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"Evidence-Based Management Of Venous Port Systems In Oncology: Infection, Thrombosis, And Beyond"

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Abstract

Venous port systems (totally implantable venous access devices) are cornerstone tools for long-term venous access in oncology. They improve patient comfort, support repeated outpatient therapy, and reduce peripheral vein damage. However, device-related complications most importantly catheter-related bloodstream infection (CRBSI), catheter-related thrombosis, occlusion, mechanical failure and extravasation continue to limit device longevity and may interrupt cancer therapy. Recent evidence (2015–2024) supports ultrasound-guided placement, strict insertion/maintenance bundles using chlorhexidine antisepsis, and selective use of antimicrobial-impregnated devices in high-risk settings to reduce CRBSI. Accumulating data indicate normal saline flushes are non-inferior to heparin for routine maintenance in many populations. In specific high-risk groups, the use of antimicrobial/ethanol lock therapies has been seen to diminish CRBSI, but their application ought to be in accordance with local protocols. It is not advisable to have routine systemic anticoagulant prophylaxis for all patients with vascular ports; rather, prophylaxis should be tailored according to the risk of VTE. This review integrates the latest guidelines and recent systematic evidence into one and suggests practical, evidence-based strategies for the insertion, maintenance, surveillance, and management of complications.

Keywords: Central venous catheter, chemotherapy, infection, thrombosis, venous port system, oncology.

Introduction

Totally implantable venous port systems (VPS, port-a-caths, TIVADs) provide long-term central venous access via a subcutaneously buried reservoir connected to a catheter positioned in a central vein. They are widely used in oncology for safe delivery of chemotherapy, supportive medications, parenteral nutrition and for blood sampling. Ports reduce repeated peripheral venipuncture, improving patient experience and preserving peripheral veins for future access [1,2].

Over decades, insertion techniques and device engineering have advanced, while care bundles and surveillance programs have matured. Nonetheless, device-related complications especially CRBSI and catheter-related thrombosis (CRT) remain clinically important because they increase morbidity, may require device removal, and can disrupt oncologic care [1,4]

Figure 01 : Venous port System

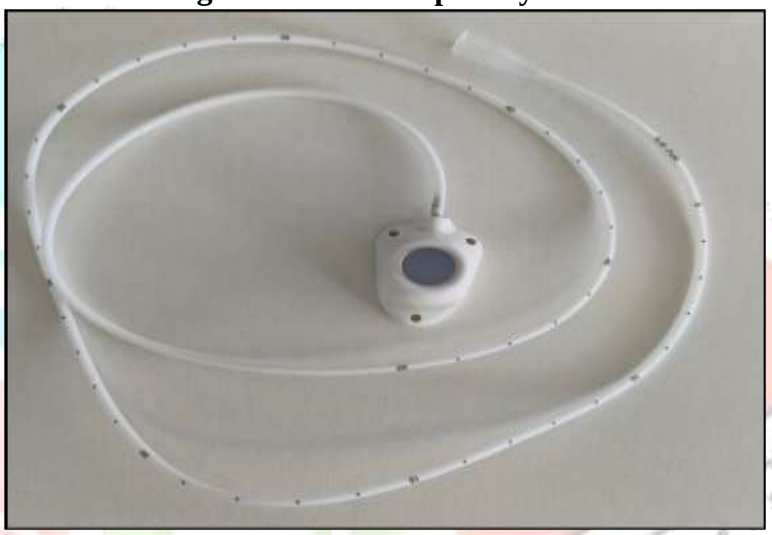
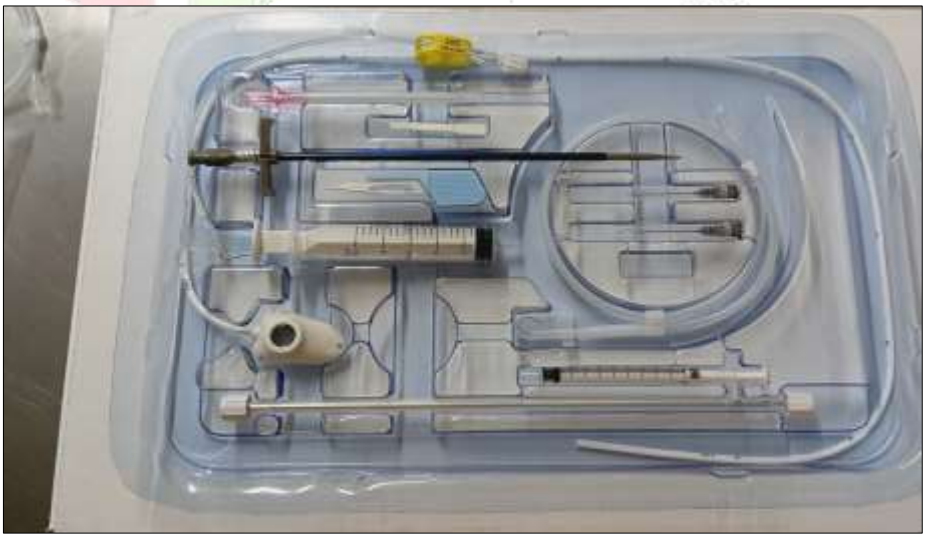


Figure 02: Venous port



Methods

A structured literature search of MEDLINE/PubMed and guideline repositories was performed covering major practice guidelines, systematic reviews and key randomized trials from 2000–2024,

with emphasis on high-quality evidence . Search terms included venous port, totally implantable venous access device, central venous catheter, catheter-related bloodstream infection, catheter-related thrombosis, heparin vs saline flushing, antimicrobial-impregnated catheters, ethanol lock, ultrasound-guided insertion and oncology. Authoritative guideline sources (CDC, IDSA, specialty societies) were prioritized for recommendations [1,2,5,9].

Epidemiology and Burden of Complications

Catheter-related bloodstream infection (CRBSI)

Low risk of catheter-related bloodstream infection (CRBSI) in patients with implanted ports occurs, when current best practices for insertion and maintenance are followed. In the case of ambulatory oncology patients, the number of clinically significant infections is commonly restricted to a few cases per 1,000 catheter-days or less than 5% [10,1].The organisms most often responsible include coagulase-negative staphylococci, Staphylococcus aureus, Gram-negative bacilli, and Candida species [10,2].

Catheter-related thrombosis (CRT)

Cancer is a hypercoagulable state, the presence of a central catheter adds to Venous Thromboembolism risk. Symptomatic CRT rates in contemporary series are often reported in the low-to-mid single digits (2-6%), though incidence is higher when systematic imaging is used to screen asymptomatic patients [11,12]. Management follows standard Venous Thromboembolism care principles adapted to the oncology context [7,11].

Occlusion and mechanical complications

Fibrin sheaths, thrombotic lumen occlusion, catheter fracture, malposition, and pinch-off syndrome are known causes of dysfunction. Routine flushing protocols and early recognition are central to prevention and salvage [12,13].

Pathogenesis and Risk Factors

- **Infection:** Pathways include peri-insertion contamination, migration of skin flora along the catheter tract, hub contamination during access/manipulation (a dominant mechanism for implanted ports), contaminated infusate, and hematogenous seeding from distant infection sites [2,10]. Immunosuppression (neutropenia, mucositis), frequent access, poor aseptic technique and prolonged indwelling time increase CRBSI risk.
- **Thrombosis:** Virchow's triad applies endothelial injury at insertion, blood stasis around a catheter, and cancer-associated hypercoagulability. Certain sites (arm veins vs chest), catheter

size relative to vessel lumen, and patient factors (active malignancy, chemotherapy type, prior VTE) modulate risk [11,12].

Diagnosis

- **CRBSI:** Diagnosis uses clinical assessment plus microbiology. Differential time to positivity (DTTP, growth from catheter blood culture at least 2 hours earlier than peripheral culture) supports catheter as infection source, IDSA guidance provides diagnostic and management algorithms [2]. Imaging (ultrasound, CT) is used for suspected septic thrombosis or abscess.
- **CRT:** Duplex ultrasonography is first-line for symptomatic upper-extremity or neck thrombosis, CT venography may be necessary for central location or complex anatomy. For catheter-lumen occlusion, inability to aspirate or infuse should trigger evaluation for thrombotic obstruction or mechanical issues [11,12].

Prevention Insertion and Maintenance Best Practices

Insertion

- Ultrasound guidance for venous access (internal jugular, brachial approaches) reduces mechanical complications and may reduce early infectious events, its routine use is recommended where feasible. Ultrasound improves first-pass success and reduces inadvertent arterial puncture and pneumothorax. [9]
- Maximal sterile barriers and chlorhexidine skin antisepsis (2% chlorhexidine in alcohol) at insertion are recommended elements of insertion bundles and reduce CRBSI risk. [1,2]

Device selection & coatings

- Antimicrobial-impregnated or coated catheters (e.g., chlorhexidine/silver sulfadiazine, minocycline-rifampin) have shown reduced colonization and in some analyses, reduced CRBSI under bundle conditions consider for patients at persistently high CLABSI rates or for individual high-risk patients. Evidence varies by coating and population, device-specific data should be reviewed before routine use. [3,20,12]

Access and maintenance

- Aseptic hub handling and use of closed systems, chlorhexidine-impregnated dressings in high-risk settings, and standardized maintenance bundles are effective, low-cost measures to reduce infection. [1,15]
- **Flushing:** Recent systematic reviews and meta-analyses show no consistent superiority of heparin over normal saline for routine flushing of many CVCs and implanted ports, many

centres now use saline flush protocols except when device- or patient-specific reasons require heparin. Use institutionally agreed protocols. [4,11]

- **Antimicrobial/ethanol locks:** Lock solutions (antibiotic or ethanol) reduce catheter colonization and CRBSI in selected high-risk cohorts (recurrent CRBSI, long-term parenteral nutrition), and can be used for salvage, risks and catheter compatibility must be considered. Routine universal use is not recommended. [5,13]

Thrombosis prevention

- Prophylaxis for systemic routine in all port patients is not recommended. Individual thrombotic risk (cancer type, history of VTE, catheter site) should be assessed and very high-risk patients can be given prophylaxis guided by the oncology-thrombosis society. For confirmed CRT, therapeutic anticoagulation with LMWH or DOACs (according to the case) is suggested following cancer VTE guidelines. [6,7,11]

Management of Complications

Catheter-related infection

- In case of a local pocket or tunnel infection, taking out the device and administering targeted antimicrobial treatment are usually the steps to follow.
- CRBSI with bacteria in the blood: IDSA guidelines state the situations leading to catheter removal decision versus salvaging attempt (e.g., the cases of persistent bacteremia, unstable hemodynamics, infection with S. aureus/Candida, tunnel/pocket infection, complicated sepsis). When salvaging is carried out, systemic antibiotics along with antimicrobial lock therapy may be the options based on organism-specific guidance. [2,16]

Catheter-related thrombosis

- Therapeutic anticoagulation is the primary treatment for symptomatic CRT duration and agent choice should follow cancer VTE guidelines and individual bleeding risk assessment (minimum 3 months recommended for many cases). Consider catheter removal only if infection, malfunction, or if catheter is no longer needed. [6,7,11]

Occlusion and fibrin sheath

- Thrombolytic therapy (alteplase or urokinase lock) can restore patency for intraluminal thrombotic occlusion. Persistent dysfunction from fibrin sheath may need interventional radiology procedures (fibrin sheath stripping) or catheter exchange. [12]

Comparative Effectiveness: Ports versus PICCs and Tunneled Lines

The comparison of data suggests that the long-term rates of catheter-related bloodstream infections are generally lower with implanted ports than with external tunneled catheters and in certain patient groups, the rates may also be lower than with PICCs; however, the latter is often chosen in short-term situations or in cases where access through the thorax is difficult. Different studies show different relations of thrombosis risk with catheter types and PICCs are reported to be associated with a higher risk of upper-extremity DVT in some cases. The selection of the device should be based on the expected duration of therapy, the patient's venous thromboembolism risk, the anatomy of the veins, and the history of complications at the institution. Differences and selection bias in comparative studies require prudence in interpretation, thus prospective head-to-head trials are still needed. [10,17]

Results

- **Insertion bundles and chlorhexidine:** Strong evidence supports maximal sterile barrier precautions and chlorhexidine antisepsis to reduce CRBSI. Ultrasound guidance reduces mechanical complications and contributes to safer insertion. [1,9,15]
- **Antimicrobial-coated devices:** Network meta-analyses show certain impregnations lower catheter colonization and CRBSI under bundle conditions benefit varies by coating and population, targeted use in high-risk settings is reasonable. [3,12]
- **Flushing:** Recent systematic reviews and meta-analyses show no consistent superiority of heparin over normal saline for routine flushing of many CVCs and implanted ports. Many centres now use saline flush protocols except when device- or patient-specific reasons require heparin. Use institutionally agreed protocols [4, 11, 19]. New comparative studies (Cureus 2024) also confirm that continuous saline infusion and intermittent saline flushes maintain catheter patency equivalently to heparin**,** supporting the transition toward saline-only maintenance protocols [19].
- **Antimicrobial/ethanol locks:** Lock solutions (antibiotic or ethanol) reduce catheter colonization and CRBSI in selected high-risk cohorts (recurrent CRBSI, long-term parenteral nutrition) and can be used for salvage; risks and catheter compatibility must be considered. Routine universal use is not recommended [5, 13, 18]. Ethanol lock therapy has demonstrated efficacy both as a treatment and as secondary prophylaxis for recurrent CRBSI in oncology and parenteral-nutrition patients, with Lancet Infectious Diseases data supporting significant infection-rate reduction without major systemic toxicity [18].
- **Thrombosis management:** Current oncology VTE guidelines advocate for therapeutic anticoagulation (LMWH/DOAC) for CRT and personalized prophylaxis strategies instead of the routine anticoagulation for the whole port patient population. [6,7,11]

Discussion

Today, modern care for venous ports has moved from a device-centered approach to a programmatic one: image-guided insertion, selection of devices based on registry evidence, standardized maintenance bundles, selective use of device coatings, and risk stratification for thromboprophylaxis. This combination of strategies minimizes complications and prolongs device life. Very good registry data and new meta-analyses shed light on the absolute risks when the evidence-based bundles are applied, however, the field still offers some gaps, especially when it comes to prospective comparative trials across device types in hematology-oncology subgroups and the long-term real-world effectiveness of new coatings and lock strategies. The literature limitations are the differences in outcome definitions (CRBSI vs catheter colonization), different surveillance (symptomatic detection vs routine screening), and inconsistent reporting of catheter-days denominators. Such circumstances make meta-analytic pooling and direct comparison difficult.

Future Directions

• **Device engineering:** It is necessary to conduct larger, better-designed trials of new antimicrobial and antithrombotic coatings in cancer populations.

• **Targeted prophylaxis:** Selective prophylaxis and interventions could be made possible through the use of risk-prediction models that consider patients, tumors, and devices.

• **Registries & digital monitoring:** Multicenter registries and remote monitoring are means by which improved surveillance, benchmarking, and quality improvement are possible.

• **Patient-reported outcomes:** Better device selection will be possible if the regular inclusion of patient comfort, function, and access-related quality of life in trials is considered.

Conclusion

Venous port systems have become necessities in today's oncology practice. The complication rates are greatly diminished when they are used with ultrasound-guided insertion, maximal sterile barriers, chlorhexidine skin antisepsis, maintenance bundles, selective use of antimicrobial devices, and evidence-based flushing protocols. Complication management should deal with guideline-based, risk-stratified approaches. Potential future studies should focus on prospective comparative effectiveness research, larger device-specific trials of coatings and lock strategies, and integrated registry-based quality improvement.

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