

MAJOR ARTICLE

Contamination of blood cultures drawn from arterial catheters versus venipuncture or venous catheters in critically ill patients: a systematic review and meta-analysis

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Background: Arterial catheter-drawn blood culture sampling may reduce patient discomfort and healthcare providers' workload. Guidelines discourage transcatheter blood culture collection due to contamination risks, mainly derived from data on venous catheter-drawn cultures. However, contamination rates of arterial catheter-drawn cultures have not been comprehensively evaluated compared with venipuncture- or venous catheter-drawn cultures.

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Methods: We searched MEDLINE, Embase, and the Cochrane Library from inception through December 5, 2023, for studies comparing arterial catheter-drawn blood cultures with venipuncture- or venous catheter-drawn blood cultures. The primary outcome was blood culture contamination rate. We performed a random-effects meta-analysis and evaluated the certainty of the evidence using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) methodology.

Results: We included six studies involving 8533 blood cultures. When comparing arterial catheter- with venipuncture-drawn cultures, the crude contamination rates were 28/1355 (2.1%) and 103/4539 (2.3%), respectively. Arterial catheter-drawn cultures may not increase contamination rates compared to venipuncture-drawn cultures (risk difference [RD], 0.01; 95% confidence interval [CI], -0.01 to 0.02; low certainty). When comparing arterial catheter- with venous catheter-drawn cultures, the crude contamination rates were 15/489 (3.1%) and 211/2639 (8.0%), respectively. Compared to venous catheter-drawn cultures, arterial catheter-drawn cultures may have lower contamination rates (RD, -0.05; 95% CI, -0.11 to 0.01; low certainty).

Conclusions: In critically ill patients, arterial catheter-drawn blood cultures may have contamination rates comparable to venipuncture-drawn cultures and potentially lower than venous catheter-drawn cultures.

Clinical Trials Registration: Prospero (CRD42023486227)

Key Words: systematic review; blood culture; contamination; arterial line; critical care

Key points: Arterial catheter-drawn blood cultures exhibit contamination rates comparable to venipuncture and may have lower contamination rates than venous catheter-drawn cultures, indicating that arterial catheters could be a practical alternative for blood culture collection in critically ill adult patients.

BACKGROUND

Blood culture contamination, typically defined by one set out of multiple sets being positive for a commensal organism, remains a significant challenge in the management of suspected bacteremia [1]. It complicates pathogen identification by introducing non-pathogenic organisms into the culture, making it difficult to distinguish true bloodstream infection from contamination. As a result, it hinders the optimization of antibiotic therapy and often leads to unnecessary antibiotic use [2]. These challenges not only affect individual patient outcomes and burden healthcare providers, but they also contribute to the broader issue of antimicrobial resistance.

Peripheral venipuncture is considered the gold standard for blood culture collection. However, in critically ill patients, several factors—such as invasive devices, severe skin edema, and coagulation disorders—can make venipuncture difficult [3,4]. Even when venipuncture is possible, it has

several drawbacks. It is labor-intensive, potentially delaying antibiotic initiation and compromising clinical outcomes [3–5]. Additionally, it can cause significant discomfort for patients and increase the risk of needlestick injuries for healthcare providers.

Arterial catheters, commonly used in critically ill patients for continuous blood pressure monitoring and repeated blood sampling (e.g., arterial blood gas analysis), offer an alternative for blood culture collection [6]. Compared to venipuncture, arterial catheter sampling allows for faster blood volume acquisition, which might facilitate timely antibiotic initiation. It also eliminates the need for additional needle punctures, reducing patient discomfort and occupational hazards [7]. These benefits are especially relevant in critically ill patients, where prompt interventions can significantly impact clinical outcomes [5].

Additionally, arterial catheters, compared to venous catheters, appear to have technological advantages. For example, closed sampling systems commonly used in arterial catheters reduce bacterial colonization at stopcocks or catheter hubs, which may reduce the risk of transcatheter blood culture contamination [8–14].

Despite these advantages, current clinical practice guidelines discourage blood culture collection from intravascular catheters due to concerns over potential contamination [15,16]. However, this recommendation is largely based on studies of blood cultures drawn from central venous catheters, leaving uncertainty about contamination risks associated with arterial catheter-drawn cultures [15,16]. To clarify this issue, we conducted a systematic review and meta-analysis comparing the contamination rates of arterial catheter-drawn blood cultures with those obtained through venipuncture or from venous catheters in critically ill patients with suspected bacteremia.

MATERIALS AND METHODS

We conducted a systematic review and meta-analysis in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [17] (see the PRISMA checklist in the Supplementary Data). The review protocol was registered with PROSPERO (registration number: CRD42023486227) and was updated to the latest version. To formulate our review question, we employed the PECOS framework: Population as adult and pediatric patients undergoing blood culture collection; Exposure as blood cultures drawn from arterial catheters; Comparison as blood cultures obtained via venipuncture or from venous catheters; Outcome as the contamination rate; and Study design as randomized controlled trials or observational studies. Since this study relied solely on published data, institutional review board approval was not required.

Selection criteria and search strategy

Eligible studies compared blood cultures drawn from arterial catheters with those obtained via venipuncture or from venous catheters in critically ill adult and pediatric patients. We excluded

reviews, commentaries, editorials, conference abstracts, and studies lacking full-text articles. All blood cultures were included regardless of the timing of collection, including those drawn immediately after catheter insertion. A comprehensive search was performed in PubMed, EMBASE, and the Cochrane Central Register of Controlled Trials from inception to December 5, 2023; the complete search strategy is provided in Supplementary Data. Four investigators independently screened titles and abstracts to identify potentially relevant articles, and full-text reviews were subsequently conducted by the same team. Discrepancies were resolved through discussion under the supervision of a senior investigator.

Data extraction

Two investigators independently extracted data using a standardized data collection form. Disagreements were resolved by consensus or with input from a third senior investigator. Extracted data included the first author, year of publication, country, study design, setting (e.g., hospital), comparators, criteria for determining blood culture contamination, and primary outcome. In cases of missing information, the corresponding authors were contacted via email. For clarification, a “set” refers to one aerobic and one anaerobic blood culture bottle collected simultaneously, and a “pair” refers to two sets drawn from different sites.

Risk of bias assessment

The risk of bias was evaluated using the ROBINS-E (Risk Of Bias In Non-randomized studies – of Exposures) tool [18]. Publication bias and small study effects were assessed by visual inspection of funnel plots.

Outcome

The primary outcome was the contamination rate of blood cultures. An absolute risk difference of 2.0% was predefined as the minimally important difference, based on the only previous study that pre-determined such a threshold in critically ill patients [19]. The previous study employed a 2% non-inferiority margin, corresponding to the difference between the baseline contamination rate in their pilot data (approximately 1%) [19] and the contamination rate recommended in clinical guidelines (< 3%) [20,21].

Statistical analysis

Data synthesis was performed using Review Manager version 5.4 [22]. We calculated risk differences (RDs) and 95% confidence intervals (CIs) using a Mantel-Haenszel random-effects model, with a p value < 0.05 considered statistically significant. Subgroup analyses were conducted comparing arterial catheters versus central venous catheters, adult versus pediatric populations, and studies with overall low risk of bias. The subgroup focusing on central venous catheters as the comparator was selected because these catheters are commonly used for transcatheter blood culture sampling in ICU settings. Additionally, prior studies have reported a

higher contamination risk associated with blood cultures drawn from central venous catheters [23,24]. A subgroup analysis comparing adult and pediatric populations was also conducted, given differences in blood culture collection practices (two bottles per set in adults vs. one bottle per set in children) and the higher contamination rates observed in pediatric patients [25]. These subgroup analyses were performed to explore potential differences in contamination risk associated with different device types and patient populations. The overall certainty of the evidence was assessed using the GRADE methodology [26], and GRADE evidence profile tables were prepared using the GRADEpro software [27]. Informative statements based on the GRADE approach were used to report the results [28].

RESULTS

We identified six observational studies that provided 8533 blood cultures (Figure 1) [7,19,23,24,29,30]. Detailed reasons for exclusions are presented in Supplementary Table 1. Three studies included only adult patients [19,23,30], two involved both adult and pediatric populations [7,24], and one focused on pediatric patients [29]. Key characteristics of the included studies are summarized in Table 1, while the operational definitions of contamination are provided in Table 2 [7,19,23,24,29,30,31–38]. Furthermore, technical details related to blood culture collection — such as skin disinfection protocols, personnel performing the draws, and the sites of arterial catheter placement—are compiled in Supplementary Table 2. Of the studies, three were rated as low risk of bias and three exhibited some concerns regarding bias (Supplementary Table 3). Visual inspection of funnel plots did not reveal any significant publication bias (Supplementary Figure 1 and Supplementary Figure 2). The pooled results are summarized in Table 3.

Arterial catheters versus venipuncture

The crude contamination rate was 28/1355 (2.1%) for arterial catheter-drawn blood cultures and 103/4539 (2.3%) for venipuncture-drawn blood cultures. The aggregated data showed that arterial catheter-drawn blood cultures exhibited minimal difference in contamination rates compared to those obtained via venipuncture (risk difference [RD], 0.01; 95% CI, -0.01 to 0.02; $I^2 = 57\%$; low certainty of evidence; Figure 2). Although subgroup analysis by age (adult versus pediatric) did not reveal a statistically significant effect modification, the pediatric subgroup's CI included a potentially clinically meaningful increase in contamination rates with arterial catheter-drawn cultures (11/276 vs 4/276; RD, 0.03; 95% CI, -0.002 to 0.05; Supplementary Figure 3). Analysis restricted to low risk of bias studies yielded results consistent with the main analysis (RD, 0.01; 95% CI, -0.01 to 0.02; Supplementary Figure 4). The GRADE assessment for this comparison is detailed in Supplementary Table 4.

Arterial catheters vs. Venous catheters

The crude contamination rate was 15/480 (3.1%) for arterial catheter-drawn blood cultures and 211/2639 (8.0%) for venous catheter-drawn blood cultures. The pooled point estimate in this meta-analysis favored arterial catheter-drawn blood cultures compared to venous catheter-drawn blood cultures (RD, -0.05; 95% CI, -0.11 to 0.01; $I^2 = 87\%$; Figure 3), although the certainty of evidence was low and the CI included the null. A subgroup analysis comparing arterial catheters with central venous catheters yielded a similar finding (RD, -0.09; 95% CI, -0.17 to -0.01; $I^2 = 92\%$; low certainty of evidence; Figure 4). Sensitivity analysis restricted to studies with low risk of bias confirmed these results (Supplementary Figure 5). The GRADE assessment for this comparison is summarized in Supplementary Table 5.

DISCUSSION

Our systematic review and meta-analysis of six observational studies compared arterial catheter-drawn blood cultures with those obtained via venipuncture or venous catheters in critically ill patients. The pooled data indicate that arterial catheter-drawn cultures do not increase contamination rates compared to venipuncture and may even reduce contamination relative to venous catheter-drawn cultures. Sensitivity and subgroup analyses largely confirmed these findings.

Venipuncture is widely recognized as the gold standard for blood culture collection because catheter-drawn samples have historically been associated with a higher risk of contamination [16,39]. Consequently, transcatheter sampling has been generally discouraged. A previous systematic review that aggregated all catheter-drawn cultures reported significantly higher contamination rates than those of venipuncture (odds ratio 2.69; 95% CI, 2.03 to 3.57) [16]. However, combining arterial and venous catheter data may have obscured distinct risk profiles. In contrast, our meta-analysis demonstrates that arterial catheter-drawn cultures have contamination rates similar to venipuncture (crude contamination rate: 2.1% vs 2.3%; meta-analyzed data: RD, 0.01; 95% CI, -0.01 to 0.02). Additionally, the contamination rates of arterial catheter-drawn cultures might be lower than those of venous catheter-drawn cultures (crude contamination rate: 3.1% vs 8.0%; meta-analyzed data: RD, -0.05; 95% CI, -0.11 to 0.01), although the certainty of this finding is low, considering that the CI crosses zero.

Prior studies have primarily focused on central venous catheter-drawn cultures, reporting contamination rates between 4.0% and 13%—substantially higher than those observed with venipuncture [23,24]. In contrast, studies specifically on arterial catheter-drawn blood cultures report lower rates (0.3%-2.3%), comparable to those of venipuncture (0.7%-2.6%) [7,19,23]. These findings suggest that arterial catheter sampling has a distinct safety profile, challenging current guidelines that broadly discourage blood culture collection from any intravascular catheter [15,16].

Technological differences between arterial and venous catheters may partly explain the variation in contamination rates. Previous studies have reported that transcatheter blood culture contamination can result from bacterial colonization at catheter stopcocks or hubs, which serve as potential entry points for microbes [8–12]. Arterial catheters are typically equipped with closed sampling systems, which reduce hub manipulation and exposure, thereby lowering the risk of contamination [13,14]. In contrast, venous catheters often lack such systems and are more susceptible to hub colonization. These mechanistic differences may contribute to the numerically lower pooled contamination rates observed in blood cultures drawn from arterial catheters compared to those drawn from venous catheters.

Our age-based subgroup analysis indicated that arterial catheter sampling's effect on contamination rates may vary depending on blood culture sampling practices. In pediatric patients, one bottle per set is commonly collected compared to two bottles per set in adult patients, which may pose challenges of differentiating true bacteremia from contamination. Although no clinically meaningful differences were observed in adults, the pediatric subgroup's CI suggested that arterial catheter-drawn blood cultures might be associated with higher contamination rates in children. Given the limited pediatric evidence — only one neonatal study reported lower contamination from arterial catheters compared to venipuncture [40] — further investigation is warranted before generalizing these findings to all pediatric critically ill patients.

Our findings suggest that arterial catheters might be a reasonable option for blood culture collection in adult critically ill patients, particularly when venipuncture is challenging. However, cautious interpretation is needed due to the low certainty of the evidence, the CI for the venous catheter comparison including the null, and substantial statistical heterogeneity—possibly related to clinical variations across studies, such as differences in catheter insertion protocols, timing of blood collection, and antiseptic agents used. Despite these limitations, our review reinforces guidelines advising against the use of venous catheters for blood culture collection [16,41]. A combined approach—obtaining one set via venipuncture and another via an arterial catheter—may optimize diagnostic accuracy while enhancing procedural efficiency. The current evidence from paired-cultures studies appears to support this strategy, although further studies addressing the limitations identified in our review are needed.

To our knowledge, this is the first meta-analysis to specify the contamination rates of arterial catheter-drawn blood cultures in critically ill patients. By separately analyzing arterial catheter-drawn cultures against both venipuncture- and venous catheter-drawn blood cultures, our study clarifies the distinct risk profiles of these sampling methods. Adherence to a pre-registered protocol further enhances the transparency and reproducibility of our findings.

Several limitations merit consideration. First, the definition of blood culture contamination varied across studies, reflecting the inherent challenge of differentiating contamination from true infection in retrospective analyses. Although this variability may have influenced pooled contamination rates, the CIs did not exceed the predefined clinically meaningful difference

between arterial and venipuncture-drawn cultures. Second, despite eligibility criteria allowing randomized controlled trials, all included studies were observational, with few conducted as multicenter trials and spanning a broad publication period. Furthermore, the number of studies evaluated was limited, with three exhibiting some concerns of bias. Nevertheless, the near-simultaneous collection of two sets of blood cultures (within 5 minutes) helps reduce confounding by minimizing background variability. Future confirmatory studies, even if not randomized, should employ this key design feature to maintain methodological rigor. Third, clinical heterogeneity—such as differences in catheter insertion sites, indwelling durations, or collection techniques—could not be fully addressed due to the study-level data limitations. Fourth, the pediatric subgroup analysis was based on a single-center study, which limits generalizability. Moreover, in pediatric patients, it is common to collect only one bottle of blood culture for each set, while two bottles are recommended in adult patients. This discrepancy in blood culture collection practices may complicate distinguishing true bacteremia from contamination in children, potentially contributing to the higher contamination rates observed in pediatric studies.

CONCLUSION

Our systematic review and meta-analysis indicate that arterial catheter-drawn blood cultures may have contamination rates comparable to venipuncture and potentially lower than venous catheter-drawn cultures in critically ill adults. These findings suggest that arterial catheters could be considered as an alternative sampling method in situations where venipuncture is difficult. However, given the limitations of the available evidence, including the observational nature of the included studies and the variability in study designs, further high-quality research addressing these limitations is needed to confirm these findings and inform clinical guidelines.

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Availability of data and materials

We collected the summary data from published manuscripts. The published article and its supplementary files include all the data generated or analyzed for this study. Further information is available from the corresponding authors upon reasonable request.

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List of abbreviations: CI: confidence interval; GRADE: Grading of Recommendations Assessment, Development and Evaluation; ICU: intensive care unit; PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses; RD: risk difference

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Table 1. Characteristics of the included studies

First author, year	Study design	Setting	Patients	Total number of blood cultures	Comparator
Everts RJ, 2001[7]	Retrospective	Tertiary-care medical center	Adults or pediatrics	2816	Venipuncture, CVC, PICC, Implantable port
Martinez JA, 2002[23]	Retrospective cohort study	Surgical and cardiothoracic ICU	Adults	998	Venipuncture, CVC
McBryde ES, 2005[24]	Retrospective	Database	Hematology/Oncology, ICU adults or pediatrics	1914	Venipuncture, CVC, Implantable port
Berger I, 2018[29]	Observational	PICU	Pediatrics	552	Venipuncture
Nakayama I, 2023[19]	Prospective	ICUs	Adults (≥ 20 years of age)	1180	Venipuncture
Ota K, 2023[30]	Prospective cohort study	ED	Adults (≥ 20 years of age)	1073	Venipuncture, CVC, Peripheral Venous Catheter, Implantable port

ICU: intensive care unit, ED: emergency department, PICU: pediatric intensive care unit, CVC: central venous catheter, PICC: peripherally inserted central catheter

Table 2. Operational definitions of blood culture contamination in the included studies

First author, year	Patients	Definition of contamination
Everts RJ, 2001 [7]	Adults or pediatrics	Each positive blood culture isolate was categorized by either an adult or pediatric infectious diseases or medical microbiology physician as clinically significant, indeterminate, or a contaminant [31].
Martinez JA, 2002 [23]	Adults	Two physicians, blinded to the source from which the blood culture was drawn, classified paired cultures with at least one positive result as true bacteremia (or fungemia) or contamination. A modification of previously published criteria [31,32] was used.

McBryde ES, 2005 [24]	Adults or pediatrics	Organisms that are common skin contaminants (coagulase-negative staphylococci, Propionibacterium spp. and Bacillus spp.) were regarded as contaminants if they were grown from a single culture and the patient did not have a focal site of sepsis [31,33,34].
Berger I, 2018 [29]	Pediatrics	Contamination was defined as the isolation of a skin contaminant from one culture only (arterial catheter or peripheral blood) of the pair of cultures.
Nakayama I, 2023 [19]	Adults	Skin contaminants were defined according to the common commensal list of the Centers for Disease Control and Prevention/National Healthcare Safety Network [35].
Ota K, 2023 [30]	Adults	A blood culture was considered contaminated if one or more of the following organisms were identified in each blood culture sample: coagulase-negative staphylococci (CoNS), Propionibacterium acnes, micrococci, Corynebacteria, Bacillus species other than Bacillus anthracis, or Clostridium perfringens. Viridans group streptococci are regarded as contaminants based on the described criteria [36,37], but are not considered as contaminants at our institution. Polymicrobial cultures showing a mixture of contaminant and true pathogens were regarded as contaminated [38].

Table 3. Summary of the pooled results

Comparator/subgroup	Arterial catheter	Comparator	Risk difference	95% CI	I ²	P value
Venipuncture	28/1355 (2.1%)	103/4539 (2.3%)	0.01	-0.01 – 0.02	57%	0.36
Low risk of bias	17/1086 (1.6%)	16/1365 (1.2%)	0.01	-0.01 – 0.02	68%	0.58
Adults only	8/851 (0.9%)	48/1893 (2.5%)	-0.00	-0.01 – 0.00	0%	0.50
Pediatrics only	11/276 (4.0%)	4/276 (1.4%)	0.03	-0.002 – 0.05	Not applicable	0.07
Venous catheters	15/489 (3.1%)	211/2639 (8.0%)	-0.05	-0.11 – 0.01	87%	0.09
Low risk of bias	4/220 (1.8%)	16/279 (5.7%)	-0.04	-0.07 – -0.01	Not applicable	0.02

Adults only	6/261 (2.3%)	41/507 (8.1%)	-0.04	-0.07 - -0.01	0%	0.006
Central venous catheters	15/489 (3.1%)	185/2178 (8.5%)	-0.09	-0.17 - -0.01	92%	0.03

CI: confidence interval

FIGURE LEGENDS

Figure 1. Flow chart of study selection

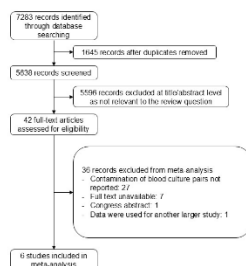


Figure 2. Forest plot for the contamination rate: arterial catheters vs. venipuncture

Legend: A forest plot comparing contamination rates between arterial catheter-drawn blood cultures and venipuncture. Results show minimal difference in contamination rates (28/1355 [2.1%] vs 103/4539 [2.3%]; risk difference 0.01; 95% CI: -0.01 to 0.02; $I^2 = 57\%$; low certainty of evidence).

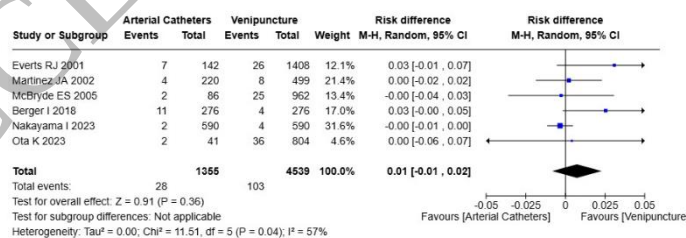
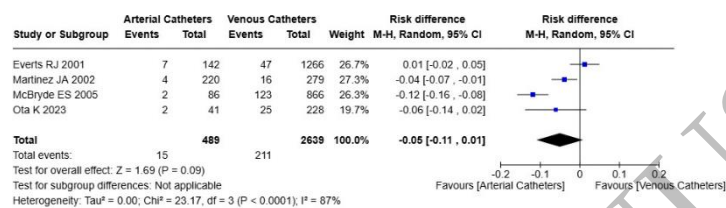
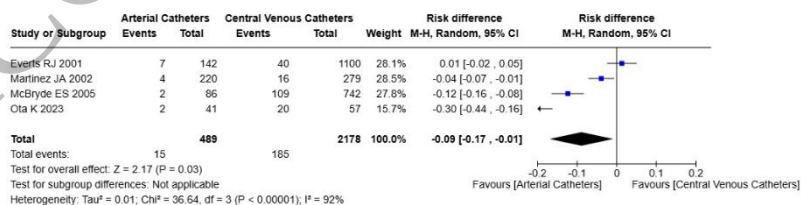


Figure 3. Forest plot for the contamination rate: arterial catheters vs. venous catheters

Legend: A forest plot comparing contamination rates between arterial catheter-drawn and venous catheter-drawn blood cultures. Arterial catheters may slightly reduce contamination rates compared to venous catheters (15/489 [3.1%] vs 211/2639 [8.0%]; risk difference -0.05; 95% CI: -0.11 to 0.01; $I^2 = 87\%$; low certainty of evidence).

**Figure 4. Forest plot for the contamination rate: arterial catheters vs. central venous catheters**

Legend: A forest plot comparing contamination rates between arterial catheter-drawn and central venous catheter-drawn blood cultures. Arterial catheters may reduce contamination rates compared to central venous catheters (15/489 [3.1%] vs 185/2178 [8.5%]; risk difference -0.09; 95% CI: -0.17 to -0.01; $I^2 = 92\%$; low certainty of evidence).



Graphical Abstract

Contamination of blood cultures drawn from arterial catheters versus venipuncture or venous catheters in critically ill patients: a systematic review and meta-analysis

DATA SOURCE 6 observational studies

PECOS

Patient
Adult and pediatric patients for whom blood cultures were obtained

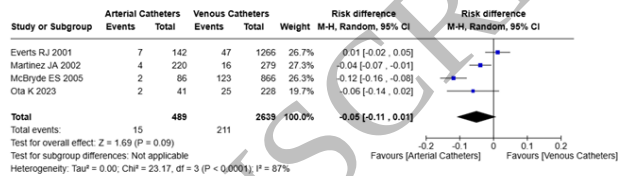
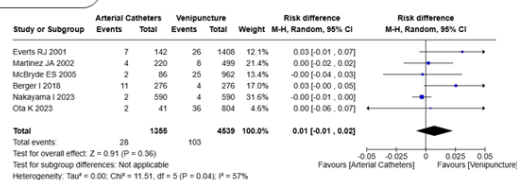
Exposure
Blood cultures drawn from arterial catheters

Control
Blood cultures drawn from venipuncture or venous catheters

Outcome
Contamination

Study design
RCT or observational study

RESULTS



CONCLUSIONS

In critically ill patients, arterial catheter-drawn blood cultures may have contamination rates comparable to venipuncture-drawn cultures and potentially lower than venous catheter-drawn cultures.