Peripherally Inserted Central Catheters: Thrombotic and Infectious Complications and How to Prevent Them

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OBJECTIVES

- Define the frequency of catheter occlusion and infection as complications of peripherally inserted central access devices (PICCs)
- State the association between central thrombosis and catheter colonization and infection
- Define the best practices for the prevention of central line-associated bloodstream infection
- Understand anti-reflux technology and the economic components to be considered for evaluation

Central Venous Access Devices

- Integral part of care for critically ill and long-term IV therapy patients
- Used to administer treatment modalities and supportive therapies: antibiotics, blood products, and total parenteral nutrition and for withdrawal of blood samples
- 75% of IV device-related bloodstream infections originate from central venous catheters (CVCs) of various types

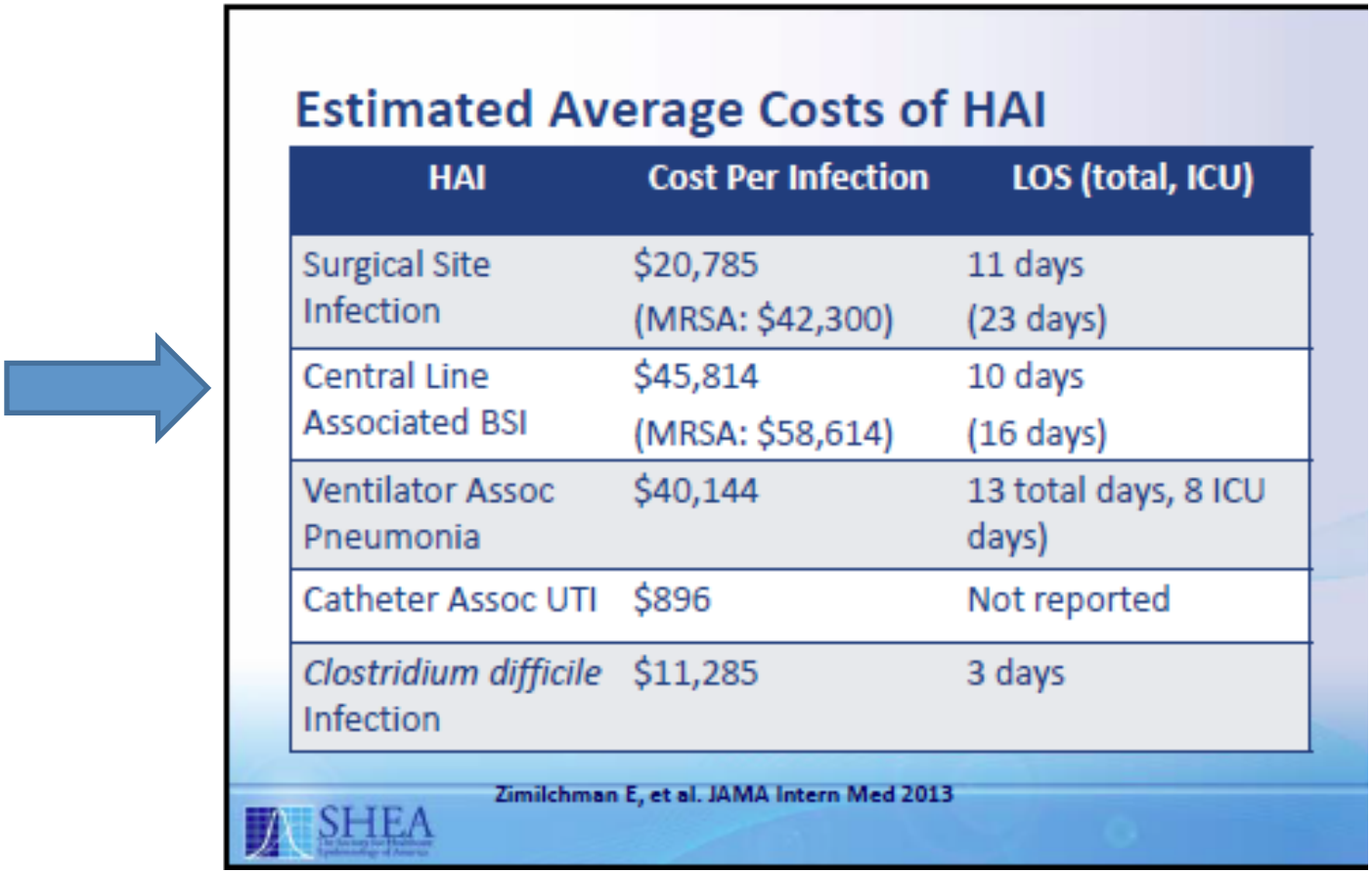
CVCs and Catheter-Related Bloodstream Infections (CRBSI)

- Estimated 250,000 cases of BSIs occur annually
  - attributable mortality rates of 12-25%[1]
  - mean excess length of stay of 12 days[2]
  - mean attributable cost of $19,000 (range of $3,592-$34,410)[2]
- Predominant mode of pathogenesis for CVCs in place for >10 days: intraluminal (contamination of the catheter hub and lumen)

[1]Pittet D, Tarara D, Wenzel R. Nosocomial Bloodstream Infection in Critically Ill Patients: Excess Length of Stay, Extra Costs and Attributable Mortality. *JAMA* 1994; 271:1598-1601

[2] Perencevich E, Stone PW, Wright SB, Carmeli Y, Fisman DN, Cosgrove SE. Raising Standards While Watching the Bottom Line: Making a Business Case for Infection Control. *Infect Control Hosp Epidemiol* 2007;28(10):

The Cost of CLABSIs – 2012 US Dollars



Estimated Average Costs of HAI

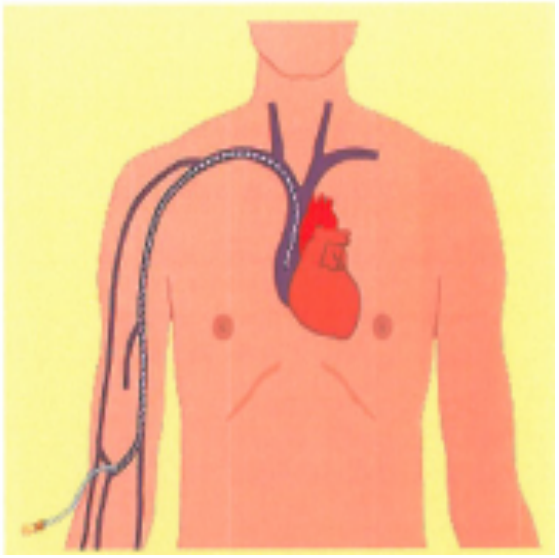
HAI	Cost Per Infection	LOS (total, ICU)
Surgical Site Infection	$20,785 (MRSA: $42,300)	11 days (23 days)
Central Line Associated BSI	$45,814 (MRSA: $58,614)	10 days (16 days)
Ventilator Assoc Pneumonia	$40,144	13 total days, 8 ICU days)
Catheter Assoc UTI	$896	Not reported
Clostridium difficile Infection	$11,285	3 days

Zimilchman E, et al. JAMA Intern Med 2013

SHEA

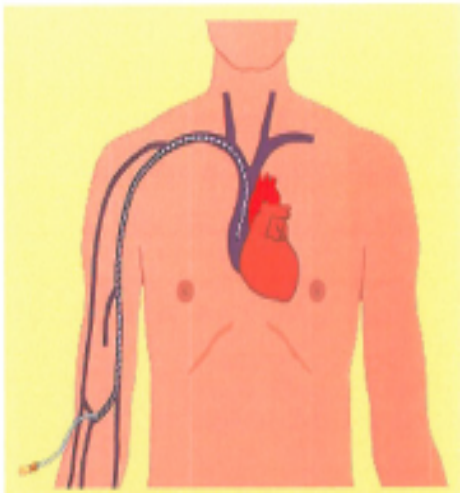
Zimlichman et al. HAIs – A Meta-analysis of Costs and Financial Impact on the US Healthcare System. *JAMA Intern Med* 2013

PICC Catheters: What's New



- Increased use in recent years
  - Factors driving the trend include low reported incidence of infection and ease of insertion
  - Nurse-based IV therapy teams insert and maintain decreasing physician workload and costs

PICC Catheters: What's New



- Safdar and Maki (2005) reported that PICCs used in ICU patients had CRBSI rates comparable to other nontunneled CVCs
- Ajenjo et al (2011) saw the use of PICCs increase throughout the hospital after the discontinuation of a nurse-based IV team
  - 3.13 PICC BSIs per 1000 catheter days
  - PICC use and PICC BSI rates were higher in the ICUs but most of the PICC BSIs occurred in non-ICU patients

Safdar N, Maki DG. Risk of catheter-related bloodstream infection with peripherally inserted central venous catheters used in hospitalized patients. *Chest 2005;128(2):489–495.*
Ajenjo MC, Morley JC, Russo AJ, McMullen KM, Robinson C, et al. Peripherally Inserted Central Venous Catheter-Associated Bloodstream Infections In Hospitalized Adult Patients. *Infect Control Hosp Epidemiol 2011;32(2):125-130*

PICCs in the Acute Care Setting

Table I. Rates of CLABSI for the different devices used

Catheter type	Infected catheters, %	CLABSI rate (cases/1000 catheter-days)	*P* value (2-sided; compared with subclavian CLABSI rate)
Subclavian	1.7 (4/242)	1.9 (4/2109)	
Internal jugular	2.7 (5/187)	3.4 (5/1454)	.28
Femoral	1.4 (3/209)	2.2 (3/1354)	.56
PICC	2.1 (13/638)	2.3 (13/5703)	.50

- Compared CLABSI rates in non-ICU patients with CVCs vs. facility-wide patients with PICCs
- Intervention: central line removal team: twice weekly evaluation for need and risk with recommendation to remove and place peripheral IV for short-term use or place a PICC for longer-term use
- 638 CVCs evaluated – 12 CLABSIs/ 4917 CL days = 2.4/1000 CL days
- 622 PICCs - 13 CLABSIs/5703 CL days = 2.3/1000 CL days

Raiy et al. *Am J Infect Control* 2010

PICCs in the Acute Care Setting

Table 2. Relationship between the duration of catheter utilization and development of CLABSIs

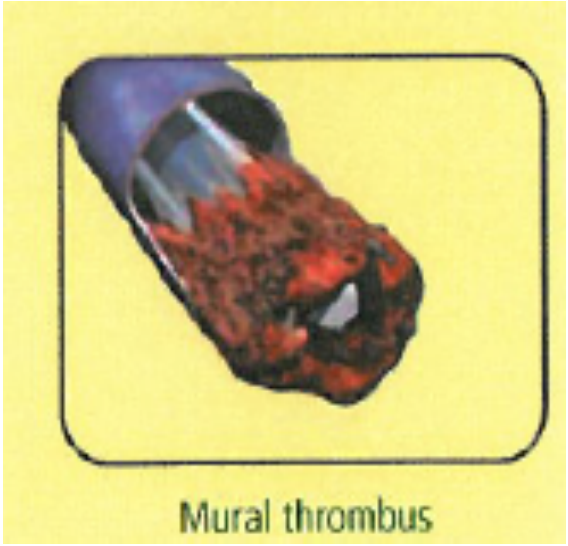
	CLABSIs	No CLABSIs	*P* value (2-sided)
Mean duration of catheter utilization, days ± SD			
CVCs	13.3 ± 4.6	7.6 ± 4.9	<.001
PICCs	27.9 ± 22.7	8.8 ± 9.1	<.001
Median duration of catheter utilization, days			
CVCs	13	7	<.001
PICCs	23	6	<.001

Raiy et al. *Am J Infect Control* 2010

- All infected PICCs were double-lumen catheters
- No significant difference in infection for PICCs placed by IV team vs. IR
- Median time to development of infection was significantly longer in the PICC group (23 vs. 13 days p=.03)

Catheter Occlusion

- Can result from extraluminal or intraluminal complications
  - Thrombi forming along the wall of the vein but exterior to the catheter - mural thrombi – can interfere with fluid flow through the catheter
  - Intraluminal thrombotic occlusions – fibrin deposits can produce a plug residing within the lumen of the catheter – can impair fluid instillation and blood withdrawal
- The type of CVC influences the risk of occlusion
  - Greatest risk with PICCs due to the narrow lumen
  - Certain catheter materials are more thrombogenic



Catheter Occlusion

- Blood can reflux into the catheter tip with changes in intrathoracic pressure
  - Sneezing
  - Coughing
  - Vomiting
- Poor infusion technique
  - Failure to flush lines properly
  - Incorrect procedure when disconnecting a displacement device from the line
- Most frequent non-infectious complication of CVCs
  - Occurs with 25% of catheters

Is there an association between thrombus formation and CRBSI?

- Pathogenic determinant of CRBSI
  - Formation of a sheath around the catheter (due to host factors consisting of protein adhesions, such as fibrin and fibronectin)
- Certain catheter materials are associated with higher risk of catheter infections
  - Silastic catheters have a higher risk than polyurethane catheters
  - Some catheter materials that are more thrombogenic might predispose to catheter colonization and infection. **This association has led to emphasis on preventing catheter-related thrombus as a mechanism for reducing CRBSI.**
- Raad and colleagues examined postmortem catheterized veins and contralateral uncatheterized veins of 72 cancer patients
  - Of 31 patients with mural thrombosis of the catheterized vein, seven developed catheter-related septicemia, whereas none of the 41 patients with normal catheterized veins developed catheter-related septicemia ($p<.01$)
  - They concluded that thrombotic complications are common in catheterized veins and are often associated with catheter sepsis

Raad I, Luna M, Khalil SM, Costerton JW, Lam C, and Bodey GP. The Relationship Between the Thrombotic and Infectious Complications of Central Venous Catheters. *JAMA* 1994;271(13):1014-1016

Grady NP, Alexander M, Burns LA, Dellinger P, Garland J, Heard SO, et al. Guidelines for the Prevention of Intravascular Catheter-Related Infections 2011 www.cdc.gov/hicpac/pdf/guidelines/bsi-guidelines-2011.pdf

Alteplase Use – Is It a Risk Factor for CLABSI?

- 4 year retrospective analysis of ICU and non-ICU patients with PICCs: 3,723: 40% received Alteplase
- Alteplase used as an indicator of line site thrombus

Table 2

Characteristics of patients who received alteplase compared with those who did not receive tissue plasminsogen activator: univariate analysis

	Patients who received TPA (n = 1,463), n (%)	Patients without TPA (n = 2,260), n (%)	Unadjusted odds ratio (95% CI)	*P* value
Age over 65 years*	836 (57.1)	1,258 (55.7)	1.06 (0.93-1.21)	.37
CLABSIs	32 (2.2)	14 (0.62)	3.60 (1.91-6.75)	<.001

Thakarar et al. *Am J Infect Control* 2014

Alteplase Use – Is It a Risk Factor for CLABSI?

Table 3
Adjusted odds ratios for risk factors associated with CLABSIs

	Adjusted odds ratio (95% CI)	*P* value
Age over 65 years*	0.59 (0.96-0.99)	.08
TPA	3.59 (1.86-6.94)	<.001
Primary hypercoagulability	3.41 (0.43-26.7)	.24
Secondary hypercoagulability	0.91 (0.44-1.88)	.81
High Charlson comorbidity index†	1.00 (0.51-1.96)	.99

TPA, tissue plasminogen activator.
*Age ≤ 65 years used as reference group.
†High Charlson comorbidity index defined as Charlson index score of ≥ 2.

- Odds of developing a CLABSI was 3.59 times greater for patients who received Alteplase than those who did not
- Neither severity of illness nor primary or secondary hypercoagulability were statistically associated with a higher risk of infection
- Key points: maintain patency of CVCs/PICCs and increase infection surveillance of patients who receive Alteplase

Thakarar et al. *Am J Infect Control* 2014

Prevention of CLABSI – Best Practices

Guidelines for the Prevention of Intravascular Catheter-Related Infections, 2011

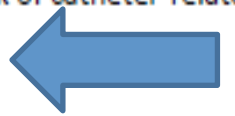
Naomi P. O'Grady, M.D.[1], Mary Alexander, R.N.[2], Lillian A. Burns, M.T., M.P.H., C.I.C.[3], E. Patchen Dellinger, M.D.[4], Jeffery Garland, M.D., S.M.[5], Stephen O. Heard, M.D.[6], Pamela

Prevention of CLABSI – Best Practices

Anticoagulants

Recommendation

Do not routinely use anticoagulant therapy to reduce the risk of catheter-related infection in general patient populations [139]. Category II



Background

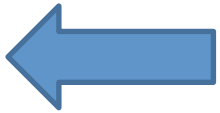
Shortly after insertion, intravascular catheters are coated with a conditioning film, consisting of fibrin, plasma proteins, and cellular elements, such as platelets and red blood cells

"Microbes interact with the conditioning film, resulting in colonization of the catheter."

Prevention of CLABSI – Best Practices

Table 1. Catheters used for venous and arterial access.

Catheter type	Entry Site	Length	Comments
Peripheral venous catheters	Usually inserted in veins of forearm or hand	<3 inches	Phlebitis with prolonged use; rarely associated with bloodstream infection
Peripheral arterial catheters	Usually inserted in radial artery; can be placed in femoral, axillary, brachial, posterior tibial arteries	<3 inches	Low infection risk; rarely associated with bloodstream infection
Midline catheters	Inserted via the antecubital fossa into the proximal basilic or cephalic veins; does not enter central veins, peripheral catheters	3 to 8 inches	Anaphylactoid reactions have been reported with catheters made of elastomeric hydrogel; lower rates of phlebitis than short peripheral catheters
Nontunneled central venous catheters	Percutaneously inserted into central veins (subclavian, internal jugular, or femoral)	≥8 cm depending on patient size	Account for majority of CRBSI
Pulmonary artery catheters	Inserted through a Teflon® introducer in a central vein (subclavian, internal jugular, or femoral)	≥30 cm depending on patient size	Usually heparin bonded; similar rates of bloodstream infection as CVCs; subclavian site preferred to reduce infection risk
Peripherally inserted central venous catheters	Inserted into basilic, cephalic, or brachial veins and enter the superior vena cava	≥20 cm depending on patient size	Lower rate of infection than nontunneled CVCs



Checklist for Prevention of CLABSI

For Clinicians:

Promptly remove unnecessary central lines

- ☐ Perform daily audits to assess whether each central line is still needed

Follow proper insertion practices

- ☐ Perform hand hygiene before insertion
- ☐ Adhere to aseptic technique
- ☐ Use maximal sterile barrier precautions (i.e., mask, cap, gown, sterile gloves, and sterile full-body drape)
- ☐ Perform skin antisepsis with >0.5% chlorhexidine with alcohol
- ☐ Choose the best site to minimize infections and mechanical complications
  - Avoid femoral site in adult patients
- ☐ Cover the site with sterile gauze or sterile, transparent, semipermeable dressings

Handle and maintain central lines appropriately

- ☐ Comply with hand hygiene requirements
- ☐ Scrub the access port or hub immediately prior to each use with an appropriate antiseptic (e.g., chlorhexidine, povidone iodine, an iodophor, or 70% alcohol)
- ☐ Access catheters only with sterile devices
- ☐ Replace dressings that are wet, soiled, or dislodged
- ☐ Perform dressing changes under aseptic technique using clean or sterile gloves

For Facilities:

- ☐ Empower staff to stop non-emergent insertion if proper procedures are not followed
- ☐ "Bundle" supplies (e.g., in a kit) to ensure items are readily available for use
- ☐ Provide the checklist above to clinicians, to ensure all insertion practices are followed
- ☐ Ensure efficient access to hand hygiene
- ☐ Monitor and provide prompt feedback for adherence to hand hygiene http://www.cdc.gov/handhygiene/Measurement.html
- ☐ Provide recurring education sessions on central line insertion, handling and maintenance

Supplemental strategies for consideration:

- 2% Chlorhexidine bathing
- Antimicrobial/Antiseptic-impregnated catheters
- Chlorhexidine-impregnated dressings

http://www.cdc.gov/HAI/pdfs/bsi/checklist-for-CLABSI.pdf

Impact of Alcohol-Impregnated Port Protectors/Neutral Pressure Connectors

- Before-after trial with adult oncology patients
  - Intervention included change from alcohol wipes to port protectors and change from a needleless hub to a neutral pressure connecor
  - Historical control period of 12 months with intervention period of 6-months
- Control period
  - 16 CLABSIs/6,851 CL days= 2.3/1000 CL days
- Intervention period
  - 1 CLABSI/3,005 CL days = 0.3/1000 CL days p=.03
- Also observed a statistically significant reduction in contaminated blood cultures 2.5% vs. 0.2% p=.002

Sweet et al. *Am J Infect Control* 2012

Importance of CVC Site Maintenance and Prevention of CLABSIs

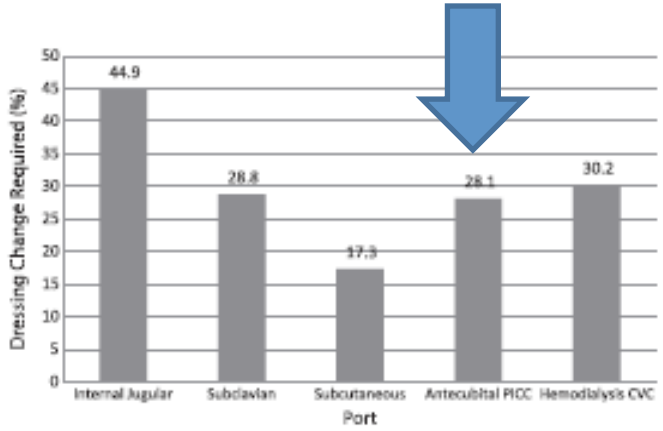


Fig 1. Need for CVC dressing change by type of catheter and location of insertion. Numerical values are the percentage of CVCs of that particular classification needing a dressing change at the time of inspection. *PICC*, peripherally inserted central catheter; *CVC*, central venous catheter.

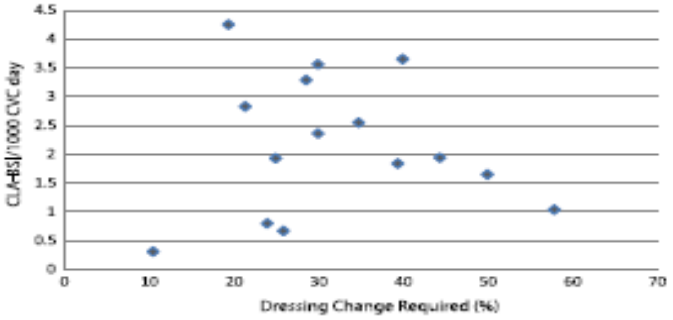


Fig 2. The CLABSI rate versus the need for dressing change. Each data point represents the unit-specific rate of CLABSI versus the percentage of CVCs that met the criteria for a necessary dressing change. Spearman's correlation coefficient = 0.007; $P = .98$. *CLA-BSI*, central line associated bloodstream infection; *CVC*, central venous catheter.

- 420 CVC sites observed weekly on 15 patient care units: 31% had deficiencies
- Direct correlation between site maintenance and CLABSI not observed
- CLABSI infections are complex and require a multimodal preventative program

Rupp et al. *Am J Infect Control* 2013

INS Standards

49. INFECTION

Standard

49.1 The assessment and treatment of infusion- and vascular access device (VAD)-related infections shall be established in organizational policies, procedures, and/or practice guidelines.
49.2 The nurse shall assess the patient for suspected infusion- and VAD-related infections; provide timely and appropriate information to the licensed independent practitioner (LIP); educate the patient and/or caregiver about infusion- and VAD-related infections, the intervention, and follow-up; and assess patient response to treatment.
49.3 The nurse shall document in the patient's permanent medical record the signs and symptoms of infusion- and VAD-related infections, interventions implemented, and patient response to treatment.
49.4 The nurse shall implement infection prevention measures with the goal of preventing all infusion- and VAD-related infections.

56. CATHETER CLEARANCE: OCCLUDED CENTRAL VASCULAR ACCESS DEVICES

Standard

56.1 Medications and/or solutions used to dissolve thrombotic deposits or precipitate in central vascular access devices (CVADs) shall be administered upon the order of a licensed independent practitioner (LIP) in accordance with organizational policies, procedures, and/or practice guidelines.
56.2 The nurse shall be competent in performing procedures used in catheter clearance.
56.3 The nurse shall assess the patient and the patient's CVAD for appropriateness of the use of catheter clearance medications and/or solutions in relation to the suspected cause of catheter occlusion.

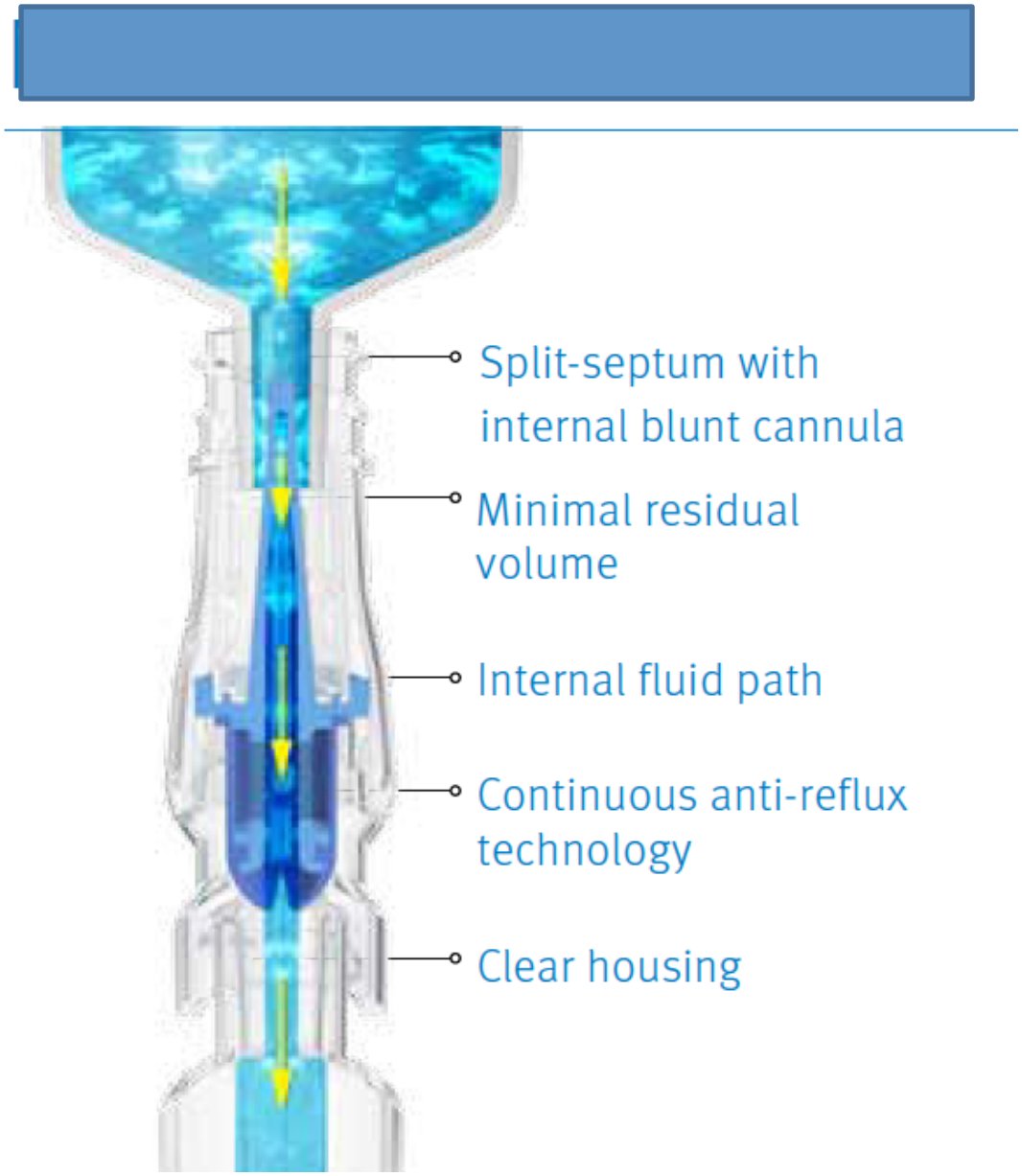
Infusion Nurses Society. 2011 Infusion Nursing Standards of Practice. *J Infus Nurs.* 2011;34(suppl 1s):S1-S110.

Case Study

- 2011 -Administration at Hospital X decide to eliminate the nurse-based intravenous therapy team as a cost containment measure
- 2012 – PICC catheter utilization has doubled (200 placements to 400 placements annually).
- Feb 2012 – Meeting of the Vascular Care Committee
  - Interventional radiology notes an increase in patients needing replacement of dysfunctional PICCs in whom patency salvage failed
  - Pharmacy reports an increase in t-PA or alteplase usage
  - Infection Preventionist reports an increase in the CRBSI rate for both ICU and non-ICU patients and expresses concern that 25% of the patients had PICCs in place when the CRBSI was detected. It is noted that the hospital recently transitioned to a split-septum needlefree connector and a performance improvement initiative was launched for “scrub the hub”

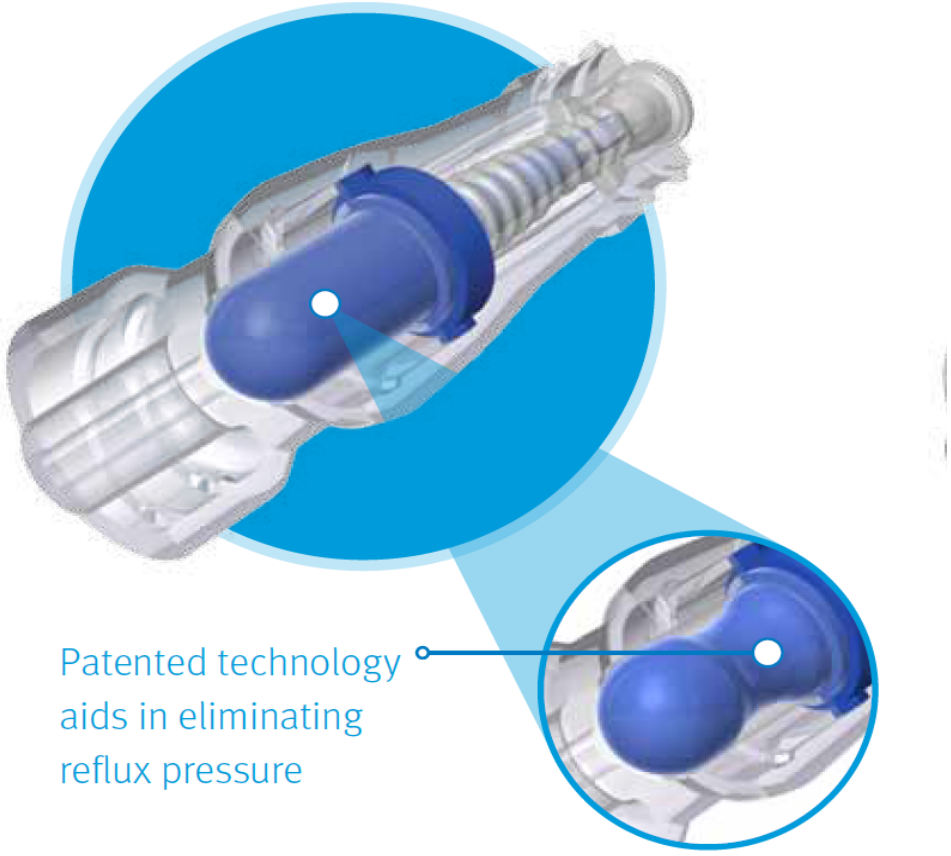
Design features

- Identical housing component
- Neutral displacement
- Split-septum seal
- Blunt cannula geometry



Anti- Reflux Technology

- Bidirectional silicone valve and bellows design work together to prevent blood reflux at all times
- Valve remains closed unless accessed for aspiration or infusion
- Bellows gives the ability to absorb and physically compensate for pressure variations that typically result in blood reflux into the catheter



CASE STUDY

- Product request initiated as a joint effort between Infection Prevention (IP), Critical Care Intensivist and Nurse Champions, Interventional Radiology (IR) Nurse Manager
- Rationale:
  - FDA-cleared device with the microbial barrier features of the in-use needleless connector with the ability to prevent reflux resulting from internal and external causes. It is recognized that catheter occlusions delay patient treatment, may be associated with catheter-related infection and affect the patient's quality of life.

IP's Position

- The risk of CRBSI from PICCs increased with wider usage among ICU patients
- Split-septum, neutral pressure needleless connector – lowest bacterial transfer rate [1]
  - Alignment with 2011 CDC Guidelines: When needleless systems are used, a split septum valve may be preferred over some mechanical valves due to increased risk of infection with the mechanical valves (Category II)
- Nursing compliance with disinfection of the needleless connector prior to access varies considerably. Recent data supports a 5 sec scrub with alcohol[2]

1 Ryder M, Fisher S, Hamilton G, Hamilton M, James G. Bacterial transfer through needlefree connectors: comparison of nine different devices. Presented at SHEA Annual Scientific Meeting, April 2007.

2 Rupp M, Yu S, Huerta T, Cavalieri J, Alter R, Fey P, et al. Adequate Disinfection of a Split-Septum Intravascular Connector with a 5-second Alcohol Scrub. *Infect Control Hosp Epidemiol* 2012;33(7):661-665.

IP's Position

- Alignment with 2011 CDC Guidelines: Minimize contamination risk by scrubbing the access port with an appropriate antiseptic and accessing the port only with sterile devices (Category 1A)

- Work collaboratively with IR and ICU clinical staff to ensure that all areas involved with the evaluation are informed of the trial and trained on its use
- Connect with IPs in other facilities using the product; did implementation go smoothly, how was the company's customer support, any concerns

ICU Champions' Position

- Patient safety focus
  - Unit-based CRBSI reduction target not met
  - Nursing competency validation needed for management of occluded PICCs with thrombolytic treatment (alteplase); restoring of catheter patency less than expected
- ICU bed utilization
  - PICC replacements delay therapy and procedures and increase patient's length of stay

IR's Position

- PICC occlusion occurring too frequently
  - Why ? Poor flushing technique
- PICC replacement rate too high
  - Failure to salvage: is proper protocol in place for use of alteplase?
- Patient safety
  - Clinical risks associated with replacement: infection, bleeding, embolization, etc.
  - Limited vessels to cannulate
- Financial
  - Loss of IR time and resources for other procedures

Product Evaluation

- Collect and analyze data that will be used as outcome metrics
  - rate of PICC occlusions
  - cost of alteplase administration for patency salvage
  - replacement of catheters in IR : success of salvage
  - CRBSI rates
- Product Performance Criteria
  - ✓ ease of use
  - ✓ clinician confidence

Anti-Reflux Valves - Cost Analysis

- Economic elements
  - Cost of current needleless connector vs. anti-reflux valve
  - Cost of alteplase administration
  - Cost of catheter replacements
    - Cost of catheter
    - IR time: staff and room time
    - Diagnostic imaging

SUMMARY

- Thrombotic complications are frequent with PICCs and contribute to the risk of CLABSI
- PICC catheters remain the recommended choice for patients requiring long-term central access
- Central catheters that are inserted and maintained using best practices as recommended by HICPAC have lower infection rates
- Further study is needed to support the use of anticoagulants as a strongly recommended CLABSI prevention strategy
- Anti-reflux valve technology is a promising alternative strategy to prevent catheter thrombosis