

Arterial Line Placement and Complications in Community ICUs: Site Selection, Ultrasound Guidance, and Infection Risk

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Abstract

Peripheral arterial catheters are among the most commonly placed invasive devices in intensive care, valued for continuous blood pressure measurement and convenient blood sampling, yet their routine use has rarely been questioned. This question carries particular weight in community hospitals, where a large share of critically ill adults is treated by smaller teams with variable access to intensivists, ultrasound equipment, and infection prevention resources. This narrative review synthesizes the clinical literature and practice guidelines on the indications, insertion site selection, ultrasound guidance, mechanical complications, and infection risk of arterial catheters, and interprets that evidence through the operational realities of community intensive care units. The review shows that the long-held assumption that every patient with shock needs an arterial line is no longer well supported, since many such patients can be managed safely with noninvasive monitoring while avoiding bleeding and other insertion-related harm. When an arterial catheter is genuinely required, the radial artery remains the most balanced choice, offering reliable insertion, acceptable durability, and the lowest infection risk, whereas the femoral artery is better reserved for emergencies or failed radial access because it carries greater bleeding and infectious risk. Ultrasound guidance emerges as a practical way to improve first-attempt success and catheter longevity, particularly in patients with shock, obesity, or edema, without increasing infection, provided operators receive structured training and maintain competence. The review also highlights that arterial catheter infections are considerably more common than clinicians often assume, occurring at rates close to those of short-term central venous catheters, yet they fall outside routine surveillance and therefore remain largely unrecognized. Taken together, these findings suggest that community ICUs can achieve meaningful safety gains not through new technology but through consistent practice: deliberate indication review, radial-first site selection, routine ultrasound use, central-line-level asepsis and site care, daily assessment of continued need, and local tracking of catheter-related infections, supported by workforce planning and organizational commitment.

Keywords: *Arterial catheter; Arterial line; Community hospital; Intensive care unit; Ultrasound guidance; Radial artery; Femoral artery; Catheter-related bloodstream infection; Shock; Noninvasive blood pressure monitoring*

INTRODUCTION

Arterial catheterization is a cornerstone procedure of critical care. Indwelling arterial catheters provide beat-to-beat blood pressure measurement during vasoactive titration, convenient access for repeated arterial blood gas sampling, and waveform-derived variables used in hemodynamic assessment. Because of this utility, arterial lines have long been regarded as low-risk, routine devices, and their placement in patients receiving vasopressors has often been treated as a default rather than a decision.

That assumption has been challenged on two fronts. First, observational work demonstrated wide, unexplained variation in arterial catheter use across ICUs, with no clear association between catheter use and survival, even among patients receiving vasopressors (Gershengorn *et al.*, 2014) or among hemodynamically stable ventilated patients (Hsu *et al.*, 2015). Second, in 2025, the EVERDAC randomized trial reported that, in selected adults with shock, deferring arterial catheterization was noninferior to early insertion for 28-day mortality while substantially reducing local bleeding complications (Gershengorn, 2025; Muller *et al.*, 2025). At the same time, a growing literature has shown that arterial

catheters are an underrecognized source of catheter-related bloodstream infection (CRBSI) (Koh *et al.*, 2008; Lucet *et al.*, 2010; O'Horo *et al.*, 2014) and that insertion technique, particularly ultrasound guidance, shapes both success and device durability (Gu *et al.*, 2014; Pacha *et al.*, 2018; Schults *et al.*, 2024b).

Much of this evidence originates in academic centers and large European research networks. Yet a substantial share of adult critical care is delivered in community hospitals (Halpern and Pastores, 2015), where ICUs are frequently smaller, may lack 24-hour in-house intensivists, rely on hospitalists, advanced practice providers, or tele-ICU support (Kahn *et al.*, 2016; Lilly *et al.*, 2011), and may perform arterial cannulation infrequently per operator. Nearly half of United States acute care hospitals with ICUs have no intensivists, and these hospitals are disproportionately small and nonmetropolitan (Halpern *et al.*, 2019). Comparable constraints in diagnostic capacity, infrastructure, and governance shape critical care delivery in resource-constrained health systems more broadly (Aminu-Ibrahim *et al.*, 2018, 2019, 2020, 2024, 2025b; Aminu-Ibrahim and Ogbete, 2023; Ogbete and Aminu-Ibrahim, 2024). These structural features influence which insertion sites are feasible, whether ultrasound is readily available and used competently, and how reliably maintenance practices and infection surveillance are applied.

Arterial catheter practice has been reviewed before, but most reviews address academic, perioperative, or cardiology settings. To our knowledge, this is the first review to examine site selection, ultrasound guidance, and infection risk together through the operational constraints of community ICUs, and to incorporate the 2025 EVERDAC findings into a practical bundle designed for these units. This narrative review therefore has three aims:

1) to summarize contemporary evidence on when arterial catheters are needed;
2) to review the evidence on insertion site selection, ultrasound guidance, and mechanical and infectious complications; and
3) to translate these findings into a pragmatic, implementable approach for community ICUs.

RESEARCH METHOD

This is a narrative, not systematic, review. Targeted searches of PubMed/MEDLINE were conducted using combinations of the terms "arterial catheter", "arterial line", "radial artery cannulation", "femoral artery", "axillary artery", "brachial artery", "ultrasound", "catheter-related bloodstream infection", "complications", "shock", "noninvasive blood pressure", and "community hospital". Reference lists of key reviews, meta-analyses, and guidelines were hand-searched. Priority was given to randomized controlled trials, meta-analyses of randomized trials, large prospective cohorts, and post hoc analyses of multicenter trials in adult ICU populations, together with infection prevention guidelines from the Centers for Disease Control and Prevention (CDC) and the Society for Healthcare Epidemiology of America (SHEA). Evidence available through late 2025 was considered. Pediatric, cardiac catheterization laboratory, and operating room data were included only where they informed ICU practice. Because community ICU-specific data are sparse, recommendations for this setting are derived by extrapolation and are labeled as expert opinion where appropriate.

RESULTS AND DISCUSSION

The evidence is presented in six themes: the indications for arterial catheterization, insertion site selection, ultrasound guidance, mechanical and ischemic complications, infection risk, and the implications of these findings for community ICUs. The limitations of the review and priorities for future research are then discussed.

Indications for Arterial Catheterization

Traditional Rationale

The classic indications for arterial catheterization include shock requiring vasoactive titration, anticipated frequent arterial blood sampling (for example, severe hypoxemic or hypercapnic respiratory failure or complex acid-base disturbances), situations in which noninvasive measurement is unreliable (morbid obesity, arrhythmias, extremity burns or injuries), and the need for continuous waveform analysis. Noninvasive oscillometric devices are known to diverge from intra-arterial measurements, particularly during hypotension, where cuff readings may overestimate pressure (Lehman *et al.*, 2013). These limitations underpinned the long-standing view that patients with shock should have an arterial line. Arm-cuff oscillometric readings nonetheless agree acceptably with intra-arterial mean pressure in many ICU patients, whereas thigh and ankle readings are less reliable (Lakhal *et al.*, 2012, 2018). The 2021 Surviving Sepsis Campaign guideline suggests invasive arterial monitoring in septic shock as soon as practical, while acknowledging that this weak recommendation rests on very low-quality evidence (Evans *et al.*, 2021). The arterial waveform also supports dynamic indices such as pulse pressure variation for predicting fluid responsiveness in ventilated patients (Michard *et al.*, 2000), and its accuracy depends on correct leveling, zeroing, and damping assessment (Saugel *et al.*, 2020). Beyond the ICU, accurate blood pressure measurement is equally central to the diagnosis and management of hypertension and cardiovascular risk (Abah *et al.*, 2025a,b; David *et al.*, 2025).

Observational Signals

Using a large multicenter ICU database, Gershengorn and colleagues found marked between-ICU variation in arterial catheter use that was not explained by patient characteristics, and no association between catheter use and hospital mortality, including among patients receiving vasopressors (Gershengorn *et al.*, 2014). Similarly, a propensity-matched analysis of hemodynamically stable mechanically ventilated patients found no mortality benefit from indwelling arterial catheters (Hsu *et al.*, 2015). These data suggested that much arterial catheter use is driven by habit and local culture rather than by measurable benefit. Commentators had argued for some time that indwelling arterial catheters might act as a harmful crutch, encouraging excess testing without clear benefit (Garland and Connors, 2010).

The EVERDAC Trial

EVERDAC was a multicenter, open-label, pragmatic noninferiority trial conducted in French ICUs (Muller *et al.*, 2025). Adults with shock admitted to the ICU within the preceding 24 hours were randomized to early arterial catheter insertion (within 4 hours) or to a noninvasive strategy using an automated brachial cuff, with later catheter insertion permitted only when prespecified safety criteria were met. Arterial catheters were ultimately placed in 98.2% of the invasive group and in only 14.7% of the noninvasive group. Death at 28 days occurred in 173 patients (34.3%) in the noninvasive group and 185 (36.9%) in the invasive group, an adjusted difference of -3.2 percentage points that met the prespecified 5-point noninferiority margin. Catheter-related hematoma or hemorrhage occurred in 1.0% versus 8.2% of patients, respectively (Muller *et al.*, 2025).

Several limitations temper generalization. The trial was unblinded; it excluded patients with a body mass index above 40 kg/m² and those receiving high doses of vasopressors; trauma, postoperative, and post-cardiac-arrest patients were underrepresented; and blood gas analysis relied heavily on central venous sampling with computational conversion. Nonetheless, the accompanying editorial framed the result as support for a less invasive default in intensive care (Gershengorn, 2025). EVERDAC also operated within contemporary mean arterial pressure targets: a higher target did not reduce mortality in septic shock (Asfar *et al.*, 2014), and permissive hypotension in older patients reduced vasopressor exposure without a significant difference in mortality (Lamontagne *et al.*, 2020), which lessens the need for beat-to-beat precision in many patients. Patients with chronic hypertension and cardio-renal comorbidity, who are common in community practice, may nonetheless warrant closer pressure control (Amadi *et al.*, 2025; Ike *et al.*, 2025; Okwah, 2022).

Applying the Evidence in Community ICUs

For community ICUs, EVERDAC is arguably more relevant than for academic units. Each avoided arterial catheter removes a procedure that may be performed by a less experienced operator, at night, without immediate backup. A practical approach is to treat arterial catheterization as a deliberate decision with documented indications, for example: inability to obtain reliable cuff pressures; escalating or high-dose vasopressor requirements or rapidly fluctuating hemodynamics; need for frequent arterial gases that cannot be replaced by venous sampling with pulse oximetry; morbid obesity or limb factors that preclude accurate cuff measurement; and conditions requiring tight pressure targets (for example, post-cardiac arrest care, acute aortic syndromes, or selected neurocritical care scenarios). In stable or improving septic shock with reliable cuff readings, a structured noninvasive strategy is a defensible default. Peripheral venous blood gas values agree closely with arterial values for pH and bicarbonate, though not for oxygen tension and less reliably for carbon dioxide, which supports venous sampling when oxygenation can be followed by pulse oximetry (Byrne *et al.*, 2014).

Insertion Site Selection

When an arterial catheter is indicated, site selection balances ease and speed of insertion, accuracy of pressure measurement, catheter durability, mechanical and ischemic risk, and infection risk. Table 1 summarizes the principal sites.

Radial Artery

The radial artery is the default site in most ICUs because it is superficial, compressible, and supported by dual palmar circulation through the ulnar artery and palmar arches (Brzezinski *et al.*, 2009). In a large pooled review of complications, temporary radial occlusion was common (on

Table 1: Comparison of arterial catheter insertion sites in adult ICU patients.

Site	Main advantages	Main disadvantages and complications	Infection considerations	Suggested role in community ICUs
Radial	Superficial, compressible; dual palmar blood supply; patient comfort; low serious complication rate	Technical difficulty in shock; higher functional failure (dampening, occlusion, dislodgement); may underestimate central pressure on high-dose vasopressors	Lowest bloodstream infection risk among common sites	Default first-line site; ultrasound-guided insertion recommended
Femoral	Large, palpable in profound shock; durable, central pressure signal; fast insertion	Pseudoaneurysm, hematoma, retroperitoneal bleeding; limits mobility; harder hemostasis	About twice the radial bloodstream infection risk; more Gram-negative organisms; full maximal barrier precautions required	Peri-arrest or refractory shock, or after failed radial attempts; reassess for exchange after stabilization
Brachial	Good caliber when radial unusable; accurate signal	End artery; median nerve injury; hematoma with compartment risk; kinking with elbow flexion	Infection data limited but appear comparable to radial	Second-line upper-limb site for experienced, ultrasound-trained operators
Axillary	Large vessel with collateral flow; near-central pressure; useful in burns and limb trauma	Technically demanding; brachial plexus injury; non-compressible; cerebral embolism risk with flushing	Grouped with femoral for maximal barrier precautions	Reserve for experienced operators; rarely first choice in community ICUs
Dorsalis pedis	Peripheral, accessible when upper limbs unavailable	Systolic overestimation; unsuitable in vascular disease, diabetes, or edema	Low infection rates in small series	Occasional alternative in selected patients

Sources: Handlogten *et al.*, 2014; Lorente *et al.*, 2006; O'Grady *et al.*, 2011; O'Horo *et al.*, 2014; Scheer *et al.*, 2002.

the order of 20% of cannulations), whereas permanent ischemic damage was very rare (approximately 0.09%), as were sepsis (approximately 0.13%) and pseudoaneurysm (approximately 0.09%) (Scheer *et al.*, 2002). Classic work in cardiac surgical patients showed that radial occlusion was frequent but rarely produced ischemic sequelae, and that the modified Allen test did not reliably predict which patients would develop ischemia (Barone and Madlinger, 2006; Slogoff *et al.*, 1983); the test is therefore of limited value as a gatekeeper, although many institutions retain it as part of a local protocol. Risk factors for severe complications include low-flow states, high-dose vasopressors, peripheral arterial disease, large catheter-to-artery ratios, prolonged dwell times, and multiple puncture attempts (Nuttall *et al.*, 2016; Scheer *et al.*, 2002). Early studies linked radial occlusion to catheter and patient factors, including smaller wrist circumference as a marker of a small artery relative to the catheter (Bedford, 1978; Kim *et al.*, 1975), and reviews of ischemic damage emphasize that thrombosis is common while permanent injury is rare (Wilkins, 1985). When hand ischemia does occur, outcomes can be poor even with surgical revascularization, which underscores prevention and early recognition (Chim *et al.*, 2015; Valentine *et al.*, 2005). Loss of hand function also threatens independence in activities of daily living, the support of which is recognized as a clinical intervention in rehabilitation (Osinem *et al.*, 2021). Large ICU series have documented the indications for and complications of arterial catheters across thousands of patients (Frezza and Mezghebe, 1998), and the ulnar artery has been studied as an alternative when the radial artery is unsuitable (Karacalar *et al.*, 2007).

The main disadvantages of the radial site are technical difficulty in hypotensive, edematous, or vasoconstricted patients and a higher rate of functional failure (dampening, positional waveform loss, occlusion, and dislodgement). An emergency department and ICU cohort found that radial lines failed more often and sooner than femoral lines (Greer *et al.*, 2018). In addition, during high-dose vasopressor therapy, radial pressures may underestimate central aortic pressure (Dorman *et al.*, 1998), a consideration when a patient appears refractory to vasopressors on the basis of radial readings alone. The radial-to-femoral gradient is most pronounced in septic shock patients receiving high-dose norepinephrine (Bhaskar *et al.*, 2022; Kim *et al.*, 2013). Insertion technique also affects radial durability: catheters placed more proximally on the forearm, usually with ultrasound, lasted longer than those placed near the wrist crease in one ICU cohort (Imbriaco *et al.*, 2021), and a practice review summarizes strategies to prevent radial catheter failure (Imbriaco *et al.*, 2022). Guidewire-assisted and direct catheter-over-needle techniques have been compared since the 1990s (Mangar *et al.*, 1993).

Femoral Artery

The femoral artery is large, readily palpable even during profound hypotension, and provides a more central and durable pressure signal. It is often chosen during cardiac arrest, profound shock, or after failed radial attempts. Its drawbacks include a higher rate of pseudoaneurysm and bleeding, the potential for retroperitoneal hemorrhage with high punctures above the inguinal ligament, difficulty with hemostasis in coagulopathic or anticoagulated patients, and, importantly, a higher infection risk. Pooled data suggest femoral permanent ischemia of roughly 0.18%, pseudoaneurysm of about 0.3%, and sepsis of about 0.44%, each higher than the corresponding radial estimates (Scheer *et al.*, 2002). Earlier experience with large-artery cannulation in ICU patients nonetheless reported low rates of serious complications for femoral and axillary catheters (Gurman and Kriemerman, 1985). In a meta-analysis of 49 studies, femoral arterial catheters carried nearly twice the bloodstream infection risk of radial catheters (relative risk 1.93; 95% CI 1.32 to 2.84) (O'Horo *et al.*, 2014). A cohort of 2,949 arterial catheters similarly found local infection to be about four times more frequent at femoral than radial sites (Lorente *et al.*, 2006), and analyses of French multicenter trial data have reinforced the higher infectious risk of the femoral site among peripheral arterial catheters (Buetti *et al.*, 2021; Lucet *et al.*, 2010).

For community ICUs, femoral placement is reasonable when speed and reliability dominate (peri-arrest or refractory shock), but such catheters should be considered for exchange to a radial site once the patient stabilizes and should be maintained with full central-line asepsis.

Brachial Artery

The brachial artery is an end artery without collateral circulation at the antecubital fossa, which has historically made clinicians wary. However, a large single-institution series, predominantly in cardiac surgical patients, reported that serious complications of brachial catheterization were rare (Handlogten *et al.*, 2014), and a series of 21,597 cardiac surgical patients found an overall complication rate of about 0.19% (Singh *et al.*, 2017). Proximity of the median nerve, the risk of compartment syndrome with hematoma, and positional kinking with elbow flexion remain concerns. With ultrasound guidance, the brachial artery is a reasonable second-line upper-extremity site when the radial arteries are unusable, provided the operator is experienced and the limb can be monitored closely. Structured neurovascular observation protocols, such as those used after orthopedic procedures, offer a practical template for these limb checks (Akinlolu *et al.*, 2025).

Axillary Artery

The axillary artery offers a large-caliber vessel with rich collateral flow and a pressure tracing close to central aortic pressure, and it is less affected by peripheral vasoconstriction. It is used in burn units and in patients with extensive extremity injuries. The site is technically more demanding, lies close to the brachial plexus, and is not readily compressible; air or clot embolism can reach the cerebral circulation via retrograde flow, particularly with left-sided catheters and vigorous flushing; retrograde flow into the brachial and axillary arteries occurs even with routine radial flushes (Lowenstein *et al.*, 1971; Murphy *et al.*, 2004; Murphy *et al.*, 2006). Because of this profile, the axillary site is best reserved for operators with specific experience, and CDC guidance groups it with the femoral site as requiring maximal sterile barrier precautions (O'Grady *et al.*, 2011). A

recent series of 99 ultrasound-guided axillary catheters in ICU patients reported mainly minor bleeding and infrequent vascular complications (Cardona *et al.*, 2024).

Dorsalis Pedis and Other Sites

The dorsalis pedis artery is a peripheral option in patients without peripheral vascular disease. In Spanish cohort data, dorsalis pedis catheters had lower infection rates than femoral catheters, though numbers were small (Lorente *et al.*, 2006). Systolic amplification in distal arteries can overestimate systolic pressure, and the site is not suitable in diabetic or vasculopathic patients or in those with lower limb edema.

Ultrasound Guidance

Efficacy for Insertion Success

Ultrasound guidance for radial artery cannulation has been evaluated in multiple randomized trials and successive meta-analyses (Table 2). An early meta-analysis of four trials found that ultrasound increased first-attempt success compared with palpation (relative risk 1.71) (Shiloh *et al.*, 2011). Later syntheses including more trials, adult and pediatric patients, and both emergency and perioperative settings confirmed the effect, with pooled relative risks of 1.47 to 1.55 for first-attempt success (Gao *et al.*, 2015; Gu *et al.*, 2014). A meta-analysis restricted to 12 randomized trials in 2,432 adults reported a relative risk of 1.35 for first-attempt success and a roughly halved risk of overall failure (relative risk 0.52), without a significant difference in hematoma (Pacha *et al.*, 2018). Technique matters: the dynamic needle tip positioning approach, in which the probe is advanced in short-axis to keep the needle tip in view as it travels within the lumen, improved first-pass success over palpation in a randomized trial of surgical patients (Kiberenge *et al.*, 2018). Individual trials in ICU, emergency department, and perioperative settings show a consistent direction of benefit (Levin *et al.*, 2003; Shiver *et al.*, 2006; Ueda *et al.*, 2015), and a 2021 Cochrane review of 48 studies concluded that ultrasound may improve first-attempt success and probably reduce hematoma (Flumignan *et al.*, 2021). In cardiac catheterization, the RAUST and FAUST trials showed higher first-pass radial success and fewer femoral vascular complications with ultrasound (Seto *et al.*, 2010, 2015). Probe orientation has been studied extensively: trials and meta-analyses comparing short-axis, long-axis, oblique, and dynamic needle tip techniques show that each can succeed in skilled hands, with modest or inconsistent differences between them (Abdalla *et al.*, 2017; Berk *et al.*, 2013; Cao *et al.*, 2023; Nam *et al.*, 2020; Quan *et al.*, 2014; Sun *et al.*, 2022). International consensus statements and society guidelines endorse ultrasound for vascular access, with the strongest evidence for venous cannulation (Lamperti *et al.*, 2012; Troianos *et al.*, 2011).

The benefit is greatest in exactly the patients for whom community ICUs most often struggle: those in shock with weak or absent pulses, obese patients, edematous patients, and patients who have already had failed attempts. Ultrasound also allows pre-procedural assessment of vessel diameter, depth, patency, calcification, and anatomical variation, and selection of a catheter that does not occupy an excessive fraction of the lumen. In obese patients, acoustic-shadow techniques improved first-attempt success and reduced complications in a randomized trial (Zou *et al.*, 2023).

Effect on Catheter Failure and Complications

Beyond first-pass success, ultrasound appears to affect what happens after insertion. In a secondary analysis of a multisite randomized trial including 664 ICU patients with arterial catheters, 26% experienced catheter failure (37 per 1,000 catheter-days), most often from suspected infection, occlusion, or accidental removal; ultrasound-assisted insertion was independently associated with less all-cause failure (adjusted hazard ratio 0.43) and markedly less occlusion (Schults *et al.*, 2024b). Fewer punctures plausibly reduce intimal injury, hematoma, and thrombosis, and a

Table 2: Key evidence on ultrasound guidance for arterial catheterization.

Study	Design and population	Main findings
Shiloh *et al.*, 2011	Meta-analysis of 4 RCTs (adults; ED, ICU, operating room)	First-attempt success higher with ultrasound (RR 1.71)
Gu *et al.*, 2014	Meta-analysis of RCTs, adults and children	First-attempt success RR 1.55; greater benefit in small children and infants
Gao *et al.*, 2015	Updated meta-analysis, 11 RCTs (adults and children)	First-attempt success RR 1.47; heterogeneity by operator and setting
Pacha *et al.*, 2018	Meta-analysis of 12 RCTs, 2,432 adults	First-attempt success RR 1.35; failure RR 0.52; no difference in hematoma
Kiberenge *et al.*, 2018	RCT, adult surgical patients	Dynamic needle tip positioning improved first-pass success over palpation
Seto *et al.*, 2015 (RAUST)	Multicenter RCT, transradial access	First-pass success 64.8% vs 43.9%; fewer attempts with ultrasound
Flumignan *et al.*, 2021	Cochrane review, 48 studies, 7,997 participants	Ultrasound may improve first-attempt success (RR 1.44) and probably reduces hematoma
Buetti *et al.*, 2020	Post hoc analysis of 2 RCTs, 3,950 arterial catheters	No increase in major infection, CRBSI, or colonization with ultrasound
Schults *et al.*, 2024b	Secondary analysis of multisite RCT, 664 ICU patients	26% catheter failure; ultrasound associated with less failure (HR 0.43) and occlusion

RR, relative risk; HR, hazard ratio; RCT, randomized controlled trial; ED, emergency department; CRBSI, catheter-related bloodstream infection.

shallower, more controlled approach may improve the catheter's intraluminal length and stability.

Effect on Infection

Concern has been raised that ultrasound probes, gel, and longer procedures might increase contamination. In a post hoc analysis of two large French randomized trials including 3,950 arterial catheters, ultrasound guidance (used for about 10% of insertions, often by less experienced operators and more often at femoral sites) was not associated with any difference in major catheter-related infection, CRBSI, or colonization, at either radial or femoral sites (Buetti *et al.*, 2020). Ultrasound can therefore be adopted without infectious penalty, provided sterile probe covers and sterile gel are used.

Training and Competency

Most meta-analyses note substantial heterogeneity driven by operator experience; benefit is not automatic. In community ICUs, where an individual clinician may place only a handful of arterial catheters each month, competency depends on deliberate training: simulation on vascular phantoms, supervised initial procedures, and periodic re-credentialing. Learning analytics, digitally delivered training, and robust competency assessment can track individual procedural experience and target refresher education where skills are fading (Adams, 2024; Orise and Niniola, 2024b). Structured ultrasound teaching improved radial cannulation success among residents in a randomized trial (Dong *et al.*, 2022), and simulation-based mastery learning has reduced complications and bloodstream infections for central venous catheterization, a model that transfers readily to arterial access (Barsuk *et al.*, 2009a,b). Work on transitional clinical training in low-resource hospitals likewise highlights supervision models as a determinant of junior clinician preparedness and perioperative care quality (Peteranaba *et al.*, 2023b). Digital learning platforms and performance dashboards for health professional training (Orise and Niniola, 2020, 2022, 2024a, 2025), ethical data practices in educational technology (Orise & Niniola, 2023), and preservation of clinical reasoning alongside automated tools (Adams, 2023) are relevant design considerations for such programs. Because many community ICUs already use ultrasound for central venous access, extending existing programs to arterial access is efficient. Advanced practice providers, respiratory therapists, and dedicated vascular access teams, where permitted by local scope of practice, can concentrate procedural volume and expertise. Multidisciplinary collaboration of this kind has been associated with better patient outcomes in acute care settings such as emergency departments (Ohunyon *et al.*, 2023). ICU evidence also suggests that nurse practitioners and physician assistants deliver care with outcomes comparable to physician-led teams (Kleinpell *et al.*, 2008).

Mechanical and Ischemic Complications

Most arterial catheter complications are minor, but their frequency is higher than is often appreciated. Hematoma and local bleeding are the most common; in EVERDAC, 8.2% of patients in the early-insertion group had catheter-related hematoma or hemorrhage (Muller *et al.*, 2025). Temporary arterial occlusion is common at the radial site but usually clinically silent because of collateral flow (Scheer *et al.*, 2002; Slogoff *et al.*, 1983). Severe complications, including permanent ischemia requiring surgical intervention, pseudoaneurysm, arteriovenous fistula, nerve injury, and infection requiring operative management, are rare, on the order of a few per 10,000 catheters, and cluster in patients with peripheral vascular disease, high-dose vasopressor exposure, emergency surgery, and multiple insertion attempts (Nuttall *et al.*, 2016).

Functional failure is a distinct and under-measured problem. Dampening, positional loss of waveform, occlusion, and accidental removal lead to repeated punctures, interruptions in monitoring, and additional blood loss (Greer *et al.*, 2018; Schults *et al.*, 2024b). Accidental removal is more likely in agitated or behaviorally dysregulated patients, for whom structured, individualized care planning is relevant (Eribenne *et al.*, 2024). Practical mitigation includes ultrasound-guided insertion with adequate intraluminal catheter length, appropriate catheter gauge (commonly 20 gauge for radial access), secure engineered securement devices rather than sutures where possible, wrist splinting where needed, and routine square-wave (fast-flush) testing to identify under- or overdamped systems before treatment decisions are based on an artifactual reading. A 2024 Cochrane review found low-certainty evidence and no clear benefit of any specific dressing or securement product for arterial catheters, so local practice should prioritize reliable application and monitoring (Schults *et al.*, 2024a).

Blood loss from diagnostic sampling is a further, often overlooked harm. Arterial catheters facilitate frequent blood draws and contribute to ICU-acquired anemia. Closed blood conservation sampling systems, protocolized rather than reflexive testing, and consolidation of sampling times reduce this burden. Anemia and transfusion are common in critically ill patients, and diagnostic blood loss contributes to both (Vincent *et al.*, 2002). Laboratory process optimization, reliable pre-analytical handling, and shorter turnaround times can reduce repeat sampling (Abdulrazaq *et al.*, 2021; Yusuf and Abdulrazaq, 2018; Yusuf *et al.*, 2025), and well-planned laboratory infrastructure supports these goals (Aminu-Ibrahim *et al.*, 2022, 2025a; Ogbete *et al.*, 2018, 2019, 2023).

Infection Risk

Magnitude of the Problem

Arterial catheters were long assumed to carry negligible infectious risk because of high-pressure arterial flow. That belief is not supported by the evidence (Table 3). In a prospective study comparing arterial catheters with concurrently placed central venous catheters (CVCs), arterial catheter infection rates were not meaningfully lower than those of CVCs (Koh *et al.*, 2008). In a large French trial dataset, the rates of catheter-related infection were 1.0 per 1,000 catheter-days for arterial catheters and 1.09 per 1,000 catheter-days for CVCs, leading the authors to conclude that arterial catheters warrant the same precautions as CVCs (Lucet *et al.*, 2010). A systematic review of 49 studies including 30,841 arterial catheters estimated a pooled CRBSI

Table 3: Selected evidence on arterial catheter infection risk.

Study	Design	Key findings
Lorente *et al.*, 2006	Prospective cohort, 2,949 arterial catheters	Local infection 3.02 vs 0.75 per 1,000 catheter-days, femoral vs radial
Koh *et al.*, 2008	Prospective study, arterial vs concurrent CVCs	Arterial catheter infection rates comparable to CVCs
Rijnders *et al.*, 2003	RCT, full vs standard barriers for arterial catheters	No reduction in colonization or infection with full sterile barriers
Traore *et al.*, 2005	Prospective multicenter ICU study	Arterial catheter colonization and bacteremia similar to CVCs
Timsit *et al.*, 2009	RCT including arterial catheters	Chlorhexidine-impregnated sponges reduced major catheter-related infection
Lucet *et al.*, 2010	Analysis of 7-ICU RCT dataset	Catheter-related infection 1.0 (arterial) vs 1.09 (CVC) per 1,000 catheter-days; femoral site a risk factor for colonization
O'Horo *et al.*, 2014	Meta-analysis, 49 studies, 30,841 catheters	Pooled CRBSI about 0.96 per 1,000 catheter-days; femoral RR 1.93 vs radial
Pirracchio *et al.*, 2011	8-year surgical ICU survey, more than 3,000 catheters	Infections fell after routine scheduled replacement was abandoned
Safdar *et al.*, 2014	Meta-analysis of RCTs	Chlorhexidine dressings reduced CRBSI and colonization
Mimoz *et al.*, 2015	Multicenter RCT (CLEAN)	Chlorhexidine-alcohol antisepsis reduced catheter-related infection vs povidone iodine-alcohol
Buetti *et al.*, 2020	Post hoc analysis of 2 RCTs	Ultrasound guidance not associated with increased infection
Buetti *et al.*, 2023	Post hoc analysis, 15,036 catheters, 24 ICUs	No rise in arterial catheter infection risk beyond 10 days of dwell time

CVC, central venous catheter; RCT, randomized controlled trial; CRBSI, catheter-related bloodstream infection; RR, relative risk.

incidence of about 0.96 per 1,000 catheter-days, rising to about 1.6 per 1,000 catheter-days when catheters were systematically cultured, a rate comparable to that of short-term CVCs (O'Horo *et al.*, 2014). Earlier prospective work and a systematic review of 200 studies reached similar conclusions (Maki *et al.*, 2006; Traore *et al.*, 2005), and narrative reviews have repeatedly described arterial catheters as an underrecognized source of sepsis (Gowardman *et al.*, 2010; Safdar *et al.*, 2013).

Insertion Site

Insertion site is the most consistent modifiable determinant. Femoral arterial catheters are associated with roughly a doubling of bloodstream infection risk compared with radial catheters (O'Horo *et al.*, 2014), higher rates of local infection (Lorente *et al.*, 2006), and higher colonization (Buetti *et al.*, 2021; Lucet *et al.*, 2010). Femoral catheter infections are also more often caused by Gram-negative organisms, a consideration for empirical antimicrobial therapy when a femoral arterial catheter is the suspected source. Local antibiograms and laboratory-based resistance surveillance should guide that choice (Yusuf *et al.*, 2020). Medicine quality failures and falsified antimicrobials further complicate resistance patterns in some settings (Aneke *et al.*, 2022; Opara *et al.*, 2025), and integrated diagnostic workflows and rapid detection technologies may shorten the time to targeted therapy (Abdulrazaq *et al.*, 2023; Asiedu, 2023; Olorunkosebi *et al.*, 2023).

Dwell Time and Replacement

Routine scheduled replacement of arterial catheters is not recommended; catheters should be replaced only when clinically indicated (O'Grady *et al.*, 2011). In a post hoc analysis of more than 15,000 intravascular catheters from 24 ICUs, the infection risk of CVCs and dialysis catheters rose after 10 days, but no such increase was observed for arterial catheters (Buetti *et al.*, 2023). In an 8-year surgical ICU survey, arterial catheter-related bloodstream infections declined after routine scheduled replacement was abandoned (Pirracchio *et al.*, 2011). The more important lever is therefore daily review of whether the catheter is still needed, and prompt removal when it is not.

Insertion and Maintenance Practices

CDC guidance recommends, at minimum, a cap, mask, sterile gloves, and a small sterile fenestrated drape for peripheral arterial catheter insertion, and maximal sterile barrier precautions (adding sterile gown and full-body drape) for femoral and axillary sites (O'Grady *et al.*, 2011). Given that infection rates approach those of CVCs, many experts argue for applying central-line-level asepsis to all arterial catheters in the ICU. A small randomized trial did not show that full sterile barriers reduced arterial catheter colonization compared with standard precautions (Rijnders *et al.*, 2003), but a statewide checklist intervention demonstrated that bundled insertion practices can sharply reduce catheter-related bloodstream infections (Pronovost *et al.*, 2006).

Skin antisepsis with chlorhexidine-alcohol is superior to povidone iodine-alcohol: the CLEAN trial, which included arterial catheters as well as CVCs, showed a large reduction in catheter-related infection with 2% chlorhexidine-alcohol (Mimoz *et al.*, 2015). Chlorhexidine-impregnated sponge and gel dressings reduced major catheter-related infections in randomized trials that enrolled both arterial and central venous catheters (Timsit *et al.*, 2009, 2012), and the 2022 SHEA/IDSA/APIC compendium supports chlorhexidine-containing dressings for short-term intravascular catheters in adults (Buetti *et al.*, 2022); a meta-analysis found that such dressings reduce catheter-related bloodstream infection and colonization (Safdar *et al.*, 2014). CDC guidance further recommends disposable rather than reusable transducers, replacement of transducers and associated tubing and flush

solution at 96-hour intervals, maintenance of a closed system, minimization of manipulations, and avoidance of glucose-containing flush solutions (O'Grady *et al.*, 2011). Reusable pressure transducers caused several historical outbreaks of bloodstream infection (Beck-Sague and Jarvis, 1989); disinfection of needleless connectors and sampling ports reduces contamination (Moureau and Flynn, 2015); and the 2024 Infusion Nurses Society standards give practical guidance on site care and blood sampling (Nickel *et al.*, 2024). Principles from acute wound care, such as regular site inspection and timely dressing change, apply equally to arterial insertion sites (Ohunyon *et al.*, 2024).

The Surveillance Gap

A structural reason arterial catheter infections remain underrecognized is surveillance. The National Healthcare Safety Network (NHSN) definition of central line-associated bloodstream infection does not count arterial catheters as central lines (CDC, 2025). As a result, bloodstream infections arising from arterial catheters are typically absent from the publicly reported metrics that drive hospital quality programs. In community hospitals with limited infection prevention staffing, this blind spot can allow poor arterial catheter practice to persist undetected. Local tracking of arterial catheter-days and suspected arterial catheter infections, even with simple definitions, closes this gap. Integrated laboratory information systems that link positive blood cultures to device records can make such tracking more accurate and less labor-intensive (Abdulrazaq *et al.*, 2019). Standard microbiological definitions should be applied when attributing an infection to the catheter (Mermel *et al.*, 2009). Public health informatics frameworks, surveillance data quality assessments, and business intelligence tools developed for wider disease surveillance offer transferable methods for this kind of local monitoring (Anioke and Atima, 2023a,b,c; Ekemezie *et al.*, 2018; Ogunboye *et al.*, 2023; Owoade *et al.*, 2022).

Implications for Community ICUs

Structural Factors

Community ICUs vary widely, from closed, high-intensity units with in-house intensivists to open units managed by hospitalists with nighttime tele-ICU coverage. High-intensity intensivist staffing is associated with lower mortality, although nighttime intensivists add benefit mainly where daytime staffing is low-intensity (Pronovost *et al.*, 2002; Wallace *et al.*, 2012). Several features recur. Arterial lines may be placed by a broad mix of operators (intensivists, hospitalists, emergency physicians, advanced practice providers, anesthesia staff, and in some systems respiratory therapists), often with low individual volume. Portable ultrasound may be shared between departments. Nursing ratios and turnover influence the reliability of maintenance bundles, which makes workforce planning part of device safety (Omaghomi *et al.*, 2023). Higher nurse staffing has been associated with fewer ICU-acquired infections (Hugonnet *et al.*, 2007), and work-schedule design influences staff fatigue and performance (Oparah *et al.*, 2024b). Mindfulness-based interventions offer one evidence-based option for reducing staff stress (Osinem *et al.*, 2023). Infection prevention programs focus on NHSN-reportable events, which exclude arterial catheters (CDC, 2025). Tele-ICU programs, associated with improved outcomes in some evaluations (Kahn *et al.*, 2016; Lilly *et al.*, 2011; Young *et al.*, 2011), can provide decision support on indications but cannot place catheters.

A Proposed Arterial Catheter Bundle

Integrating the evidence above, Table 4 proposes a bundle tailored to community ICUs. Recommendations are graded informally by the strength of supporting evidence; where community-specific data are absent, they represent the authors' opinion.

Table 4: Proposed arterial catheter bundle for community ICUs.

Domain	Recommended practice	Evidence basis
Indication	Document a specific indication; in selected shock patients with reliable cuff readings, consider a structured noninvasive strategy with explicit escalation criteria	RCT (EVERDAC) (Muller *et al.*, 2025); observational (Gershengorn *et al.*, 2014; Hsu *et al.*, 2015)
Site	Radial first; femoral for peri-arrest, refractory shock, or failed radial access; brachial or axillary only by experienced operators	Meta-analysis and cohorts (Lorente *et al.*, 2006; O'Horo *et al.*, 2014; Scheer *et al.*, 2002)
Technique	Ultrasound guidance as the default for radial insertion, especially in shock, obesity, and edema; dynamic needle tip positioning	Meta-analyses and RCTs (Gu *et al.*, 2014; Kiberenge *et al.*, 2018; Pacha *et al.*, 2018)
Competency	Simulation training, supervised procedures, credentialing and periodic refreshers; consider concentrating insertions in a vascular access team	Expert opinion; heterogeneity by operator in meta-analyses
Asepsis at insertion	Hand hygiene, cap, mask, sterile gloves, sterile drape for all sites; full maximal barrier for femoral and axillary; sterile probe cover and gel	Guidelines (Buetti *et al.*, 2022; O'Grady *et al.*, 2011)
Skin antisepsis and dressing	2% chlorhexidine-alcohol; chlorhexidine-impregnated sponge or gel dressing; engineered securement	RCTs (Mimoz *et al.*, 2015; Timsit *et al.*, 2009; Timsit *et al.*, 2012)
Maintenance	Disposable transducers; change transducer, tubing, and flush every 96 hours; closed system; minimal access; scrub hubs; daily fast-flush test	Guidelines (O'Grady *et al.*, 2011)
Necessity review	Daily assessment of need; remove promptly; no routine scheduled replacement; consider exchanging femoral to radial after stabilization	Guidelines and cohorts (Buetti *et al.*, 2023; O'Grady *et al.*, 2011)
Surveillance	Track arterial catheter-days, failures, and suspected infections locally; review every bloodstream infection for an arterial source	Expert opinion; NHSN definitions exclude arterial lines (CDC, 2025)

RCT, randomized controlled trial; NHSN, National Healthcare Safety Network.

Implementation Strategies

Bundles succeed through reliability rather than novelty, and sustained compliance with infection prevention practices depends on organizational as well as individual factors (Omaghomi *et al.*, 2022). Practical tools include an arterial catheter insertion checklist mirroring the central line checklist, a procedure kit that contains a sterile probe cover and chlorhexidine dressing by default, inclusion of arterial catheters in daily rounding device checklists, and electronic health record prompts for daily necessity review. Accurate digital documentation of insertion site, date, and daily review, designed for data integrity and HIPAA compliance, underpins both these prompts and later audit (Peteranaba *et al.*, 2023a). Real-time informatics can shorten the delay between a catheter ceasing to be needed and its removal (Nnaji and Akinlolu, 2022). Tele-ICU teams can support indication decisions and prompt removal. Feedback of local data, such as arterial catheter utilization ratios, insertion success, and infection counts, helps sustain engagement, particularly when presented through simple real-time dashboards (Oparah *et al.*, 2023). Reliable kits depend on resilient supply chains for antiseptics, dressings, and catheters; lean distribution methods, shortage early-warning systems, vendor performance and supply forecasting analytics, and data integrity controls developed for pharmaceutical supply chains are directly applicable (Abdulrazaq *et al.*, 2025; Aneke *et al.*, 2023; Asiedu and Asiedu, 2022, 2023, 2024; Asiedu, 2025; Awulu *et al.*, 2022; Eze *et al.*, 2022; Obukadata *et al.*, 2021).

Health-System and Digital Context

Arterial catheter safety in community ICUs also sits within wider health-system dynamics. Conceptual work on health system transformation argues that clinical innovations improve outcomes only when delivery infrastructure, organizational strategy, and workforce capability are in place (Ilodigwe and Adesemoye, 2019b, 2024b, 2025b), and that interoperable data, provider payment reform, and new delivery models can align quality improvement with financial sustainability (Ilodigwe and Adesemoye, 2019a, 2020, 2021), particularly when value is measured across both clinical and financial systems (Osinem *et al.*, 2025a). Community and safety-net hospitals face particular financial and administrative constraints that influence investment in ultrasound equipment, training, and infection prevention staffing (Odeyemi and Idowu, 2025; Ogundipe and Ominde, 2024).

Digital tools increasingly mediate ICU care. Tele-ICU and remote monitoring raise questions of trust, privacy, and regulatory governance (Akintola *et al.*, 2025; Oparah *et al.*, 2021b, 2024c), and artificial intelligence applications for early detection and clinical decision support require organizational readiness and oversight (Afrihyia *et al.*, 2023, 2024a, 2025; Ilodigwe and Adesemoye, 2025a; Osinem *et al.*, 2025b). Because tele-ICU platforms and electronic records are attractive targets, secure network architecture, privacy-preserving data governance, and resilience against ransomware are prerequisites for relying on these systems (Adebayo *et al.*, 2023, 2025; Afrihyia *et al.*, 2024b; Ekechi *et al.*, 2022; Nnaji and Akinlolu, 2024a; Ozowara *et al.*, 2022, 2025; Peteranaba *et al.*, 2022). Analytics-driven operations and digital information flow models can reduce workflow inefficiency and support timely decisions (Nnaji and Akinlolu, 2023, 2024b).

Nursing practice frameworks for patient safety, care coordination, quality monitoring, and nurse leadership provide the organizational foundation on which a device bundle depends (Akinlolu *et al.*, 2023; Ekemezie *et al.*, 2023a,b; Fapohunda *et al.*, 2024; Ohunyon *et al.*, 2025; Omaghomi *et al.*, 2024). Coordination across hospital units during emergencies and patient-flow surges, when arterial lines are often placed in suboptimal conditions, benefits from explicit policies and digital tracking (Akinlolu *et al.*, 2024; Fapohunda *et al.*, 2025a,b,c). Climate-related disasters can trigger such surges, and hazard mitigation funding for climate-vulnerable communities is one lever for strengthening local resilience (Hilliman *et al.*, 2025). Nurse-led and community-based models of chronic disease management also shape the comorbidity burden that patients bring to the ICU (Obi *et al.*, 2025; Omaghomi *et al.*, 2025a,b). Care plans that integrate behavioral, medical, and community services for underserved populations (Peteranaba *et al.*, 2024), and environmental exposures in resource-extraction regions (Osinem *et al.*, 2025), influence that burden as well.

Limitations

This review has several limitations. It is narrative rather than systematic, so study selection may be subject to bias, and no formal quality appraisal or meta-analysis was performed. Few studies were conducted specifically in community ICUs, and recommendations for this setting are therefore extrapolated from academic and multicenter research data. Much of the infection evidence comes from French and Spanish ICUs with established research protocols, and the largest trial of deferred arterial catheterization excluded important subgroups. Several cited frameworks addressing health-system, informatics, and workforce issues are conceptual rather than empirical and were included to describe the organizational context of device safety rather than as direct clinical evidence.

Future Research

Almost no trials or cohorts focus on community ICUs, and studies of arterial catheter utilization, complications, and outcomes across hospital types are needed; real-world data drawn from electronic health records offer a feasible route to generating them (Ilodigwe and Adesemoye, 2024a). Predictive models and national dashboards developed for public health surveillance could be adapted for this purpose (Oparah *et al.*, 2021a, 2022, 2024a, 2025). The findings of EVERDAC require confirmation in populations it excluded or underrepresented, including obese patients, those receiving high-dose vasopressors, post-cardiac-arrest and trauma patients, and units with different nurse staffing ratios. Validation of continuous noninvasive blood pressure devices and of venous-to-arterial blood gas conversion in shock could further reduce the need for arterial access. Randomized evidence comparing maximal and limited barrier precautions for radial catheters remains scarce, and standardized

definitions for arterial catheter-associated bloodstream infection would allow benchmarking across hospitals. Finally, the minimum training and procedural volume needed to maintain competence in ultrasound-guided arterial cannulation in low-volume units has not been defined.

CONCLUSION

Arterial catheters are valuable but not benign. The case for routine placement in every patient with shock has weakened, and arterial catheterization is better treated as a deliberate decision based on clear indications. When an arterial line is needed, radial placement under ultrasound guidance offers the best balance of success, durability, and safety, while the femoral site remains useful in emergencies at the cost of higher bleeding and infection risk. Because arterial lines carry an infection risk comparable to that of central venous catheters, they deserve the same standards of insertion asepsis, site care, daily review, and surveillance. For community ICUs, translating these principles into a simple, reliable bundle supported by focused training and organizational commitment is likely to yield the greatest gains in patient safety.

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Conflict of Interest

The author declares that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy, have been completely observed by the author.

Life Science Reporting

No life science threat was practised in this research.

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