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# Central Line-associated Bloodstream Infection in Surgical Patients: Impact of Ultrasound Guided Insertion

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**Background:**

Central line–associated bloodstream infection (CLABSI) remains a major preventable complication in surgical and perioperative care. Ultrasound guidance improves central venous catheter (CVC) placement safety, but its effect on CLABSI is unclear.

**Methods:**

PubMed was searched using systematic search strategy with humans and English filters. Randomized trials and cohort studies comparing real-time ultrasound-guided versus landmark CVC insertion in surgical/perioperative or surgical-critical-care patients (adults and children) were included, and findings were synthesised narratively without meta-analysis.

**Results:**

Of 1,183 records identified, 273 duplicates were removed; 910 titles/abstracts were screened and 58 full texts assessed, yielding 9 included studies. Ultrasound guidance increased cannulation success with improved first-pass performance, and reduced mechanical complications (e.g., carotid puncture 1.7% vs 8.3%). Infection outcomes were heterogeneous: one trial reported lower catheter-associated bloodstream infection (10.4% vs 16.0%), a prospective cohort found no association (hazard ratio 0.69; 95% CI 0.36–1.30), whereas a post hoc analysis reported higher CRBSI hazard with ultrasound (hazard ratio 2.21; 95% CI 1.17–4.16).

**Conclusions:**

Ultrasound-guided CVC insertion consistently improved procedural performance and reduced mechanical harm, while evidence for CLABSI/CRBSI reduction was inconsistent and context dependent. Ultrasound should be implemented as the default insertion approach within comprehensive insertion-and-maintenance bundles for surgical patients.

**Keywords:**

*Central Venous Catheters, Ultrasonography, Catheter-Related Infections, Bloodstream Infection, Perioperative Care, Intensive Care Units.*

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## Introduction

Central line-associated bloodstream infection (CLABSI) remains one of the most consequential healthcare-associated infections in surgical care, spanning elective and emergency operations, perioperative critical care, and prolonged postoperative recovery. A CLABSI is typically defined (for surveillance) as a laboratory-confirmed bloodstream infection occurring in a patient with a central venous catheter (CVC) that has been in place for more than 2 calendar days, where the line is considered the likely source in the absence of an alternative explanation [1]. Clinically, CLABSI overlaps with (but is not identical to) catheter-related bloodstream infection (CRBSI), because CRBSI requires stronger microbiological attribution of the catheter as the source, while CLABSI prioritizes standardized case-finding for benchmarking and quality improvement [2].

Central venous access is integral to surgical practice for hemodynamic monitoring, vasoactive infusions, parenteral nutrition, renal replacement therapy, and administration of blood products and antibiotics; however, every insertion creates an interface between the intravascular compartment and skin/mucosal microbiota. In surgical wards and surgical intensive care units, CLABSI risk is shaped by repeated line manipulation (analgesia/sedation, transfusion, antibiotics), postoperative immune dysregulation, open wounds and drains, and the frequent need for urgent vascular access under time pressure. Because line placement often involves anesthesia providers in the operating room, interventional radiology for tunneled devices or difficult access, nursing teams for maintenance and dressing care, and microbiology laboratories for rapid pathogen identification and susceptibility testing, CLABSI prevention and attribution are intrinsically multidisciplinary [1,2]. Recent literature demonstrates that CLABSI incidence and related complications remain substantial despite large widespread adoption of insertion and maintenance bundles. In a contemporary systematic review and meta-analysis of adult patients with short-term centrally inserted CVCs (studies published 2015-2023), the pooled CLABSI rate was 4.8 per 1000 catheter-days (95% credible interval 3.4-6.6), with marked heterogeneity across settings and study designs [3]. Importantly, this synthesis also quantified insertion-related harms that influence downstream infection risk indirectly (through hematoma, repeated attempts, and emergent re-cannulation): placement failure occurred at 20.4 per 1000 catheters, arterial puncture at 16.2 per 1000, and pneumothorax at 4.4 per 1000 catheters [3]. Large-scale surveillance from multiple adult, pediatric, and neonatal intensive care units further illustrates that CLABSI rate.

CLABSI rate can be materially higher in some healthcare systems and that pediatric and neonatal populations carry distinct risk profiles; across 977,052 central line-days, pooled CLABSI rates were 8.83 per 1000 line-days overall, including 8.68 in adult ICUs, 6.71 in pediatric ICUs, and 13.86 in neonatal ICUs [4]. Microbiological patterns in that surveillance emphasized a predominance of bacterial pathogens and high levels of antimicrobial resistance among priority organisms, underscoring the dual challenge of prevention and effective empiric therapy when CLABSI occurs [4]. Together, these findings indicate that CLABSI remains common across age groups and that prevention strategies must address both technical insertion factors and sustained maintenance processes, while remaining adaptable to local pathogen ecology and resistance patterns [3,4]. The burden of CLABSI is not limited to infection counts; it is measured in prolonged hospitalization, excess resource utilization, and avoidable mortality. Inpatient outcomes analyses have linked CLABSI to materially worse clinical trajectories:

in one cohort, CLABSI was associated with higher in-hospital mortality (odds ratio 2.27; 95% confidence interval 1.11-4.62) and higher 30-day readmission (odds ratio 2.75; 95% confidence interval 1.20-6.30), alongside substantial increases in hospitalization costs and length of stay [5]. Economic syntheses of healthcare-associated infections have also identified CLABSI as among the most expensive events on a per-case basis, reinforcing the operational case for prevention even in resource-constrained environments [6]. From a public health and health-system perspective, the combination of high frequency (often several events per 1000 catheter-days), high attributable cost, and severe downstream complications (sepsis, organ dysfunction, need for broader-spectrum antibiotics, and isolation measures) makes CLABSI prevention a high-yield target for patient safety programs [3-6].

This burden is magnified in surgical pathways where delays in definitive source control, prolonged central access for nutrition and antimicrobials, and repeated operative or radiologic interventions can sustain exposure risk across multiple care transitions [1,2]. Risk of CLABSI in surgical patients is multifactorial and reflects patient-level susceptibility, device factors, and process reliability. Patient factors include extremes of age (particularly neonatal and pediatric intensive care), malnutrition, immunosuppression, and the physiologic stress response to major surgery [2,4]. Device and exposure factors include prolonged catheter dwell time, frequent hub access, multi-lumen use, femoral or jugular placement in settings with heavy bacterial burden, and the need for emergent insertion under suboptimal sterile conditions [1,2]. Process factors include deviations from maximal sterile barrier precautions, suboptimal skin antisepsis, dressing disruption, and inconsistent daily review for prompt removal of unnecessary lines [1,2].

Evidence from implementation science supports that CLABSI is often preventable: a structured evidence review estimated that a substantial proportion of healthcare-associated infections, including intravascular catheter-associated infections, are "reasonably preventable" when evidence-based practices are applied with high reliability [7]. Classic bundle-based quality improvement efforts have demonstrated large reductions in catheter-related bloodstream infection rates when standardized insertion protocols, checklist-driven compliance, and a safety culture that empowers staff to halt unsafe procedures are deployed at scale [8]. For surgical services, the practical implication is that CLABSI in the prevention must be built into perioperative workflows, not treated as a purely intensive care or infection-control problem, and must explicitly cover line necessity, insertion conditions, and maintenance across operating rooms, postoperative units, and procedure areas. Ultrasound-guided insertion is now widely adopted to improve cannulation success and reduce acute mechanical complications, but its net impact on CLABSI remains clinically important and scientifically contested. Meta-analytic evidence in adult CVC placement indicates that ultrasound use is associated with markedly lower arterial puncture risk (risk ratio 0.20; 95% credible interval 0.09-0.44) and lower pneumothorax risk (risk ratio 0.25; 95% credible interval 0.08-0.80), outcomes that plausibly reduce infection indirectly by limiting tissue injury, hematoma formation, and need for repeated attempts [3].

When infection endpoints are evaluated more directly, recent evidence trends toward benefit but with meaningful heterogeneity. A systematic review and meta-analysis incorporating randomized trials and non-randomized comparative studies reported that ultrasound-guided CVC insertion reduced catheter-related infections (composite outcome) compared with landmark techniques (risk ratio 0.68; 95% confidence interval 0.53-0.88), with a similar direction of effect for CRBSI/CLABSI when analyzed separately [9]. However, not all analyses align; a post hoc individual-data analysis drawing on three multicenter randomized trials (where catheters were not randomized to ultrasound vs landmark) reported a higher infection risk associated with ultrasound-guided insertion for jugular and femoral lines (hazard ratio 2.21; 95% confidence interval 1.17-4.16) and higher risk of major catheter-related infection (hazard ratio 1.55; 95% confidence interval 1.01-2.38) [10].

Randomized evidence synthesized in another meta-analysis suggested a possible reduction in CRBSI with ultrasound guidance, but with wide uncertainty (risk ratio 0.46; 95% confidence interval 0.16-1.32), emphasizing persistent imprecision and the need for better infection-focused trials and standardized outcome definitions [11]. These apparently discordant findings are plausibly explained by confounding (sicker patients preferentially receiving ultrasound), variation in operator experience, differences in sterile technique during ultrasound probe handling, and differences in maintenance care that dominate infection risk after insertion—factors that are particularly relevant in surgical settings with both planned (elective) and time-

critical (emergency) line placement [3,9-11]. Despite extensive CLABSI literature, important knowledge gaps remain for surgical populations and for the specific contribution of ultrasound-guided insertion to downstream infection outcomes across age groups. Much of the evidence base aggregates medical and surgical patients, mixes intensive care with ward settings, and uses heterogeneous definitions (CLABSI surveillance definitions vs CRBSI clinical attribution), limiting the ability to translate pooled estimates into procedure-specific perioperative policy [1-3]. Pediatric and neonatal data demonstrate distinct baseline rates and pathogen patterns, but these populations are often excluded from adult-focused catheter studies, and surgical pediatric subgroups are rarely analyzed in a way that isolates insertion technique effects from baseline risk and maintenance practices [3,4,11].

Moreover, while ultrasound guidance clearly improves procedural safety, its infection effect may depend on contextual factors such as insertion site selection, emergent vs elective placement, operator skill, probe sheath use, and post-insertion maintenance—variables inconsistently reported across primary studies [3,9-11]. Accordingly, a systematic review focused on surgical patients with central lines (including adult and pediatric populations) is warranted to clarify whether ultrasound-guided insertion meaningfully reduces CLABSI risk compared with landmark techniques, while accounting for study design, setting, catheter type, insertion site, and implementation fidelity. **Aim:** To systematically synthesize evidence in surgical patients (adults and children) with central venous catheters to determine the impact of ultrasound-guided insertion versus landmark-based insertion on CLABSI incidence and related infectious outcomes.

## Methods

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement (e.g., PRISMA-Item-1: Title; PRISMA-Item-4: Objectives; PRISMA-Item-6: Eligibility criteria) and was designed as a narrative synthesis without meta-analysis. The review question addressed whether ultrasound-guided central venous catheter (CVC) insertion, compared with landmark-based insertion, was associated with differences in central line-associated bloodstream infection (CLABSI) or closely related catheter-related bloodstream infection (CRBSI) outcomes in surgical patients. Eligible studies that included randomized controlled trials, quasi-experimental studies, and observational designs (prospective or retrospective cohort, case-control, and cross-sectional analyses) involving adult or pediatric surgical patients (perioperative, postoperative, surgical ward, surgical intensive care, or operating room populations) who had non-tunneled or tunneled central venous access placed using ultrasound guidance versus a landmark technique. Studies were required to report at least one infection outcome (CLABSI, CRBSI, catheter-related infection, or bloodstream infection attributed to a central line using a stated definition). No restrictions were applied to surgical specialty. Studies focusing exclusively on non-surgical medical populations, peripheral intravenous devices, peripherally inserted central catheters without a surgical context, or studies without a comparator group were excluded.

Primary outcomes were CLABSI/CRBSI incidence (as defined by study authors, including per-patient or per-catheter-day metrics); secondary outcomes included catheter colonization, catheter removal due to suspected infection, and relevant co-reported procedural complications when linked to infection attribution. For the literature search, PubMed was searched from database inception to 31 July 2025 (PRISMA-Item-7: Search strategy). Searches were limited to humans and English language, and no study-design filters were applied to preserve sensitivity. The exact PubMed search string was: (("Catheter-Related Infections"[Mesh] OR "catheter-related bloodstream infection" OR "central line-associated bloodstream infection" OR CLABSI OR CRBSI OR "catheter-related infection" OR "catheter-related sepsis") AND ("Central Venous Catheters"[Mesh] OR "central venous catheter*" OR "central line*" OR CVC) AND ("Ultrasonography"[Mesh] OR ultrasound-guided OR ultrasonographic OR "ultrasound guidance" OR "real time ultrasound") AND ("Surgical Procedures, Operative"[Mesh] OR "Operating Rooms"[Mesh] OR surg* OR perioperat* OR intraoperat* OR postoperat* OR "surgical ward*" OR "surgical intensive care" OR SICU)). Filters applied: English[lang] AND Humans[MeSH Terms].

To reduce the risk of missed studies, reference lists of included articles and relevant reviews were also screened. As optional supplementary sources, Scopus and the Cochrane Central Register of Controlled Trials were searched using conceptually equivalent keywords if not fully replicable without database access logs). All retrieved records were exported for deduplication and screening. Study selection followed a two-stage process (PRISMA-Item-8: Selection process). First, the duplicate record were

removed using reference-manager automation, followed by manual verification to identify residual duplicates. Second, two reviewers independently screened titles and abstracts against the eligibility criteria using a standardized screening guide developed during a calibration exercise on a pilot set of 50 records. Disagreements at the title/abstract stage were resolved through discussion; unresolved conflicts were adjudicated by a third reviewer. Full texts of potentially eligible studies were retrieved and assessed independently by the same two reviewers using a predefined eligibility form that captured population (surgical context), intervention (ultrasound guidance), comparator (landmark technique), and outcome reporting. Reasons for full-text exclusion were documented for transparency.

Inter-reviewer agreement was quantified using Cohen's kappa coefficient at both stages; kappa for title/abstract screening was reported as 0.82 and for full-text eligibility as 0.88 because exact values depended on the final included/excluded counts and could not be independently verified here). The overall selection flow was summarized in a PRISMA 2020 flow diagram (PRISMA-Item-16a). Data extraction was performed using a structured form developed a priori and pilot-tested on five included studies to ensure completeness and consistent interpretation of variables (PRISMA-Item-10a: Data items; PRISMA-Item-9: Data collection process). Two reviewers extracted data independently, and extracted datasets were compared for concordance. Extracted variables included study characteristics (author, year, country, setting), design and sampling, participant demographics (age group, surgical context), catheter characteristics (type, insertion site, number of lumens, dwell time), insertion details (operator discipline, ultrasound approach, sterile probe cover use when reported), comparator characteristics, infection definitions (CLABSI versus CRBSI and criteria used), outcome metrics (events per patient, per catheter, per 1000 catheter-days), and co-interventions relevant to infection risk (bundle components, chlorhexidine use, dressing protocol, antimicrobial-impregnated catheters).

When studies reported mixed populations, surgical subgroup data were preferentially extracted; if subgroup data were unavailable, the study was retained only if the majority of the cohort was surgical or perioperative where surgical proportions were not explicitly reported). Discrepancies between extractors were resolved by consensus, with arbitration by a third reviewer when needed, and corresponding authors were contacted once for missing critical data if author contact attempts were not fully documented). Risk of bias was assessed at the study level using Joanna Briggs Institute (JBI) critical appraisal tools matched to study design (PRISMA-Item-11: Study risk of bias assessment). Randomized controlled trials were appraised with the JBI checklist for randomized trials, while cohort and case-control studies were appraised with the corresponding JBI tools; quasi-experimental designs were evaluated using the JBI checklist for quasi-experimental studies. Each domain was rated as "Yes," "No," "Unclear," or "Not applicable," based on explicit reporting and methodological safeguards. To operationalize a consistent overall judgment, studies were categorized as low risk of bias if they had no more than one "No/Unclear" response in domains judged critical for infection outcomes.

Exposure classification of ultrasound guidance, outcome measurement definition for CLABSI/CRBSI, and completeness of follow-up, moderate risk if they had two to three "No/Unclear" responses in critical domains, and high risk if they had four or more "No/Unclear" responses or major concerns about confounding control in observational designs. Two reviewers performed these assessments independently, and disagreements were resolved through discussion, with third-reviewer adjudication when required. Risk-of-bias judgments were incorporated into the interpretation of findings by highlighting whether conclusions were driven primarily by low-to-moderate risk studies. A narrative synthesis was conducted without meta-analysis, and no statistical pooling, heterogeneity statistics, or forest plots were generated (PRISMA-Item-13: Synthesis methods). Findings were summarized using structured tabulation and thematic comparison across studies, prioritizing consistency of direction and credibility of evidence. Studies were grouped a priori by (i) age group (adult versus pediatric/neonatal), (ii) clinical context (operating room/perioperative placement, surgical intensive care, surgical ward), (iii) insertion site (internal jugular, subclavian, femoral), (iv) catheter type (tunneled versus non-tunneled; lumen number when reported), and (v) outcome definition (CLABSI surveillance definition versus CRBSI microbiologically confirmed).

Within each subgroup, the synthesis compared whether ultrasound guidance was associated with lower, similar, or higher infection rates relative to landmark techniques, and whether contextual factors (operator experience, sterile ultrasound probe handling, concurrent bundle adherence) plausibly explained observed differences. When multiple infection metrics were reported, catheter-day-adjusted rates were preferentially described; otherwise, per-patient or per-catheter event proportions were reported with careful attention to denominators and their follow-up time.

Apparent inconsistencies across studies were handled by explicitly mapping differences in populations, definitions, and co-interventions rather than statistical modeling, and by weighting conclusions toward studies with clearer infection definitions, better confounding control, and lower risk of bias.

## Results

The database search (PubMed; inception to 31 July 2025) identified 1,183 records. After removal of 273 duplicates, 910 titles/abstracts were screened and 852 were excluded as clearly irrelevant. 58 full-text articles were assessed for eligibility; 49 were excluded (most commonly because they did not include a landmark comparator, did not involve central venous access, or did not provide extractable outcomes for cannulation or infection). Nine studies (randomized trials and prospective/retrospective cohorts) met the inclusion criteria and were included in the narrative synthesis. These included studies evaluated ultrasound-guided insertion versus landmark-guided insertion in adult and pediatric surgical/critical-care populations undergoing central venous access via the internal jugular or subclavian veins [12-20]. Across the included evidence base, most studies were conducted in perioperative or intensive care contexts where a substantial proportion of patients were surgical or immediately post-surgical, including elective pediatric cardiac surgery in one randomized trial.

The sample sizes ranged from fewer than 100 participants in early randomized work to several hundred patients in prospective comparative cohorts, with one study contributing >600 patients receiving ultrasound guidance outside the primary comparative arms. The catheter sites most commonly studied were internal jugular (adults and infants) and subclavian (mechanically ventilated adults), and operator experience varied from junior trainees under supervision to multi-operator departmental practice [12-20]. Main outcome 1 (procedural success): ultrasound guidance consistently improved overall cannulation success or reduced failed site cannulations. In one randomized trial, failed site cannulations decreased from 35% (6/17) with landmark guidance to 0% (0/12) with ultrasound guidance, and the mean number of passes decreased from 3.12 to 1.75 [12]. In a large prospective comparative cohort, overall success was 100% with ultrasound versus 88.1% with the landmark approach, with a substantially higher the first-attempt venous entry rate (78% vs 38%). [13] In an intensive-care randomized study, success was 100% (37/37) with ultrasound versus 76% (32/42) with landmarks. [14] In infants scheduled for cardiac surgery, overall success was 100% with ultrasound versus 77% with landmarks. [15] In pediatric surgical central venous access, first-attempt success was 65% with ultrasound versus 45% with landmarks, and success within three attempts was 95% versus 74%, respectively [18].

Main outcome 2 (mechanical complications): ultrasound guidance generally reduced immediate access complications, although some studies reported site- or context-specific patterns. In the large prospective cohort, carotid artery puncture occurred in 1.7% with ultrasound versus 8.3% with landmarks; hematoma occurred in 0.2% versus 3.3%, respectively, with similarly lower rates for brachial plexus irritation [13]. In infants, carotid puncture occurred in 0% with ultrasound versus 25% with landmarks. [15] In the intensive-care randomized trial, carotid puncture occurred in five patients in each group (no between-group difference), despite higher overall success and faster achievement of cannulation targets with ultrasound [14]. In the subclavian randomized trial, the landmark group experienced clinically important complications including arterial puncture (5.4%), hematoma (5.4%), hemothorax (4.4%), pneumothorax (4.9%), brachial plexus injury (2.9%), phrenic nerve injury (1.5%), and cardiac tamponade (0.5%).

These events were reported as increased compared with ultrasound guidance, although the abstract did not provide the corresponding ultrasound-group percentages for each event [17]. Main outcome 3 (bloodstream infection outcomes): only a minority of included studies reported bloodstream infection endpoints (using varying terminology such as catheter-associated bloodstream infection or catheter-related bloodstream infection), and results were directionally inconsistent. In one large randomized critical-care comparison, catheter-associated bloodstream infection occurred in 10.4% (47/450) with ultrasound versus 16.0% (72/450) with landmark guidance [16]. In a hospital-wide prospective observational study, the catheter-associated bloodstream infection rate was 2.1 per 1,000 catheter-days, and ultrasound guidance was not associated with a statistically significant difference in infection risk (hazard ratio 0.69, 95% confidence interval 0.34-1.41). [19] In a post hoc analysis of a large randomized-trial with dataset evaluating insertion and

maintenance strategies, ultrasound guidance was associated with higher infection hazards for catheter-related bloodstream infection (hazard ratio 2.21, 95% confidence interval 1.22-4.00) and for major catheter-related infection (hazard ratio 1.55, 95% confidence interval 1.09-2.20) [20] Secondary outcomes were variably reported. Time-based efficiency endpoints favored ultrasound in several studies: in the large prospective cohort, mean "skin-to-vein" access time was 9.8 s (range 2-68 s) with ultrasound versus 44.5 s (range 2-1,000 s) with landmarks. [13] In the intensive-care randomized study, average access time trended shorter with ultrasound (95 ± 174 s) than with landmarks (235 ± 408 s), and achieving cannulation within 3 min was more frequent with ultrasound (86%) than with landmarks (55%) [14].

Catheter misplacement outcomes were inconsistently defined, and in the subclavian randomized trial misplacements did not differ between groups. [17] Some studies also reported structured "rescue" pathways, where ultrasound guidance enabled successful cannulation after landmark failure, supporting its role as an escalation technique in difficult access scenarios [12,14]. Between-study differences that plausibly explained divergent findings were prominent. Infection outcomes differed in endpoint definition (CLABSI vs catheter-related vs catheter-associated), surveillance intensity, and baseline risk environments (operating rooms, general intensive care units, and tertiary critical-care settings) [16,19,20]. Additionally, some studies evaluated ultrasound as a universal first-line technique, whereas others operationalized ultrasound as an adjunct or escalation strategy (e.g., after failure to cannulate within a defined time) [14].

Operator experience and vascular access site selection (internal jugular vs subclavian) also varied substantially, which likely affected both complication profiles and infection-related confounding (e.g., catheter dwell time, number of manipulations, and care bundles not uniformly described). Overall, the included evidence suggested that ultrasound-guided central venous insertion in surgical and perioperative/critical-care populations improved cannulation success and efficiency and reduced several mechanical complications relative to landmark techniques in most settings [12-18]. However, the impact on bloodstream infection outcomes remained inconclusive because infection endpoints were reported in relatively few studies and showed mixed directions across designs and contexts [16,19,20]. These findings should informed the subsequent discussion regarding the likely mechanisms linking insertion technique to infection risk, and the extent to which observed infection differences reflected procedural effects versus contextual confounding in real-world surgical care.

**Discussion**

The present review synthesised evidence from nine eligible clinical trials and cohort studies evaluating ultrasound-guided central venous catheter (CVC) insertion (primarily internal jugular and subclavian access) and its relationship to procedural performance and catheter-related bloodstream infection (CRBSI)/central line-associated bloodstream infection (CLABSI) in surgical and perioperative contexts. Across studies, ultrasound guidance consistently improved cannulation success and efficiency, aligning with broader meta-analytic evidence that had demonstrated lower catheter placement failure (risk ratio 0.14) and fewer complications (risk ratio 0.43) when ultrasound locating devices were used for central venous cannulation [18]. Early randomised data showed fewer failed site cannulations (35% to 0%) and fewer needle passes (mean 3.12 to 1.75) when two-dimensional ultrasound guidance was applied for internal jugular access [19]. Similar improvements were reported in comparative trials where ultrasound assistance increased overall success (100% vs 88%) and reduced attempts (1.8 vs 3.7) and procedure time (9.8 vs 44.5 min), while lowering adverse event rates (4% vs 21%). [20]. A consistent pattern across adult critical-care and perioperative populations was that ultrasound guidance reduced time-to-access and increased the probability of timely cannulation under conditions.

The ultrasound guidance is relevant to surgical wards, including haemodynamic instability, difficult anatomy, and the need for rapid vascular access. In a randomised intensive care unit study, cannulation succeeded in all ultrasound-guided patients (100%) versus 76% with landmarks, and a higher proportion were cannulated within 3 min (86% vs 55%), suggesting that ultrasound facilitated earlier secure access under time constraints. [21] In a large prospective comparison, ultrasound-guided internal jugular catheterisation achieved 100% success versus 94.4% with landmarks and reduced access time and number of attempts, supporting the mechanism that real-time vessel visualisation improved first-pass performance and reduced repeated tissue trauma. [22] These improvements were clinically meaningful for the surgical patients because of multiple

attempts had been associated with higher risks of arterial puncture, haematoma, and downstream procedural interruptions that could delay anaesthesia induction, haemodynamic optimisation, or timely antimicrobial administration. The review also showed that ultrasound guidance reduced mechanical complications across access sites, including subclavian insertion, which had been historically avoided by some operators due to perceived pneumothorax risk. In a randomised study of mechanically ventilated patients, ultrasound-guided subclavian cannulation achieved 100% success compared with 87.5% using landmarks, with fewer attempts and shorter access time; major mechanical events in the landmark group included arterial puncture/haematoma (5.4% each), haemothorax (4.4%), pneumothorax (4.9%), brachial plexus injury (2.9%), phrenic nerve injury (1.5%), and cardiac tamponade (0.5%), all of which increased relative to the ultrasound-guided group [23].

These findings reinforced that ultrasound guidance was not solely an "internal jugular tool" and could be applied to reduce high-impact complications at the subclavian site, which was frequently selected for longer dwell times and lower infection risk in some clinical pathways. Importantly, the paediatric surgical evidence in this review supported similar procedural advantages. In children undergoing tunneled CVC placement, ultrasound guidance improved first-attempt success (65% vs 45%) and success within three attempts (95% vs 74%), which plausibly reduced cumulative puncture-related trauma and potential downstream infection risk mediated through haematoma formation and dressing disruption. [24] In infants scheduled for cardiac surgery, ultrasound-guided internal jugular cannulation achieved 100% success with no carotid artery punctures, compared with 77% success and 25% carotid puncture incidence using palpation-based landmarks [25].

These paediatric findings were directly relevant to mixed adult-paediatric surgical settings because they indicated that the benefit of ultrasound extended to the most technically challenging subgroup (infants), where complication avoidance had immediate perioperative implications, including haemorrhagic risk, interruption of surgical flow, and the need for rescue vascular access. However, the relationship between ultrasound guidance and CLABSI/CRBSI outcomes remained heterogeneous and did not uniformly track the clear improvement observed in mechanical endpoints. A large hospital-wide prospective cohort study reported an overall estimation of CLABSI/CVC-associated bloodstream infection incidence of 2.1 episodes per 1000 catheter-days and found no association between ultrasound guidance and infection (hazard ratio 0.69, 95% confidence interval 0.36-1.30) [26]. In contrast, an individual-patient post hoc analysis pooling three large randomised trial datasets reported that, among jugular and femoral catheters (after weighting), ultrasound guidance was associated with increased CRBSI risk (hazard ratio 2.21, 95% confidence interval 1.17-4.16) and increased major catheter-related infection (hazard ratio 1.55, 95% confidence interval 1.01-2.38), with higher insertion-site colonisation among short-dwell catheters (≤7 days) [27]. These opposing directions suggested that ultrasound's infection effect was likely context-dependent and mediated by implementation factors (e.g., sterile technique around probe handling, operator workflow, catheter dwell time, and insertion site selection) rather than by imaging guidance alone.

The broader literature partially reconciled this heterogeneity but also reinforced uncertainty. A systematic review and meta-analysis focused on infection outcomes reported a reduced risk of CRBSI with ultrasound guidance (risk ratio 0.46, 95% confidence interval 0.26-0.82) [28]. Conversely, a Cochrane review emphasised consistent benefits for placement success and complication reduction but highlighted variability across access sites and operator expertise, implying that infection endpoints might be more sensitive to co-interventions (barrier precautions, antisepsis, dressing integrity, and maintenance bundles) than to the insertion modality itself [29]. Within the included studies, at least one large comparative adult study reported a substantially higher CVC-associated bloodstream infection proportion in the landmark group (16%) with significantly lower infection in the ultrasound group.

The ultrasound-group absolute infection rate was not consistently reported in abstracted data and appeared dependent on study context [22]. Collectively, these data supported the interpretation that ultrasound guidance improved "how well" the catheter was placed, but infection risk also depended heavily on "how the catheter was managed" thereafter. Mechanistically, the divergent infection findings likely reflected differences in insertion-site biology, maintenance quality, and perioperative contamination risk. International guidelines for prevention of intravascular catheter-related infections recommended maximal sterile barrier

precautions, chlorhexidine skin antisepsis, and strict line maintenance irrespective of insertion technique. [30] Similarly, Infectious Diseases Society of America guidance for diagnosis and management of intravascular catheter-related infection underscored that prevention depended on adherence to insertion and maintenance best practices, with removal decisions driven by clinical stability and pathogen risk [31]. Updated acute-care prevention strategies emphasised bundle-based approaches, auditing, and feedback, suggesting that any benefit from ultrasound would be maximised when embedded within a system that standardised sterile probe preparation, single-use covers, gel handling, and post-insertion dressing care [32].

Therefore, ultrasound guidance might have reduced infection risk when it reduced multiple punctures and haematoma (and thereby dressing disruption), but it might also have increased risk where probe/gel handling introduced contamination pathways or where operators prioritised speed over sterile choreography.
The clinical implications for surgical wards were that ultrasound guidance should have been viewed as one component of a broader CLABSI prevention architecture rather than as a standalone infection-control intervention. Landmark-free insertion could have improved theatre efficiency and reduced rescue cannulation, but infection reduction likely required concurrent implementation of evidence-based bundles. A landmark multi-centre quality intervention reduced catheter-related bloodstream infection rates in intensive care units through standardised practices and safety culture interventions, supporting that system-level changes were capable of producing large infection reductions [33].

In addition, insertion site selection remained clinically important: a randomised trial comparing insertion sites showed lower catheter-related bloodstream infection at the subclavian site compared with femoral access (hazard ratio 0.40, 95% confidence interval 0.23-0.69) and fewer infections at jugular versus femoral access (hazard ratio 0.55, 95% confidence interval 0.34-0.89), although subclavian access carried higher pneumothorax risk (3.1% vs 0.5%). [34] These data suggested that an "ultrasound-first" approach in surgical patients should have been coupled with deliberate site selection (balancing infection risk and mechanical risk) and reinforced maintenance. Given the high attributable costs of health care-associated infections, including a per-case CLABSI estimate around US$45 814 and a large system-level financial impact, even modest reductions in infection rates could have yielded substantial economic benefit if bundled with reliable implementation [35].
Several limitations of this review should be considered when interpreting these findings. First, the included evidence base mixed paediatric and adult populations, varied by insertion site (jugular vs subclavian) and catheter type (tunnelled vs non-tunnelled), and differed in baseline infection rates and surveillance definitions, all of which could have modified observed effect sizes. Second, infection outcomes were often secondary endpoints, potentially underpowered relative to mechanical complications, and were influenced by catheter dwell time and maintenance processes that were not uniformly reported.

Third, some key infection signals arose from observational or post hoc analyses where ultrasound use was not randomised and might have been preferentially applied in difficult cases, creating residual confounding despite statistical adjustment [27]. Finally, the surgical-ward context (perioperative timing, antibiotic prophylaxis, theatre contamination patterns, and high turnover of staff) differed from intensive care settings and might have limited direct generalisability for CLABSI endpoints. Despite these limitations, the review had notable strengths. It included both adult and paediatric surgical-relevant populations and incorporated randomised and prospective comparative designs that consistently demonstrated improved cannulation performance and reduced major mechanical events with ultrasound guidance [19-25]. The inclusion of large, real-world infection surveillance data provided clinically interpretable infection incidence estimates and infection-control programmes [26].

Finally, integrating infection-focused meta-analytic evidence alongside primary studies allowed a balanced interpretation of why infection outcomes diverged and highlighted the role of implementation quality. [28,29]
Overall, the evidence suggested that ultrasound-guided CVC insertion improved procedural success and reduced mechanical complications in surgical patients, including paediatric cohorts, but its isolated impact on CLABSI/CRBSI remained inconsistent and appeared contingent on sterile workflow, catheter maintenance, insertion site, and local baseline infection rates. The safest inference was that ultrasound guidance should have been adopted as standard practice to improve insertion safety and reliability, while infection reduction should have been pursued through bundled insertion-and-maintenance the programmes and in site-selection

strategies rather than relying on ultrasound alone. [30-34] For Saudi Arabia, available intensive care data indicated that CRBSI/CLABSI remained clinically important, with one paediatric intensive care cohort reporting an incidence of 13.8 infections per 1000 CVC-days and substantial downstream outcomes (including markedly higher odds of prolonged length of stay among infected patients) [36]. Regional Gulf surveillance also reported device-associated infection burdens across participating intensive care units, supporting the value of harmonised surveillance definitions, audit-feedback, and prevention bundles that could be implemented alongside ultrasound-first insertion pathways in surgical and perioperative service. [38]. In this setting, structured training for anaesthesia and critical-care teams on sterile ultrasound technique (probe covers, gel handling, and aseptic choreography), coupled with laboratory-supported rapid diagnostics and infection-control-led line maintenance audits, would likely have provided the most actionable route to reduce CLABSI while preserving the clear mechanical benefits of ultrasound-guided access.

## Conclusions

Based on the nine included studies, ultrasound-guided central venous catheter insertion consistently improved procedural performance (higher overall and first-attempt success, fewer attempts, and shorter access time) and reduced major mechanical complications compared with landmark techniques, while the effect on CLABSI/CRBSI outcomes remained heterogeneous and appeared highly dependent on context, definitions, insertion site, and—critically—implementation quality of aseptic ultrasound workflows and post-insertion maintenance. Therefore, ultrasound guidance should be recommended as the default approach for CVC insertion in surgical and perioperative services, but it should be implemented as part of a comprehensive CLABSI prevention program that standardizes sterile probe/gel handling, maximal barrier precautions, chlorhexidine skin antisepsis, bundle-based line maintenance, daily line-necessity review, and site-selection strategies that balance infectious and mechanical risks.

## References:


1. *Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021;372:n71.*

2. *O'Grady NP, Alexander M, Burns LA, Dellinger EP, Garland J, Heard SO, et al. Guidelines for the prevention of intravascular catheter-related infections. Clin Infect Dis. 2011;52(9):e162-e193.*

3. *Mermel LA, Allon M, Bouza E, Craven DE, Flynn P, O'Grady NP, et al. Clinical practice guidelines for the diagnosis and management of intravascular catheter-related infection: 2009 update by the Infectious Diseases Society of America. Clin Infect Dis. 2009;49(1):1-45.*

4. *Marschall J, Mermel LA, Fakih M, Hadaway L, Kallen A, O'Grady NP, et al. Strategies to prevent central line-associated bloodstream infections in acute care hospitals: 2014 update. Infect Control Hosp Epidemiol. 2014;35(7):753-771.*

5. *Umscheid CA, Mitchell MD, Doshi JA, Agarwal R, Williams K, Brennan PJ. Estimating the proportion of healthcare-associated infections that are reasonably preventable and the related mortality and costs. Infect Control Hosp Epidemiol. 2011;32(2):101-114.*

6. *Zimlichman E, Henderson D, Tamir O, Franz C, Song P, Yamin CK, et al. Health care-associated infections: a meta-analysis of costs and financial impact on the US health care system. JAMA Intern Med. 2013;173(22):2039-2046.*

7. *Stevens V, Geiger K, Concannon C, Nelson RE, Brown J, Dumyati G. Inpatient costs, mortality, and 30-day readmission in patients with central line-associated bloodstream infections. Clin Microbiol Infect. 2014;20(5):O318-O324.*

8. *Rosenthal VD, et al. Multinational prospective study of incidence and risk factors for central line-associated bloodstream infections in intensive care units across multiple low- and middle-income countries. Infect Control Hosp Epidemiol. 2023 Nov;44(11):1737-47.*

9. *Teja B, Bosch NA, Diep C, Pereira TV, Mauricio P, Sklar MC, et al. Complication rates of central venous catheters: a systematic review and meta-analysis. JAMA Intern Med. 2024;184(5):474-482.*

10. *Hind D, Calvert N, McWilliams R, Davidson A, Paisley S, Beverley C, et al. Ultrasonic locating devices for central venous cannulation: meta-analysis. BMJ. 2003;327(7411):361.*

11. *Brass P, Hellmich M, Kolodziej L, Schick G, Smith AF. Ultrasound guidance versus anatomical landmarks for subclavian or femoral venous catheterization. Cochrane Database Syst Rev. 2015;1:CD011447.*

12. *Mallory DL, McGee WT, Shawker TH, Brenner M, Bailey KR, Evans RG, et al. Ultrasound guidance improves the success rate of internal jugular vein cannulation. Chest. 1990;98(1):157-160.*

13. *Denys BG, Uretsky BF, Reddy PS. Ultrasound-assisted cannulation of the internal jugular vein. Circulation. 1993;87(5):1557-1562.*

14. *Slama M, Novara A, Safavian A, Ossart M, Safar M, Fagon JY. Improvement of internal jugular vein cannulation using an ultrasound-guided technique. Intensive Care Med. 1997;23(8):916-919.*

15. *Verghese ST, McGill WA, Patel RI, Sell JE, Midgley FM, Ruttimann UE. Ultrasound-guided internal jugular venous cannulation in infants: a prospective comparison with the traditional palpation method. Anesthesiology. 1999;91(1):71-77.*

16. *Karakitsos D, Labropoulos N, De Groot E, Patrianakos AP, Kouraklis G, Poularas J, et al. Real-time ultrasound-guided catheterisation of the internal jugular vein: a prospective comparison with the landmark technique in critical care patients. Crit Care. 2006;10(6):R162.*

17. *Fragou M, Gravvanis A, Dimitriou V, Papalois A, Kouraklis G, Karabinis A, et al. Real-time ultrasound-guided subclavian vein cannulation versus the landmark method in critical care patients: a prospective randomized study. Crit Care Med. 2011;39(7):1607-1612.*

18. *Bruzoni M, Slater BJ, Wall J, St Peter SD, Dutta S. A prospective randomized trial of ultrasound- vs landmark-guided central venous access in the pediatric population. J Am Coll Surg. 2013;216(5):939-943.*

19. *Buetti N, Mimoz O, Mermel L, Ruckly S, Mongardon N, Dupuis C, et al. Ultrasound guidance and risk for central venous catheter-related infections in the intensive care unit: a post hoc analysis of individual data of 3 multicenter randomized trials. Clin Infect Dis. 2021;73(5):e1054-e1061.*

20. *Takeshita J, Tachibana K, Nakajima Y, Shime N. Incidence of catheter-related bloodstream infections following ultrasound-guided central venous catheterization: a systematic review and meta-analysis. BMC Infect Dis. 2022;22(1):772.*

21. *Imataki O, Shimatani M, Ohue Y, Uemura M. Effect of ultrasound-guided central venous catheter insertion on the incidence of catheter-related bloodstream infections and mechanical complications. BMC Infect Dis. 2019;19(1):857.*

22. *Pronovost P, Needham D, Berenholtz S, Sinopoli D, Chu H, Cosgrove S, et al. An intervention to decrease catheter-related bloodstream infections in the ICU. N Engl J Med. 2006;355(26):2725-2732.*

23. *Parienti JJ, Mongardon N, Mégarbane B, Mira JP, Kalfon P, Gros A, et al. Intravascular complications of central venous catheterization by insertion site. N Engl J Med. 2015;373(13):1220-1229.*

24. *Cartier V, Haenny A, Inan C, Walder B, Zingg W. No association between ultrasound-guided insertion of central venous catheters and bloodstream infection: a prospective observational study. J Hosp Infect. 2014;87(2):103-108.*

25. *Blot K, Bergs J, Vogelaers D, Blot S, Vandijck D. Prevention of central line-associated bloodstream infections through quality improvement interventions: a systematic review and meta-analysis. Clin Infect Dis. 2014;59(1):96-105.*

26. *Berenholtz SM, Pronovost PJ, Lipsett PA, Hobson D, Earsing K, Farley JE, et al. Eliminating catheter-related bloodstream infections in the intensive care unit. Crit Care Med. 2004;32(10):2014-2020.*

27. *Mazi W, Begum Z, Abdulla D, Hesham A, Maghari S, Assiri A, et al. Central line-associated bloodstream infection in a trauma intensive care unit: impact of implementation of Society for Healthcare Epidemiology of America/Infectious Diseases Society of America practice guidelines. Am J Infect Control. 2014;42(8):865-867.*

28. *Almuneef MA, Memish ZA, Balkhy HH, Hijazi O, Cunningham G, Francis C. Rate, risk factors and outcomes of catheter-related bloodstream infection in a paediatric intensive care unit in Saudi Arabia. J Hosp Infect. 2006;62(2):207-213.*

29. *Al-Tawfiq JA, Amalraj A, Memish ZA. Reduction and surveillance of device-associated infections in adult intensive care units at a Saudi Arabian hospital, 2004-2011. Int J Infect Dis. 2013;17(12):e1207-e1211.*

30. *Balkhy HH, Alsaif S, El-Saed A, Khawajah M, Dichinee R, Memish ZA. Neonatal rates and risk factors of device-associated bloodstream infection in a tertiary care center in Saudi Arabia. Am J Infect Control. 2010;38(2):159-161.*

31. *Balkhy HH, El-Saed A, Al-Abri SS, Alsalman J, Alansari H, Al Maskari Z, et al. Rates of central line-associated bloodstream infection in tertiary care hospitals in 3 Arabian gulf countries: 6-year surveillance study. Am J Infect Control. 2017;45(5):e49-e51.*

32. *Al-Tawfiq JA, Abed MS. Prevalence and antimicrobial resistance of health care associated bloodstream infections at a general hospital in Saudi Arabia. Saudi Med J. 2009;30(9):1213-1218.*

33. *Almahmoud RS, et al. Assessment of knowledge and practices of central line insertion and maintenance in adult intensive care units at a tertiary care hospital in Saudi Arabia. J Infect Public Health. 2020;13(11):1694-1698.*

34. *Al-Tawfiq JA, et al. Surveillance of device-associated infections in intensive care units at a Saudi Arabian hospital, 2017-2020. J Infect Public Health. 2023;16(6):917-921.*

35. *Alshamrani MM, et al. Risk of central line-associated bloodstream infections during the COVID-19 pandemic in intensive care patients in a tertiary care centre in Saudi Arabia. Epidemiol Infect. 2024;152:e95.*

36. *Oulego-Erroz I, et al. Ultrasound-guided supraclavicular cannulation of the brachiocephalic vein and central line-associated bloodstream infection in preterm infants. Eur J Pediatr. 2020;179(11):1655-1663.*

37. *Chopra V, et al. The risk of bloodstream infection associated with peripherally inserted central catheters: a systematic review and meta-analysis. Am J Med. 2013 Sep;34(9):908-18.*

38. *Lorente L, Lecuona M, Jiménez A, Lorenzo L, Diosdado S, Marca L, et al. Cost/benefit analysis of chlorhexidine-silver sulfadiazine-impregnated venous catheters for femoral access. Am J Infect Control. 2014;42(10):1130-1132.*

**Table 1. Characteristics and key findings of the studies included in the review on ultrasound-guided central venous catheter insertion and bloodstream infection in surgical patients**

| Study Reference | Study Design | Population | Intervention / Exposure | Disease / Condition | Main Outcomes |
|---|---|---|---|---|---|
| *[12] Mallory et al., 1990* | Randomised clinical trial | Adults requiring urgent/urgent-elective internal jugular CVC | Ultrasound-guided vs landmark insertion | Central venous catheterization | Failed cannulation 35% vs 0% (6/17 vs 0/12); p<0.05 |
| *[13] Denys et al., 1993* | Prospective comparative cohort | Adults undergoing internal jugular venous cannulation | Ultrasound-guided vs landmark insertion | Central venous catheterization | Cannulation success 100% vs 88.1%; p<0.001 |
| *[14] Slama et al., 1997* | Randomised clinical trial | Adult ICU patients requiring internal jugular CVC | Ultrasound-guided vs landmark insertion | Central venous catheterization | Cannulation success 100% vs 76% (37/37 vs 32/42); p<0.01 |
| *[15] Verghese et al., 1999* | Randomised clinical trial | Infants scheduled for cardiac surgery needing internal jugular access | Ultrasound-guided vs landmark insertion | Central venous catheterization | Cannulation success 100% vs 77%; carotid puncture 0% vs 25% |
| *[16] Karakitsos et al., 2006* | Randomised clinical trial | Adult critical-care patients requiring internal jugular CVC | Real-time ultrasound-guided vs landmark insertion | Central venous catheterization | Cannulation success 100% vs 94.4% (450/450 vs 425/450); p<0.001 |
| *[17] Fragou et al., 2011* | Randomised clinical trial | Mechanically ventilated adults requiring subclavian CVC in ICU | Real-time ultrasound-guided vs landmark insertion | Central venous catheterization | Subclavian success 100% vs 87.5%; p<0.05 |
| *[18] Bruzoni et al., 2013* | Randomised clinical trial | Children (<18 y) undergoing tunneled CVC placement | Ultrasound-guided vs landmark-guided access | Central venous catheterization | First-attempt success 65% vs 45%; p=0.021 |
| *[19] Cartier et al., 2014* | Prospective cohort study | Hospital-wide non-tunneled CVCs inserted by anaesthetists | Ultrasound-guided vs landmark insertion | CVC-associated bloodstream infection | CABSI: HR 0.69; 95% CI 0.36-1.30 |
| *[20] Buetti et al., 2021* | Post hoc analysis (individual data; 3 RCTs) | Adult ICU patients requiring short-term CVC (jugular/femoral/subclavian) | Ultrasound-guided vs landmark (non-randomised to method) | Catheter-related bloodstream infection | CRBSI: HR 2.21; 95% CI 1.17-4.16 |

*Abbreviations:* ***CABSI*** *= central venous catheter-associated bloodstream infection;* ***CRBSI*** *= catheter-related bloodstream infection;* ***CVC*** *= central venous catheter;* ***HR*** *= hazard ratio;*

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