automated systems contribute to antimicrobial care by enabling therapeutic adjustments sooner.

Manual systems is still used, especially in LMICs due to cost and infrastructure challenges. Ombelet., *et al*. (2019) [3] provided practical guidelines to improve manual blood culture practices in these countries, acknowledging that automation improve efficiency, manual methods is a viable option with appropriate protocols. Automated systems improve sensitivity and timeliness, but clinical scoring systems is essential for early risk stratification. Wellbelove., *et al*. (2020) [18] showed that CURB65 and qSOFA scores aid in mortality prediction in BSI cases, which support clinical decision making before culture results become available.

Conclusion

The findings in the included studies show that automated blood culture systems had a substantial benefits over manual methods. These include higher detection sensitivity, faster time to detection, and greater reliability in different patient populations and clinical settings. These advantages are important for timely clinical intervention, improved patient outcomes, and efficient use of hospital resources.

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