

Risk factors for central venous catheter-related infections in general surgery

Huan-Sheng Chen¹, Fu-Der Wang^{2,3}, Man Lin³, Yi-Chun Lin⁴, Ling-Ju Huang², Chen-Yi Liu²

¹Department of Medicine, Li-Shin Hospital, Taoyuan; ²Section of Infectious Diseases, Department of Medicine, Taipei Veterans General Hospital and National Yang-Ming University of Medicine, Taipei; ³Department of Infection Control, Taipei Veterans General Hospital, Taipei; and ⁴Department of Medicine, Taichung Hospital, Department of Health, The Executive Yuan, Taipei, Taiwan

Received: May 17, 2004 Revised: November 30, 2004 Accepted: August 25, 2005

Background and Purpose: Central venous catheter (CVC) infection is a common problem during hospitalization and nosocomial bloodstream infection in these patients is associated with increased morbidity, mortality, and health care cost. This prospective study examined the risk factors of CVC-related infections.

Methods: During a 6-month period, a total of 281 patients who underwent central venous catheterization after general surgery were enrolled.

Results: The mean duration from CVC insertion to the development of infection was 7.12 days. The rate of bloodstream infection without isolation of the same organism from the catheter was 1.4% (4/281). The rate of catheter-related bloodstream infection was 6.0% (17/281). The rate of catheter bacteremia, defined as positive culture from a catheter blood sample in a patient without signs of infection, was 8.5% (24/281). The incidence of catheter-related bloodstream infection was 7.5/1000 catheter-days. Risk factors for catheter-related infection on univariate analysis included place of insertion (operating room or surgical ward), total parenteral nutrition (TPN), more than 3 tubings, and duration of catheterization. TPN was a significant risk factor in the logistic regression analysis.

Conclusions: Established infection control guidelines should be rigorously observed with regard to catheter use and various risk factors controlled to prevent the occurrence of CVC-related infection, especially in patients receiving TPN.

Key words: Bacteremia, central venous catheterization, infection control, risk factors, surgery

Introduction

Central venous catheter (CVC) infection is a common problem. In patients with compromised immunity, bacteria and fungi can more easily migrate from the skin surrounding the catheter insertion site and colonize at the catheter tip [1-3]. The increase in the prevalence of CVC use has been accompanied by a corresponding increase in cases of catheter-related sepsis. Previous studies estimated that 20-30% of nosocomial bloodstream infections were associated with CVCs [4-7]. These studies also found CVC colonization or contamination rates ranging from 3.8-4.7%, and

catheter-related infection rates from 2.5-25% [4-7]. Given that nosocomial bloodstream infection results in higher morbidity, mortality, and health care cost, there should be good infection control and a quality assurance program to prevent infection [8]. Severe digestive tract disorders frequently occur in patients after general surgery and a CVC is frequently inserted for parenteral nutrition support [9,10]. This study was conducted to assess the risk factors for catheter-related infections in patients undergoing general surgery.

Methods

The study was conducted from July 1, 2002 to December 31, 2002. All patients who underwent central venous catheterization at general surgery wards of a medical center or who were transferred to general surgery wards

Corresponding author: Fu-Der Wang, Section of Infectious Diseases, Department of Medicine, Taipei Veterans General Hospital, No. 201, Sec. 2, Shih-Pai Road, Taipei, Taiwan.
E-mail: fdwang@vghtpe.gov.tw

within 24 h after undergoing central venous catheterization in operating rooms were enrolled in this prospective study. Data for patients were collected for as long as the patient retained the CVC under any circumstances, until CVC removal due to stabilization of clinical condition or death. Patients who received repetitive insertion of CVC were excluded from the study.

When central venous catheterization (ARROW⁺ard Blue[®] [Arrow International Inc., Reading, PA, USA] catheter, 7 Fr. × 20 cm) was performed, maximal precaution was always taken. The doctors responsible for the procedure washed their hands by the standard procedure and wore masks, sterile gowns and gloves. The insertion site was covered with sterile drapes after disinfecting with 10% povidone-iodine [11] and then with 70% alcohol. The disinfectant was allowed to remain on the skin for at least 30 sec to air-dry before inserting the catheter. After the catheter was inserted, the insertion site was sutured and covered with sterile transparent membranes (Tegaderm[™]; 3M, St. Paul, MN, USA). No topical antimicrobial ointment was applied to the insertion site. The procedures performed were the same both in the wards and operation rooms. The insertion site was regularly observed for any symptoms or signs of redness, swelling, heat, pain or suppuration. The dressings were changed every 3 days and the injection site was disinfected using 10% povidone-iodine. After the catheter had been inserted, it was normally connected to the tubing through a hub. The hub was not used in drawing blood.

After removal, the catheter tip was cultured immediately with the roll-plate semi-quantitative method. Blood culture was immediately taken from the catheter after its insertion and before its removal. Peripheral venous blood cultures were performed if the insertion site showed signs of redness, inflammation, heat, tenderness or the patient experienced unexplained fever.

Bloodstream infection was defined as isolation of bacteria from peripheral venous blood in a patient with systemic inflammatory response syndrome, while other infection sources were excluded. Catheter-related bloodstream infection was defined as isolation of the same organism from a semi-quantitative culture of a catheter tip and a peripheral blood culture with systemic inflammatory response syndrome, after exclusion of other infection sources [12]. Catheter bacteremia was defined as isolation of bacteria from culture of a blood sample obtained via the catheter in a patient without clinical symptoms of sepsis. Colonization of the catheter

tip was defined as the finding of more than 15 colony-forming units of bacteria in the semi-quantitative culture from the catheter tip in a patient without clinical symptoms of sepsis [12,13]. Exit site infection was defined as signs of erythema, tenderness, induration or exudate over the skin within 2 cm around the insertion site in the absence of concomitant bloodstream infection. Patients who had bacteremia before insertion or positive blood culture obtained from the catheter immediately after insertion were excluded from this study. Non-infection was defined to include those patients who did not receive antimicrobial therapy and develop sepsis whether positive culture or not. Catheter bacteremia and colonization of the catheter tip were classified as non-infection.

Several continuous factors, including age, gender, underlying diseases, place of insertion (operating room or surgical ward), site of insertion (jugular vein or others), use of parenteral nutrition, use of blood products, use of pain control device, number of tubings, use of a 3-way hub, operations, types of wound (clean, clean-contaminated, contaminated, and dirty-infected [14]), use of antibiotics, and duration of catheterization were analyzed using Student's *t* test. Categorical variables were analyzed using chi-squared test or Fisher's exact test. The duration of catheterization, use of parenteral nutrition, number of tubings, and place of insertion, which were statistically significant in Student's *t* test, were analyzed using logistic regression model. Epi info 6.02 software (USD Inc., Stone Mountain, GA, USA) and the Statistical Package for the Social Sciences (SPSS) for Windows (Version 10.0; SPSS, Chicago, IL, USA) were used to process odds ratio and 95% confidence interval values. A value of $p < 0.05$ was considered to be statistically significant.

Results

During the 6-month study period, a total of 281 patients underwent central venous catheterization. The mean duration from CVC insertion until its removal was 7.12 days. None of the patients experienced mechanical complications after CVC insertion. The mean number of catheter days without infection sign at the insertion site was 5.8 days. The rate of bloodstream infection was 1.4% (4/281), the rate of catheter-related bloodstream infection was 6.0% (17/281), the rate of catheter bacteremia was 8.5% (24/281), the rate of colonization of the catheter tip was 5% (14/281), and the rate of exit site infection was 0.7% (2/281).

Table 1. Analysis of risk factors

| Risk factor | Infection (n = 23) | Non-infection (n = 258) | OR (95% CI) | p |
|---|--------------------|-------------------------|-----------------------|-------|
| Age (mean ± SD; years) | 66.74 ± 11.89 | 63.99 ± 15.51 | | |
| ≥76 | 6 | 66 | 1.027 (0.393-2.712) | 0.958 |
| Gender | | | | |
| Female | 5 | 73 | 0.421 (0.509-3.968) | 0.501 |
| Underlying diseases | | | | |
| Diabetes mellitus | 11 | 24 | 0.471 (0.022-3.791) | 0.749 |
| Malignancy | 7 | 95 | 0.823 (0.281-2.402) | 0.889 |
| Place of insertion | | | 8.001 (3.012-21.648) | 0.000 |
| Operating room | 9 | 216 | | |
| Ward | 14 | 42 | | |
| Site of insertion | | | 1.879 (0.594-5.944) | 0.276 |
| Jugular | 19 | 232 | | |
| Others | 4 | 26 | | |
| Use of TPN | 19 | 43 | 23.750 (7.676-73.289) | 0.000 |
| Use of PPN | 7 | 48 | 1.914 (0.746-4.909) | 0.171 |
| Use of blood products | 3 | 48 | 0.656 (0.187-2.298) | 0.507 |
| Use of PCD | 4 | 48 | 0.921 (0.300-2.831) | 0.886 |
| No. of tubing ≥3 | 8 | 32 | 3.767 (1.479-9.590) | 0.003 |
| No. of 3-way >1 | 5 | 37 | 1.659 (0.580-4.474) | 0.340 |
| Operation | 17 | 240 | 0.79 (0.390-1.591) | 0.488 |
| Type of wound | | | | 0.993 |
| Clean | 1 | 17 | | |
| Clean-contaminated | 13 | 183 | | |
| Contaminated | 2 | 29 | | |
| Dirty-infected | 1 | 11 | | |
| Use of antibiotics | 20 | 224 | 1.010 (0.261-4.532) | 1.000 |
| Duration of catheterization (mean ± SE) | 9.87 ± 4.06 | 6.88 ± 4.08 | | |
| >7 days | 16 | 87 | 4.493 (1.782-11.329) | 0.001 |

Abbreviations: OR = odds ratio; CI = confidence interval; SD = standard deviation; TPN = total parenteral nutrition; PPN = partial parenteral nutrition; PCD = pain control device; 3-way = 3-way hub connected to the central venous catheter; SE = standard error

Catheter-related bloodstream infection was combined with exit site infection in 4 patients. The incidence of catheter-related bacteremia was 7.5/1000 catheter-days. The mean duration between changing dressing was 2.3 days. The main causes of changing dressing were regular order (48.2%), loosening of dressing (22.7%), exudate (14.1%), and return from operating room (12.5%).

Table 1 shows the results of risk factor analysis of infections which included bloodstream infection (n = 4), catheter-related bloodstream infection (n = 17), and exit site infection (n = 2). The patients were divided into groups by age 76, since a quarter of patients were older than 76 years. The factors which were statistically significant for CVC-related infections included place of insertion, total parenteral nutrition (TPN), more than 3 infusion lines in a single CVC, and duration of catheterization. The types of wound were not associated with CVC-related infections ($p=0.99$). Diabetes mellitus and malignancy were not associated with CVC-related

infections. None of the 102 patients with malignancies received chemotherapy during the hospitalization. Only 1 patient, who took oral prednisolone for systemic lupus erythematosus, received corticosteroid therapy during hospitalization. As shown in Table 2, TPN was a significant risk factor in the logistic regression analysis. As shown in Table 3, the most frequent isolates were coagulase-negative staphylococci (23.66%), fungi including *Candida* spp. (20.51%), *Staphylococcus aureus* (11.83%), Gram-positive cocci (10.75%), and enterococci (8.6%). The 4 isolates from bloodstream infection were viridans group streptococcus (50%), *Proteus* spp. (25%), and *Candida albicans* (25%). The 17 isolates from catheter-related bloodstream infection were coagulase-negative staphylococci (41.18%), *S. aureus* (23.53%), enterococci (17.65%), *Enterobacter cloacae* (5.88%), *C. albicans* (5.88%), and *Candida norvegensis* (5.88%). The most frequent isolates from the colonization of catheter tip were Gram-positive cocci (35.71%) and yeast (35.71%).

Table 2. Logistic regression of risk factors

| Variables | RC | SE | OR (95% CI) | <i>p</i> |
|-----------------------------|--------|-------|----------------------|----------|
| Duration of catheterization | 0.939 | 0.606 | 2.558 (0.780-8.383) | 0.121 |
| Use of TPN | 1.927 | 0.685 | 6.868 (1.793-26.309) | 0.005 |
| No. of tubing ≥ 3 | -0.957 | 1.122 | 0.384 (0.043-3.465) | 0.394 |
| Place of insertion | -0.820 | 0.613 | 0.440 (0.132-1.464) | 0.181 |

Abbreviations: RC = regression coefficient; SE = standard error; OR = odds ratio; CI = confidence interval; TPN = total parenteral nutrition

Discussion

CVCs have extensive clinical applications, particularly in intensive care. But catheter use may cause a variety of mechanical complications, such as pneumothorax, hemothorax, bleeding and thrombosis, and infectious complications, of which catheter-related sepsis poses the highest risk [2]. Previous studies reported a prevalence of infection at the injection site ranging from 2.99-24% [15,16] which was higher than the 0.7% rate found in this study.

In this study, catheterization for more than 7 days was a risk factor for infections on Student's *t* test, but not in the logistic regression analysis. A previous study found that intravascular catheter use for more than 48 h was a risk factor for infection [17]. Ullman et al suggested catheter replacement once every 7 days to reduce catheter-related sepsis [18]. The mean time in place for all lines in their study was 13 days, and 45% (14/31) of the catheters and 30% (28/93) of the lumens had bacteria or fungi isolated. In a study of colonization and sepsis in critically ill patients who had CVCs

Table 3. Results of organism culture

| Isolate | Peripheral blood n = 224 | | Cathetered blood n = 52 | | Catheter tip n = 281 | | Total (%) n = 557 |
|--------------------------------------|-----------------------------|-------|----------------------------|-------|-------------------------|-------|----------------------|
| | Inf | N-Inf | Inf | N-Inf | Inf | N-Inf | |
| Total | 21 | 14 | 7 | 6 | 17 | 28 | 93 (16.70) |
| Gram-positive cocci | | | | | | | |
| Coagulase-negative staphylococci | | | | | | | |
| <i>Staphylococcus aureus</i> | 4 | 0 | 2 | 0 | 4 | 1 | 11 (11.83) |
| Gram-positive cocci (unclassified) | 0 | 0 | 0 | 0 | 0 | 10 | 10 (10.75) |
| <i>Enterococcus</i> spp. | 3 | 1 | 0 | 1 | 3 | 0 | 8 (8.60) |
| Viridans group streptococcus | 2 | 0 | 0 | 0 | 0 | 0 | 2 (2.15) |
| Gram-negative Bacilli | | | | | | | |
| <i>Enterobacter cloacae</i> | 1 | 0 | 1 | 0 | 1 | 0 | 3 (3.23) |
| <i>Acinetobacter junii</i> | 0 | 2 | 0 | 0 | 0 | 0 | 2 (2.15) |
| <i>Citrobacter freundii</i> | 0 | 0 | 0 | 1 | 0 | 1 | 2 (2.15) |
| <i>Enterobacter aerogenes</i> | 0 | 0 | 0 | 1 | 0 | 1 | 2 (2.15) |
| <i>Acinetobacter baumannii</i> | 0 | 0 | 0 | 0 | 0 | 1 | 1 (1.08) |
| <i>Acinetobacter johnsonii</i> | 0 | 1 | 0 | 0 | 0 | 0 | 1 (1.08) |
| <i>Flavobacterium</i> spp. | 0 | 1 | 0 | 0 | 0 | 0 | 1 (1.08) |
| <i>Klebsiella pneumoniae</i> | 0 | 0 | 0 | 0 | 0 | 1 | 1 (1.08) |
| <i>Proteus</i> spp. | 1 | 0 | 0 | 0 | 0 | 0 | 1 (1.08) |
| <i>Stenotrophomonas maltophilia</i> | 0 | 1 | 0 | 0 | 0 | 0 | 1 (1.08) |
| Gram-negative bacilli (unclassified) | 0 | 0 | 0 | 0 | 0 | 1 | 1 (1.08) |
| Gram-positive Bacilli | | | | | | | |
| <i>Bacillus</i> spp. | 0 | 3 | 0 | 0 | 0 | 0 | 3 (3.23) |
| Gram-positive bacilli (unclassified) | 0 | 0 | 0 | 0 | 0 | 1 | 1 (1.08) |
| Fungi | | | | | | | |
| Yeast | 0 | 0 | 0 | 1 | 0 | 10 | 11 (11.83) |
| <i>Candida albicans</i> | 2 | 0 | 1 | 0 | 1 | 0 | 4 (4.30) |
| <i>Candida norvegensis</i> | 1 | 0 | 1 | 0 | 1 | 0 | 3 (3.23) |
| <i>Candida parapsilosis</i> | 0 | 0 | 0 | 1 | 0 | 1 | 2 (2.15) |

Abbreviations: Inf = infection; N-Inf = non-infection

replaced every 48-72 h or 73-120 h, Mantese et al reported that positive tip cultures were found in 35% of all catheters, with 39% in the 48-72 h group and 29% in the 73-120 h group displaying no significant difference between groups [4]. In our study, the mean of number of catheter-days without infection signs at the insertion site was 5.8 days and 0.7% (2/281) of patients developed exit site infection. The prevalence of catheter-related bloodstream infection was 7.5/1000 catheter-days.

Catheter-related infections frequently occurred when catheter insertion was performed in the ward in this study. Doctors who performed CVC insertion were residents in wards and anesthesiologists in the operating room in this study. The cause of the higher rates of infection among patients with catheter insertion performed in wards may have been due to incomplete precaution of isolation and lower skill level among operators. Cronin et al reported that colonization of central venous line occurred in 27% of patients, and that heavily manipulated devices and those in place for longer periods of time were the most frequently colonized [1]. Education of residents about the necessary precautions and skills required to perform CVC catheterization is mandated.

This study showed that TPN was a significant risk factor for CVC-related infection in the logistic regression analysis. Other studies also reported similar findings [19,20]. In our previous study, duration of TPN and frequency of catheter insertion were the main risk factors for catheter-related infections in multivariate logistic regression analysis [21]. Dimick et al [22] and Eggimann et al [23] found that proper insertion and care of catheters are essential to avoid infection. Personnel must have a high level of training when TPN infusion is used.

The prevalence of CVC use has led to a 2-3-fold increase in primary nosocomial bloodstream infections in the past decade [24]. The relative frequencies of coagulase-negative *Staphylococcus*, *Candida* spp., *S. aureus*, and enterococci as etiologic agents of these infections have increased significantly [24]. Our findings were similar to these reports.

Peripheral blood samples from the patients classified as having non-infection yielded 14 different species of isolates. These isolates, including coagulase-negative *Staphylococcus*, *Acinetobacter junii*, *Acinetobacter johnsonii*, *Flavobacterium* spp. and *Bacillus* spp., are all common skin commensals [11] and no specific procedures were performed before drawing the blood. *Stenotrophomonas maltophilia* was isolated from 1

patient, but no sepsis developed and no antimicrobial therapy was given, suggesting it might have been a contaminant. One *Enterococcus* spp. was isolated after replacing the Foley catheter and it might have been due to a transient bacteremia. A true 'gold standard' for differentiating pathogens from contaminants does not exist [25] and the judgment must be made on both microbiological and clinical grounds. Interpretation of positive blood cultures is critical and should receive due attention, especially for commensal organisms.

This study demonstrated that factors including place of insertion, TPN, more than 3 tubings, and duration of catheterization were significantly associated with infection in general surgery patients. TPN was the only independent risk factor in the logistic regression analysis. Established infection control guidelines should be rigorously observed with regard to catheter use and various risk factors controlled to prevent the occurrence of CVC-related infection, especially in patients receiving TPN.

References

1. Cronin WA, Germanson TP, Donowitz LG. Intravascular catheter colonization and related bloodstream infection in critically ill neonates. *Infect Control Hosp Epidemiol* 1990; 11:301-8.
2. Cunha BA. Diagnosis and prevention of intravenous central line-associated infections. *Heart Lung* 1995;24:261-2.
3. Jarvis WR, Cookson ST, Robles MB. Prevention of nosocomial bloodstream infections: a national and international priority. *Infect Control Hosp Epidemiol* 1996;17:272-5.
4. Mantese VA, German DS, Kaminski DL, Herrmann VM. Colonization and sepsis from triple-lumen catheters in critically ill patients. *Am J Surg* 1987;154:597-601.
5. Hilton E, Haslett TM, Borenstein MT, Tucci V, Isenberg HD, Singer C. Central catheter infections: single-versus triple lumen catheters. Influence of guide wires on infection rates when used for replacement of catheters. *Am J Med* 1988;84:667-72.
6. Moro ML, Vigano EF, Cozzi Lepri A. Risk factors for central venous catheter-related infections in surgical and intensive care units. The Central Venous Catheter-Related Infections Study Group. *Infect Control Hosp Epidemiol* 1994;15:253-64.
7. Egebo K, Toft P, Jakobsen CJ. Contamination of central venous catheters. The skin insertion wound is a major source of contamination. *J Hosp Infect* 1996;32:99-104.
8. Fridkin SK, Pear SM, Williamson TH, Galgiani JN, Jarvis WR. The role of understaffing in central venous catheter-associated bloodstream infections. *Infect Control Hosp Epidemiol* 1996; 17:150-8.
9. Bai WY, Shi WM, Zhou K. Nutrition support of severe illness

- patients of general surgery during perioperation period. *Zhongguo Wei Zhong Bing Ji Jiu Yi Xue* 2003;15:117-9. [In Chinese, English abstract].
10. Huckleberry Y. Nutritional support and the surgical patient. *Am J Health Syst Pharm* 2004;61:671-82.
 11. O'Grady NP, Alexander M, Dellinger EP, Gerberding JL, Heard SO, Maki DG, et al. Guidelines for the prevention of intravascular catheter-related infections. Centers for Disease Control and Prevention. *MMWR Recomm Rep* 2002;51:1-29.
 12. Mermel LA. Defining intravascular catheter-related infections: a plea for uniformity. *Nutrition* 1997;13(Suppl 4):S2-4.
 13. Maki DG, Weise CE, Sarafin HW. A semiquantitative culture method for identifying intravenous-catheter-related infection. *N Engl J Med* 1977;296:1305-9.
 14. Mangram AJ, Horan TC, Pearson ML, Silver LC, Jarvis WR. Guideline for Prevention of Surgical Site Infection, 1999. Centers for Disease Control and Prevention (CDC) Hospital Infection Control Practices Advisory Committee. *Am J Infect Control* 1999;27:97-132.
 15. White MC, Ragland KE. Surveillance of intravenous catheter-related infections among home care clients. *Am J Infect Control* 1994;22:231-5.
 16. Sherertz RJ, Stephens JL, Marosok RD, Carruth WA, Rich HA, Hampton KD, et al. The risk of peripheral vein phlebitis associated with chlorhexidine-coated catheters: a randomized, double-blind trial. *Infect Control Hosp Epidemiol* 1997;18:230-6.
 17. Pujol M, Pena C, Pallares R, Ayats J, Ariza J, Gudiol F. Risk factors for nosocomial bacteremia due to methicillin-resistant *Staphylococcus aureus*. *Eur J Clin Microbiol Infect Dis* 1994;13:96-102.
 18. Ullman RF, Gurevich I, Schoch PE, Cunha BA. Colonization and bacteremia related to duration of triple-lumen intravascular catheter placement. *Am J Infect Control* 1990;18:201-7.
 19. Kudsk KA, Croce MA, Fabian TC, Minard G, Tolley EA, Poret HA, et al. Enteral versus parenteral feeding. Effects on septic morbidity after blunt and penetrating abdominal trauma. *Ann Surg* 1992;215:503-11.
 20. Moore FA, Moore EE, Jones TN, McCroskey L, Peterson VM. TEN versus TPN following major abdominal trauma--reduced septic morbidity. *J Trauma* 1989;29:916-22.
 21. Wang FD, Cheng YY, Kung SP, Tsai YM, Liu CY. Risk factors of catheter-related infections in total parenteral nutrition catheterization. *Zhonghua Yi Xue Za Zhi (Taipei)* 2001;64:223-30. [In Chinese, English abstract].
 22. Dimick JB, Swoboda S, Talamini MA, Petz RK, Hendrix CW, Lipsett PA. Risk of colonization of central venous catheters: catheters for total parenteral nutrition vs other catheters. *Am J Crit Care* 2003;12:328-35.
 23. Eggimann P, Harbarth S, Constantin MN, Touveneau S, Chevrolet JC, Pittet D. Impact of prevention strategy targeted at vascular-access care on incidence of infections acquired in intensive care. *Lancet* 2000;355:1864-8.
 24. Banerjee SN, Emori TG, Culver DH, Gaynes RP, Jarvis WR, Horan T, et al. Secular trends in nosocomial primary bloodstream infections in the United States, 1980-1989. National Nosocomial Infections Surveillance System. *Am J Med* 1991;91:S86-9.
 25. Weinstein MP. Blood culture contamination: persisting problems and partial progress. *J Clin Microbiol* 2003;41:2275-8.