

Catheter-related blood stream infection: Incidence and pathophysiology

Introduction

- Intravascular devices are indispensable in modern clinical practice
- Central venous catheters (CVCs) are commonly inserted in critically ill patients
- Approx 90% of the CRBSI occur with CVCs

Mermel LA. Prevention of intravascular catheter-related infections. Ann Intern Med. 2000;132(5):391- 402

Central line - Definition

- A catheter whose tip terminates in a great vessel - the aorta, PA, SVC, Inferior VC, brachiocephalic veins, IJV, subclavian veins, external iliac veins, and common femoral veins.
- Femoral lines
- Peripherally inserted central catheter (PICC) lines

the National Healthcare Safety Network (NHSN)

CRBSI - Incidence

Based on the North American data compiled from the NNIS from October 1986 to December 1990

- 2.1 per 1000 catheter days for respiratory ICUs
- 5.1 for medical-surgical ICUs
- 5.8 for trauma ICUs
- 30.2 for burn units

Jarvis WR, Edwards JR, Culver DH et al. Nosocomial infection rates in adult and pediatric intensive care units in the United States. Am J Med 1991 Sep 16; 91(3B):185S-191S7

CRBSI - Incidence

More recent data from NNIS from January 1992 through June 2004:

- the median rate of CRBSI in ICUs of all types ranged from 1.8 to 5.2 per 1000 catheter-days

National Nosocomial Infections Surveillance System. (NNIS) System report, data summary from January 1992 through June 2004, issued October 2004. Am J Infect Control 2004; 32:470-85

CRBSI - Incidence

From 1 May 2000 to 30 April 2003:

- CR-BSI rate of 2.79 per 1000 catheter days

*Lorente L, Henry C, Martin MM, Jimenez A, Mora ML.
Central venous catheter-related infection in a prospective
and observational study of 2595 catheters. Crit Care
2005; 9(6): R631-R635*

- 48% of ICU patients have CVCs, accounting for about 15 million central-venous-catheter-days per year in ICUs
- If 5.3 CRBSI occur per 1,000 catheter days, the attributable mortality is approx 18%
- Probably about 14,000 deaths occur annually due to central line infections. Some estimates put this figure as high as 28,000 deaths per year

Pittet D et al. Nosocomial bloodstream infection in critically ill patients. Excess length of stay, extra costs, and attributable mortality. JAMA. 1994;271:1598-1601

Saint S. Chapter 16. Prevention of intravascular catheter-related infection. Making health care safer: a critical analysis of patient safety practices. AHRQ evidence report, number 43, July 20, 2001

Berenholtz SM et al. Eliminating catheter-related bloodstream infections in the intensive care unit. Crit Care Med. 2004;32:2014-2020

- In addition, CRBSI prolong hospitalization by a mean of 7 days. Estimates of attributable cost per bloodstream infection are estimated to be between \$3,700 and \$29,000.

Soufir L, Timsit JF, Mahe C, Carlet J, Regnier B, Chevret S.

Attributable morbidity and mortality of catheter-related septicemia in critically ill patients: a matched, risk-adjusted, cohort study.

Infect Control Hosp Epidemiol. 1999;20(6):396-401.

CRBSI - Incidence

Data from NAICU 2007:

- 66.2% of ICU patients have CVCs

Data from HSA JB 2005:

- 9.43 per 1000 catheter-in-situ days

CRBSI - Pathogenesis

- 4 major sources:
 - a. colonization from skin
 - b. intraluminal or hub contamination
 - c. secondary seeding from a bloodstream infection
 - d. rarely contamination of the infusate

Colonization from skin

- Colonization of the intracutaneous and intravascular portions of the catheter by micro-organisms
- Micro-organisms from patient's skin and occasionally hands of health care workers
- Micro-organisms on the skin can migrate along the s/c tract created by indwelling catheter

Colonization from skin

- The deposition of biofilm on external and internal surface of vascular catheters → the colonization process
- Biofilms are protected colonies where micro-organisms exist

Biofilm formation

- takes place in 2 stages:
 - a. attachment of microbes to the object
 - b. production of an extracellular matrix (called a glycocalyx or slime) that surrounds the microbes and protects them from adverse environmental conditions

*O, Toole G et al. Biofilm formation as microbial development.
Annu Rev microbiol 2000;54:49-79*

Biofilms on vascular catheters

- Can shield the encased microbes from circulating antibiotics
- Antibiotic concentrations must be 100 to 1000 times greater to eradicate bacteria in biofilms than to kill free-flowing bacteria

Intraluminal or hub contamination

- Microbes can gain access to the internal lumen of vascular catheters through break points in the infusion system such as stopcocks and catheter hubs
- A prominent route of infection for CVCs in place > 2 weeks or in patients with a surgically implanted device

Linares J et al. Pathogenesis of catheter sepsis: A prospective study with quantitative and semiquantitative cultures of catheter hub and segments. J Clin Microbiol 1985; 21:357

Tenney et al. Adherent microorganisms on luminal surfaces on long term intravenous catheters. Importance of Staphylococcus epidermidis in patients with cancer. Arch Intern Med 1986; 146:1949

Miller JJ et al. Comparison of the sterility of long-term central venous catheterization using single lumen, triple lumen, and pulmonary artery catheters. Crit Care Med 1984; 12:634

Salzman MB et al. A prospective study of the catheter hub as the portal of entry for microorganisms causing catheter-related sepsis in neonates. J Infect Dis 1993; 167:487

Secondary seeding from a bloodstream infection

- Microbes in circulating blood can attach directly to indwelling vascular catheters or can become trapped in the fibrin meshwork that surrounds indwelling catheters
- More likely to occur in long-term catheters

Raad II et al. Diagnosis of catheter-related infections: The role of surveillance and targeted quantitative skin cultures. Clin Infect Dis 1995; 20:593

Mermel LA et al. The pathogenesis and epidemiology of catheter-related infection with pulmonary artery Swan-Ganz catheters: A prospective study utilizing molecular subtyping. Am J Med 1991; 91(3B):197S

Contamination of the infusate

- Infusate or additives such as heparin flush may become contaminated
- A rare source of CRBSI
- Causes epidemic infections

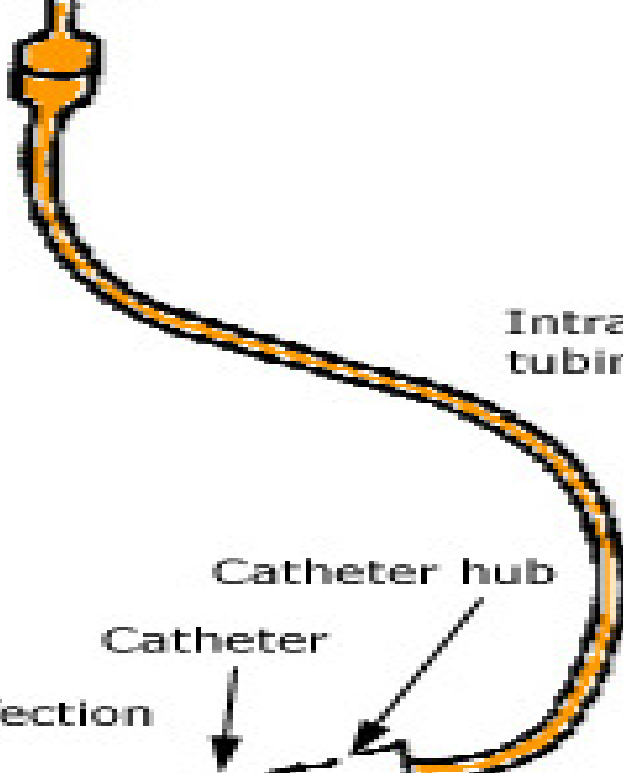
*Maki, DG. Nosocomial bacteremia. An epidemiologic overview.
Am J Med 1981; 70:719*

*Kimura AC et al. Outbreak of Ralstonia pickettii bacteremia in a
neonatal intensive care unit. Pediatr Infect Dis J 2005; 24:1099*



Infusion fluid

Intrinsic contamination- during manufacture or preparation
In use contamination- via ports, stopcocks, changing bags, etc



Intravenous tubing

Catheter hub

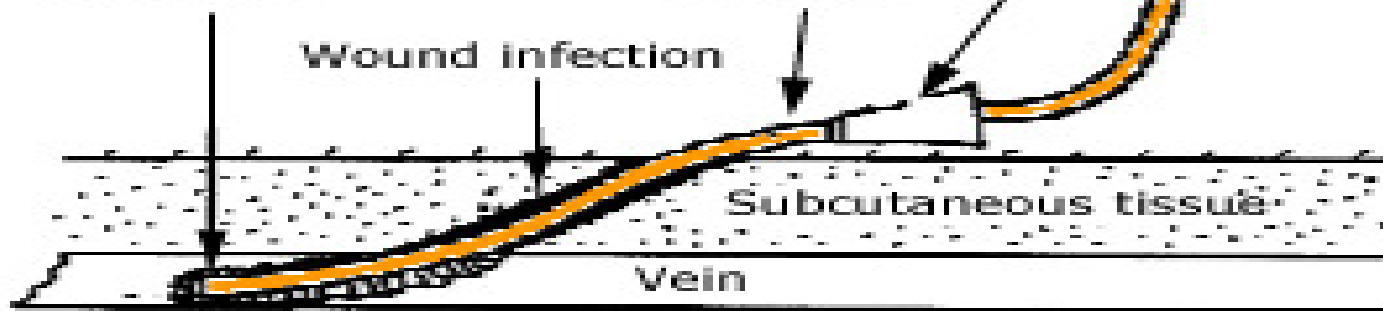
Catheter

Wound infection

Fibrin sheath thrombus

Subcutaneous tissue

Vein



Risk factors

- Femoral or internal jugular more than subclavian

Mermel LA et al. The pathogenesis and epidemiology of catheter-related infection with pulmonary artery Swan-Ganz catheters: A prospective study utilizing molecular subtyping. Am J Med 1991; 91(3B):197S

Richet H et al. Prospective multicenter study of vascular-catheter-related complications and risk factors for positive central-catheter cultures in intensive care unit patients. J Clin Microbiol 1990; 28:2520

Merrer J et al. Complications of femoral and subclavian venous catheterization in critically ill patients. A randomized controlled trial. JAMA 2001; 286:700

Lorente L et al. Central venous catheter-related infection in a prospective and observational study of 2595 catheters. Crit Care 2005; 9:631

Risk factors

- Repeated catheterization
- Presence of septic focus elsewhere

Mermel LA et al. The pathogenesis and epidemiology of catheter-related infection with pulmonary artery Swan-Ganz catheters: A prospective study utilizing molecular subtyping. Am J Med 1991; 91(3B):197S

Richet H et al. Prospective multicenter study of vascular-catheter-related complications and risk factors for positive central-catheter cultures in intensive care unit patients. J Clin Microbiol 1990; 28:2520

Risk factors

- Catheter insertion using submaximal barrier precautions

Raad II et al. Prevention of central venous catheter-related infections by using maximal sterile barrier precautions during insertion. Infect Control Hosp Epidemiol 1994; 15:231.

Maki, DG. Yes, Virginia, aseptic technique is very important: Maximal barrier precautions during insertion reduce the risk of central venous catheter-related bacteremia. Infect Control Hosp Epidemiol 1994; 15:227.

Risk factors

- Nontunneled more than tunneled

Pessa ME et al. Complication of Hickman-Broviac catheters.

Surg Gynecol Obstet 1985; 161:257

Darbyshire PJ et al. Problems associated with indwelling central venous catheters. Arch Dis Child 1985; 60:129

Risk factors

- Tunneled more than totally implantable device

Groeger JS et al. Infectious morbidity associated with long-term use of venous access devices in patients with cancer. Ann Intern Med 1993; 119:1168

Ross MN et al. Comparison of totally implanted reservoirs with external catheters as venous access devices in pediatric oncology patients. Surg Gynecol Obstet 1988; 167:141

Carde P et al. Classical external indwelling central venous catheter versus totally implanted venous access systems for chemotherapy administration: A randomized trial in 100 patients with solid tumors. Eur J Cancer Clin Oncol 1989; 25:939

Risk factors

- Lower risk with silver-chelated collagen cuff

Flowers RH et al. Efficacy of an attachable subcutaneous cuff for the prevention of intravascular catheter-related infection. A randomized, controlled trial. JAMA 1989; 261:878

Maki DG et al. An attachable silver-impregnated cuff for prevention of infection with central venous catheters: A prospective randomized multicenter trial. Am J Med 1988; 85:301

Peripheral intravascular catheters

- Lower extremities > upper extremities
- Wrist > hands
- Placement > 3-4 days
- PVC and polyethylene > teflon

PAC

- Catheterization >3-5 days
- Colonization at insertion site
- Int jug > subclavian
- Catheter insertion using submaximal barrier precautions
- Regular protective plastic sleeves > shield sleeves

CVC

- Int jug > subclavian
- repeated catheterization
- Presence of septic focus elsewhere
- Nontunneled >tunneled
- Tunneled > totally implanted device
- Catheter insertion using submaximal barrier precautions
- Lower risk with silver-chelated collagen cuff
- Lower risk with antibiotic or antiseptic impregnated short term catheters

Catheter-care factors

- Emergent > elective
- Skill of inserter
- Skin under dressing – moist > dry
- Cutaneous antiseptic – 70% alcohol and 10% povidone iodine more
- Antibiotic-lock solutions – lower risk in neutopenic patients with long term catheters

- **Microbiology**

- A number of studies also reported coagulase-negative staphylococci as the most common organism

Lorente L et al. Central venous catheter-related infection in a prospective and observational study of 2595 catheters. Crit Care 2005; 9(6): R631-R635

National Nosocomial Infections Surveillance System. (NNIS) System report, data summary from January 1992 through June 2004, issued October 2004. Am J Infect Control 2004; 32:470-85

Gowardman JR et al. Central venous catheter-related bloodstream infections: an analysis of incidence and risk factor in a cohort of 400 patients. Intensive Care Med 1998; 24:1034-1039

Safdar N, Maki DG. The pathogenesis of catheter-related bloodstream infection with noncuffed short-term central venous catheters. Intensive Care Med 2004 Jan; 30(1):62-7

Sadoyama G, Gontijo Filho PP. Comparison between the jugular and subclavian vein as insertion site for central venous catheters: microbiological aspects and risk factors for colonization and infection. Braz J Infect Dis 2003 Apr; 7(2):142-8

- A survey of 112 medical ICUs in the United States:

CoNS, mostly *Staph epidermidis* (36%)

Enterococci (16%)

Gram-negative aerobic bacilli (16%)

(Pseudomonas aeruginosa, Klebsiella pneumoniae, E coli, etc)

Staph aureus (13%)

Candida species (11%)

Other organisms (8%)

Richards M, Edwards J, Culver D, Gaynes RP. Nosocomial infections in medical intensive care units in the United States. Crit Care Med 1999(5); 27:887-892

- A study in HSA ICU 2005:

80.6% Gram –ve bacteria: K. pneumoniae (38.9%)

P. aeruginosa (19.4%)

A. baumannii (13.9%)

Enterobacter spp (8.3%)

19.4% Gram +ve bacteria: MRSA (13.9%)

MSSA (2.8%)

CoNS (2.8%)

CC Tan et al. Central venous catheter-related blood stream infections: incidence and an analysis of risk factors. Med J Malaysia Dec 2007;62(5):370-374