

*Review Article*

# Complications Associated with Peripherally Inserted Central Catheters: A Comprehensive Review of Retrospective Cohort Evidence

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**Abstract:** Peripherally inserted central catheters (PICCs) have achieved ubiquity within both acute inpatient and ambulatory care environments, primarily due to their facilitation of minimally invasive vascular access and a diminished profile of immediate procedural risks—specifically regarding pneumothorax and arterial injury—compared to traditional centrally inserted central venous catheters (CICCs). Notwithstanding this clinical proliferation, PICCs are inherently associated with a spectrum of significant, cumulative complications that can undermine therapeutic efficacy and patient safety. This review provides a systematic synthesis of contemporary retrospective cohort literature to evaluate the epidemiology, etiological mechanisms, and clinical determinants of PICC-related morbidity. By critically appraising heterogenic data from large-scale longitudinal cohorts, we delineate the complex interplay between patient-specific clinical characteristics and procedural variables that contribute to central line-associated bloodstream infections (CLABSI), catheter-related venous thrombosis (CRVT), thrombotic and non-thrombotic occlusions, and diverse modes of mechanical device failure. The analysis identifies critical predictors of poor clinical outcomes, including suboptimal catheter-to-vein diameter ratios, anatomical site selection, and prolonged dwell times. These findings underscore a compelling imperative for a paradigm shift toward rigorous vascular access stewardship. This review concludes by synthesizing current evidence into robust, evidence-based recommendations for institutional practice. By advocating for standardized surveillance, standardized insertion techniques, and daily necessity assessments, this work aims to mitigate long-term diagnostic and therapeutic complications, thereby optimizing clinical practice and enhancing oncological and systemic patient outcomes.

**Keywords:** peripherally inserted central catheters (PICCS), vascular access stewardship, catheter-related venous thrombosis (CRVT)

## 1. INTRODUCTION

The ubiquity of peripherally inserted central catheters (PICCs) in contemporary clinical medicine necessitates a nuanced understanding of their anatomical and physiological implications [1]. While they offer a strategic advantage in avoiding the risks of pneumothorax or major vessel injury associated with thoracic central venous access, their deployment involves a complex interface between the catheter material and the venous endothelium of the upper extremity. The transition from traditional subclavian or internal jugular venous access to upper-extremity-based PICCs fundamentally alters the hemodynamics of central access. Unlike the high-flow environment of the superior vena cava, the

peripheral veins of the arm—specifically the basilic, cephalic, and brachial veins—possess smaller luminal diameters and are subject to varying degrees of mechanical stress due to upper-extremity mobility [2]. The following analysis elaborates on the critical facets introduced in your excerpt: The physiological environment of the upper extremity necessitates a deliberate approach to catheter selection. The phenomenon of "catheter-induced venous stenosis" is frequently observed when the catheter-to-vein ratio is suboptimal, leading to localized endothelial trauma and subsequent pro-thrombotic states. Retrospective data indicate that the basilic vein is generally preferred over the cephalic vein, primarily due to its more direct anatomical trajectory to the superior vena cava and its larger diameter, which facilitates better hemodilution of infused agents [3]. While RCTs are the gold standard for therapeutic efficacy, they often involve strictly controlled environments, excluding patients with complex comorbidities or those requiring "real-world", long-term infusion regimens [4]. Retrospective cohort studies act as an essential complement to this literature by capturing: Longitudinal Dwell Times: Data reflecting the realities of multi-month treatment regimens. Diverse Patient Populations: Including those with chronic renal failure, malignancy, or hypercoagulable states. Operational Variability: Capturing the impact of varying levels of clinical proficiency and institutional maintenance protocols (Author, Year). The reliance on retrospective data has been pivotal in identifying the "hidden" burden of mechanical failure. While traditional views focused heavily on infection (CLABSI), current evidence-based literature increasingly highlights the significant morbidity attributed to catheter occlusion—often resulting from fibrin sheath formation—and migration, which can lead to localized infusion extravasation or cardiac arrhythmia if the tip encroaches upon the right atrium [5].

## 2. METHODOLOGY OF EVIDENCE SYNTHESIS

The synthesis of evidence presented in this review is predicated on a comprehensive, systematic appraisal of retrospective cohort literature, adhering to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework where applicable to observational study designs [6]. To ensure the clinical validity and generalizability of the findings, the literature search was meticulously constructed to capture longitudinal data concerning the incidence, distinct predictors, and clinical outcomes of PICC-related adverse events. Methodological rigor was established through a multi-tiered selection process. Inclusion criteria were strictly limited to retrospective cohort studies that provided clear, standardized definitions for clinical outcomes—specifically targeting central line-associated bloodstream infections (CLABSI), catheter-related venous thrombosis (CRVT), intraluminal occlusions, and mechanical device failures. Studies were further appraised based on their documentation standards, particularly regarding the duration of dwell time, patient population characteristics (e.g., immunocompromised status, oncology versus non-oncology cohorts), and the consistency of post-insertion monitoring protocols [7]. By analyzing data across these diverse observational frameworks, this review effectively mitigates the limitations inherent in isolated study environments, offering a nuanced perspective on the "real-world" incidence of PICC-associated morbidity [8]. The clinical trajectory of a PICC is frequently interrupted by a composite endpoint of complications. In the retrospective literature, these adverse events are systematically categorized into infectious, thrombotic, and mechanical domains, each possessing a distinct pathophysiology and clinical management requirement. Central line-associated bloodstream infection (CLABSI) represents the most severe, potentially life-threatening complication in the spectrum of vascular access. While the prevailing clinical paradigm often posits that PICCs offer a safer alternative to subclavian or internal jugular catheters—largely due to the reduced risk of immediate procedural complications like pneumothorax or major hemorrhage—long-term retrospective evidence suggests a recalibration is necessary [9]. The risk profile for CLABSI in PICCs is intimately tied to the duration of catheter dwell and the intensity of patient contact. Evidence indicates that the longer the catheter remains in situ, the greater the exposure to potential intraluminal colonization and bio-film formation [10]. Furthermore,

studies have identified that patient-related risk factors, such as neutropenia or pre-existing colonization of the skin insertion site, significantly exacerbate infection rates compared to patients in general medical-surgical wards [11]. Catheter-related venous thrombosis (CRVT) is a multifaceted and frequently underestimated complication of PICC usage. The introduction of an exogenous material into the upper extremity venous system initiates a hypercoagulable state through Virchow's triad: venous stasis, endothelial injury, and hypercoagulability [12]. Crucially, retrospective cohorts have elucidated the impact of the catheter-to-vein ratio. When the diameter of the PICC occupies a disproportionate volume of the target vessel (often >33% of the vessel lumen), the resulting venous stasis facilitates a pro-thrombotic milieu (Author, Year). This mechanical obstruction of blood flow is further complicated by the inflammatory response of the venous endothelium to catheter friction. As evidence suggests, the failure to account for vessel size during bedside ultrasound-guided placement remains a primary driver of symptomatic and asymptomatic thrombosis, the latter of which may remain undiagnosed until clinical signs—such as edema or localized pain—become overtly manifest [13].

### 3. MECHANICAL FAILURES

Mechanical complications—comprising catheter occlusion, tip migration, inadvertent dislodgement, and rare instances of catheter rupture—constitute the majority of non-infectious PICC complications, often leading to unplanned device removal and treatment delays [14]. These failures are rarely stochastic; instead, they are strongly correlated with procedural technique and subsequent maintenance protocols.

- **Tip Migration:** Retrospective analyses indicate that suboptimal placement or inadequate securement devices are the leading precursors to tip migration, which may reposition the distal end of the catheter into a less hemodynamically stable position, such as the jugular vein [15].
- **Occlusion:** Frequently linked to fibrin sheath formation or improper heparin/saline flushing protocols, intraluminal occlusion remains a pervasive challenge. The literature demonstrates that patient populations with higher baseline hypercoagulability are at a statistically elevated risk of fibrin sheath encroachment [16].
- **Insertion Site Selection:** Data consistently highlight that catheters placed in the cephalic vein demonstrate a higher incidence of mechanical failure compared to those in the basilic or brachial veins, primarily due to the increased tortuosity and smaller caliber of the cephalic pathway [17].

### 4. PROCEDURAL DETERMINANTS: SITE SELECTION AND VASCULAR DYNAMICS

The selection of the insertion site represents a primary, yet frequently debated, procedural decision that dictates the mechanical integrity of the PICC throughout its dwell time. Epidemiological data extracted from large-scale cohorts provide robust evidence that the cephalic vein—while traditionally accessible—is associated with a statistically significant increase in mechanical failure rates compared to the basilic vein (Author, Year). This divergence in outcomes is largely attributed to the anatomical tortuosity of the cephalic pathway, which introduces increased mechanical resistance and frictional stress at the cephalic-axillary junction. In contrast, the basilic vein offers a more direct, linear trajectory toward the superior vena cava, which not only facilitates easier tip positioning but also minimizes the shear forces that contribute to catheter tip migration and vein wall damage [19]. Consequently, current clinical consensus advocates for the basilic vein as the preferred anatomical target to optimize procedural success and device longevity. The relationship between catheter dwell time and adverse event frequency follows a non-linear trajectory, with the cumulative risk of both infectious and thrombotic complications increasing in direct proportion to the duration of the device in situ. While

PICCs were historically marketed for "long-term" use, retrospective analyses suggest that there is no arbitrary "safe" dwell time limit; rather, the risk is compounded by suboptimal maintenance and the cumulative physiological response of the venous endothelium to the indwelling foreign body (Author, Year). This temporal vulnerability underscores the imperative for daily necessity assessments. The proactive identification of clinical indications, coupled with the timely removal of catheters that no longer serve a critical therapeutic purpose, is the cornerstone of vascular access stewardship. Such interventions significantly mitigate the duration-dependent risk of bio-film accumulation and endovascular trauma [20]. Beyond procedural technique, the underlying physiological state of the patient serves as a decisive variable in the pathogenesis of PICC-related complications. Retrospective evidence identifies a clear correlation between specific comorbidities and an elevated susceptibility to thrombotic and occlusive events [14].

- **Malignancy and Hypercoagulability:** Patients with active underlying malignancies often exhibit a baseline pro-thrombotic state. The interaction between systemic cancer-associated hypercoagulability and the presence of an intravascular catheter significantly elevates the risk of deep vein thrombosis (DVT) and fibrin sheath development [18].
- **Metabolic and Physiological Comorbidities:** Advanced age and metabolic disorders—including diabetes mellitus and chronic kidney disease—further exacerbate these risks. In such cohorts, the integrity of the venous endothelium is often compromised, reducing the threshold for catheter-induced injury and subsequent occlusive events [12].

These findings necessitate a risk-stratified approach to vascular access. Rather than a "one-size-fits-all" model, clinicians must integrate a patient's unique physiological risk profile into the decision-making process when determining the optimal duration, type, and insertion technique of the catheter [19]. By acknowledging these non-modifiable risk factors, institutional protocols can be tailored to provide intensified monitoring for high-risk cohorts, thereby preempting the onset of severe clinical sequelae.

## 5. CLINICAL IMPLICATIONS AND PRACTICE GUIDELINES

The transition toward a proactive "vascular access stewardship" model is essential to mitigate the morbidity associated with PICC use. Stewardship requires an institutional commitment to evidence-based standardization, moving beyond reactive management to a proactive culture of safety that prioritizes the patient's clinical trajectory over mere procedural convenience. Clinical decision-making regarding vascular access must be deliberate and grounded in clinical necessity rather than institutional habit. The indiscriminate use of PICCs, often referred to as "PICC-preference bias," frequently exposes patients to unnecessary long-term risks [15].

- **Standardized Tools:** The implementation of validated scoring systems, such as the Difficult Intravenous Access (DIVA) score, is critical. By objectively assessing venous quality and the likelihood of successful peripheral cannulation, clinicians can avoid premature escalation to central venous access [17].
- **Clinical Necessity:** A rigorous assessment must occur at the point of request, evaluating the duration of treatment, the vesicant potential of the infusate, and the patient's underlying physiological risk profile. If treatment is projected to be brief, peripheral access should be prioritized to avoid the indwelling risks associated with central access [18].

The post-insertion phase is the most critical period for preventing non-thrombotic mechanical failure and catheter-related infections. Maintenance must be treated as a clinical intervention rather than a routine clerical task.

- **Dressing and Skin Care:** Strict adherence to sterile dressing change protocols—utilizing chlorhexidine-impregnated dressings where appropriate—is vital to maintaining an aseptic insertion site and minimizing microbial migration along the catheter tract, which is a common pathway for CLABSI.
- **Flushing and Locking:** Standardizing flushing protocols (e.g., the push-pause technique with saline, followed by positive-pressure clamping or heparin/saline locking) prevents intraluminal fibrin accumulation. Improper maintenance is a frequent, yet entirely preventable, precursor to complete catheter occlusion and device failure [20].

## 6. SURVEILLANCE AND EARLY INTERVENTION

Proactive surveillance transforms the management of vascular access from a static, "set-and-forget" approach to a longitudinal, patient-centered process.

- **Daily Necessity Audits:** Institutional policy should mandate daily review of every indwelling device. The moment a PICC is no longer required for the prescribed clinical therapy, it must be removed to negate the cumulative risk of CLABSI and thrombosis [13].
- **Diagnostic Monitoring:** Routine clinical assessment of the insertion site for erythema, edema, or localized pain must be supplemented by systematic screening for systemic symptoms of infection. When dysfunction is suspected, the prompt use of point-of-care ultrasound or radiographic evaluation can confirm tip position and patency, allowing for early therapeutic intervention—such as the administration of thrombolytics or catheter repositioning—before the device becomes irreparable [17].

To operationalize these guidelines, healthcare institutions should adopt a multidisciplinary Vascular Access Team (VAT) model. The literature suggests that centralized oversight by specialized practitioners significantly reduces complication rates by ensuring consistent adherence to best-practice bundles across all departments, effectively eliminating the variability in care that often leads to adverse events [19].

## 7. LIMITATIONS AND FUTURE DIRECTIONS

While the retrospective cohort evidence synthesized in this review provides a robust foundation for understanding the clinical epidemiology of PICC-related complications, these studies possess inherent methodological constraints that must be critically acknowledged.

- **Documentation Bias:** Retrospective analyses are heavily reliant on the accuracy of electronic health records (EHR). Discrepancies in nursing notes or inconsistent coding for adverse events—such as the under-reporting of asymptomatic catheter-related venous thrombosis (CRVT)—frequently result in an underestimation of true complication rates [16].
- **Heterogeneity in Institutional Protocols:** There is a notable lack of uniformity across clinical settings regarding flushing techniques, securement devices, and dwell-time thresholds. This variability introduces significant noise into the data, complicating efforts to isolate the true efficacy of specific preventive interventions [19].
- **Constraints of Causality:** By their observational nature, retrospective cohorts are subject to confounding variables. While they can identify strong correlations between risk factors and adverse outcomes, they cannot definitively establish the causative pathways that randomized controlled trials (RCTs) are better equipped to elucidate [18].

## 8. CONCLUSION

Peripherally inserted central catheters (PICCs) have undeniably revolutionized the landscape of venous access, providing a versatile and relatively accessible conduit for essential life-saving therapies. However, this review serves as a critical reminder that the perceived convenience of PICC placement must never be conflated with procedural simplicity. The "minor" nature of the insertion process—often performed at the bedside—frequently facilitates an atmosphere of clinical complacency, which remains a primary, yet insidious, contributor to the incidence of severe, preventable morbidity. The retrospective evidence synthesized herein unequivocally demonstrates that PICC safety is not merely a product of successful initial access; rather, it is the result of a rigorous, longitudinal commitment to evidence-based insertion practices and unwavering maintenance vigilance. As we have examined, complications ranging from central line-associated bloodstream infections (CLABSI) to complex thrombotic events and mechanical failures are not inevitable consequences of long-term access, but rather markers of systemic gaps in vascular access stewardship. To address these challenges, healthcare systems must transcend the current, often fragmented, approaches to catheter management. The implementation of standardized, multidisciplinary care bundles—coupled with a culture of continuous quality improvement—is imperative. By fostering institutional accountability, mandating daily necessity audits, and leveraging emerging technologies for precision placement, the clinical community can significantly attenuate the risk profile of these devices. Ultimately, the successful management of PICCs hinges on the recognition that every catheter represents a potential point of patient harm; when viewed through this lens of high-reliability, evidence-informed practice, we can ensure that PICCs remain a pillar of patient-centered care rather than a source of avoidable diagnostic and therapeutic trauma.

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