Arterial catheter-related bloodstream infections: Results of an 8-year survey in a surgical intensive care unit*

Romain Pirracchio, MD; Matthieu Legrand, MD; Mathieu Resche Rigon, MD, PhD; Joaquim Mateo, MD; Anne Claire Lukaszewicz, MD, PhD; Alexandre Mebazaa, MD, PhD; Laurent Raskine, MD; Marie José Sanson Le Pors, MD, PhD; Didier Payen, MD, PhD

Objectives: To determine whether a policy based on provisional replacement of catheters every 5 days had an impact on the incidence of arterial catheter-related bloodstream infections in a population of adult surgical intensive care unit patients.

Design: Prepost study in which all patients with an arterial catheter who were admitted between 1997 and 2004 were observed. Scheduled replacement of arterial catheters every 5 days during period A (before 2000) was compared to nonscheduled replacement during period B (after 2000).

Setting: A 20-bed surgical intensive care unit at a French university hospital.

Patients: All intensive care unit patients requiring an arterial catheter.

Interventions: Modification to the catheter maintenance policies between period A and period B.

Measurements and Main Results: A total of 1,672 consecutive patients were included, and 3,247 arterial catheters were analyzed, yielding an average number of 1.9 (SD, 1.7) arterial catheters per patient. The rate of colonization (14.2% before 2000 vs. 16.4% after 2000; $p = .10$) and the incidence density of arterial catheter colonization (31.32 [95% confidence interval] 27.07–36.25 per 1,000 catheter-days before 2000 vs. 29.79 [95% confidence interval, 26.72–33.21] per 1,000 catheter-days after 2000; $p = .11$) did not differ significantly between the two periods. However, the rate of arterial catheter-related bloodstream infections (1.4% before 2000 vs. 0.6% after 2000; $p = .01$) and the arterial catheter-related bloodstream infections incidence density (3.13 [95% confidence interval, 1.97–4.97] before 2000 vs. 1.01 [95% confidence interval, 0.56–1.82] per 1,000 catheter-days after 2000; $p < .0001$) was significantly higher before 2000.

Conclusion: Discontinuation of scheduled replacement of arterial catheters every 5 days did not increase the risk of colonization but decreased the risk of bloodstream infections. (Crit Care Med 2011; 39:1372–1376)

KEY WORDS: arterial catheters; bloodstream infections; maintenance policies; systematic removal

Arterial catheterization is routinely performed in critically ill patients (1), but specific data concerning arterial catheter (AC)-related complications are still scarce, especially in surgical intensive care unit (ICU) patients. In 2002, the Healthcare Infection Control Practices Advisory Committee published guidelines for the prevention of intravascular catheter-related infections (2). Those guidelines recommended that to prevent catheter-related infections, ACs should not be routinely replaced (2). However, the lack of specific clinical data on ACs prevented the creation of formal recommendations regarding the replacement of ACs in prolonged ICU stays (2).

In our surgical ICU, AC maintenance policies changed in 2000 from a scheduled replacement of ACs to a strategy in which catheters were changed when required. This allowed a comparison between the two periods to provide evidence for future recommendations.

The objectives of the present study were to determine the incidence of AC-related bloodstream infections (ACBIs) in a population of adult surgical ICU patients and to evaluate whether there was a difference in the rate of AC infections with systematic replacement of catheters as compared to provisional replacement.

PATIENTS AND METHODS

This retrospective study evaluated an 8-yr period (1997–2004) in the adult surgical ICU of a 1000-bed university hospital. Informed consent was waived by the local ethics committee.

Patients

Between January 1997 and December 2004, all consecutive ICU adult patients who received an arterial catheter for >24 hrs were included in the study.

Catheterization Technique

AC insertion was performed by senior attending physicians or residents in anesthesiology and intensive care with >1 year of experience. The same polyurethane uncoated catheters were used during the entire study period (Seldicath; Prodimed, Le Plessis Bouchard, France). ACs were inserted into the radial or femoral artery using the Seldinger technique. Local anesthesia with lidocaine was used in nonsedated patients. Strict sterile barrier precautions were used for catheter insertion: large sterile drapes, surgical antiseptic hand wash, sterile gloves, mask, cap, and single use gowns. A sterile gown was used for femoral AC insertion.

***See also p. 1573.**

From the Department of Anesthesiology (RP, ML, ACL, AM, DP), Critical Care and SAMU, APHP Lariboisière Hospital, Paris; University Paris 7 (RP, ML, MRR, JM, ACL, AM, LR, MJSLP, DP); Department of Biostatistics (RP, MRR), APHP Saint Louis Hospital, University Paris 7; U942 Inserm (AM), Paris; Department of Microbiology (LR, MJSLP), APHP Lariboisière Hospital; University Paris 7, France.

R. Pirracchio and M. Legrand equally contributed to the paper.

The authors have not disclosed any potential conflicts of interest.

For information regarding this article, E-mail: romainpirracchio@yahoo.fr

DOI: 10.1097/CCM.0b013e3182120cf7

Table 1. Patient demographics and comparisons between the two replacement policies

	Overall (n = 1672)	Before 2000 (n = 637)	After 2000 (n = 1035)	p
Age, yr (IQR)	45 (31–64)	45 (30–65)	45 (31–63)	.80
Gender (female/male)	728/944	256/381	472/563	.03
Comorbid disease (%)	137 (8.2)	48 (7.5)	89 (8.6)	.52
Acquired immune deficiency syndrome	15 (0.9)	7 (1.1)	8 (0.8)	
Hematologic disease	35 (2.1)	11 (1.7)	24 (2.3)	
Cancer	87 (5.2)	30 (4.7)	57 (5.5)	
Acute Physiology and Chronic Health Evaluation II score (IQR)	15 (10–22)	15 (9–22)	15 (10–22)	.67
Simplified Acute Physiology Score II score (IQR)	33 (23–47)	33 (22–48)	33 (24–46)	.52
Intensive care unit length of stay in survivors (days)	7 (3–17)	6 (3–15)	7 (4–17)	.11
Intensive care unit mortality (%)	169 (10.1)	76 (11.9)	93 (9.0)	.005

IQR, interquartile range.

The p value refers to the comparison between the two periods (before and after 2000). Intensive care unit lengths of stay in survivors are expressed as medians (interquartile range).

Local skin cleaning was performed using a three-step procedure: 1) skin washing with a povidone-iodine liquid soap; 2) skin disinfection with a 10% povidone-iodine solution; and 3) a second skin disinfection with a povidone-iodine alcoholic solution after application of the sterile drapes. The catheter was then sterilely connected to the arterial line. After insertion, the catheter was sutured to the skin and a sterile, occlusive, and transparent dressing (Tegaderm; 3M, London, ON, Canada) was used to cover the insertion site. The arterial line was continuously perfused with a 3-mL/hr infusion of saline.

Maintenance Policies

Maintenance policies were empirically changed during the study. Period A was between 1997 and 2000. ACs were systematically removed and a new AC was inserted at a new site if needed every 5 days. Period B was after 2000. Systematic changes were discontinued and ACs were removed or changed when an infection was suspected or when they were no longer needed.

The transducer administration sets were not routinely changed but were only replaced when catheters were replaced. Local inspection of the insertion site was performed and recorded twice per day. The catheter dressing was changed when it became soiled or nonocclusive. An AC infection was suspected in cases of local inflammation, positive blood cultures, or unexplained fever. In such situations, the ACs were systematically removed and immediately sent to the microbiological unit.

Microbiology

The distal tip of the catheter was systematically collected in sterile containers and immediately brought to the microbiological laboratory. The culture of the tips was performed using the quantitative technique (3). Catheter colonization was defined as a positive culture of the tip with $>10^3$ colony-forming units/mL. A catheter-related bloodstream infection was defined when all of the following clinical conditions were met: a positive catheter culture, a positive blood culture drawn from a peripheral vein (same microorganism, identical susceptibility) obtained between 2 days before and 2 days after AC removal, a negative culture of the central venous catheter, and no other apparent source of infection other than the arterial catheter (5). In the case of coagulase-negative staphylococci, two positive blood cultures were required.

Statistical Analysis

Continuous variables were expressed as means (SD) or medians (interquartile range), whereas categorical variables were expressed as counts and percentages. The numbers of ACs per patient are expressed as means (minimum–maximum). AC colonization and ACBI incidences were expressed using the incidence density with its 95% confidence interval (CI): number of colonizations or infections per 1,000 days of AC catheterization.

Differences between the two periods were tested using the Wilcoxon and Fisher's exact tests. The effect of period (before 2000 vs. after 2000) on the risk of catheter infections was evaluated using a Cox model adapted for multiple events as described by Andersen and Gill (4). Other potential risk factors were identified and included in a multivariable analysis using the same regression model. Hazard ratios (HRs) were expressed with their 95% CIs.

A sensitivity analysis was also performed by restricting the analysis to the patients with ICU stays of >5 days. All tests were two-sided and $p < .05$ was considered statistically significant. Statistical analyses were performed with R (R version 2.9.2; The R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

Patient Characteristics and Maintenance Policies

At total of 3,682 patients were admitted during the study period. Of those, 1,672 patients (45.4%) had at least one AC maintained for >24 hrs (Table 1). The baseline characteristics of patients were similar before and after 2000, except for gender (there was a higher proportion of women after 2000: 45.6% vs. 40.2%; $p = .03$). Among the 1,672 patients, a total of 3,247 ACs were analyzed, yielding an average number of 1.9 (1.7 SD) ACs per patient (Table 2). Despite the change in the maintenance policy, the total number of ACs per patient did not differ between the two study periods. However, ACs remained in place for shorter periods before 2000: 4 days ([95% CI, 3–6]) before 2000 vs. 5 days ([95% CI, 3–7]) after 2000, $p < .0001$.

Incidence of AC Colonization and ACBI

A total of 505 ACs (15.6%) were colonized, and 29 episodes of ACBI were diagnosed (0.9% of all ACs and 5.7% of positive ACs). The overall incidence density of AC colonization was 30.32 (95% CI, 27.79–33.08) per 1000 catheter-days, and the overall incidence density of ACBI was 1.74 (95% CI, 1.21–2.51) per 1,000 catheter-days (Table 2, Fig. 1).

Neither the rate of colonization (14.2% before 2000 vs. 16.4% after 2000; $p = .10$) nor the incidence density of AC colonization (31.32 [95% CI, 27.07–36.25] per 1,000 catheter-days before 2000 vs. 29.79 [95% CI, 26.72–33.21] per 1000 catheter-days after 2000; $p = .11$) was statistically different between the two periods.

The rate of ACBI was significantly higher before 2000 (1.4% before 2000 vs. 0.6% after 2000; $p = .01$), as was the ACBI incidence density, which was 3.13 (95% CI, 1.97–4.97) per 1,000 catheter-days before 2000 vs. 1.01 (95% CI, 0.56–1.82) per 1,000 catheter-days after 2000 ($p < .0001$).

Microbiology

In terms of AC colonization, coagulase-negative staphylococci (56%) was the most common microorganism (Table 3). In terms of ACBI, the most frequent

Table 2. Comparison of arterial catheter characteristics between the two periods

	Overall Period (n = 3247)	Before 2000 (n = 1266)	After 2000 (n = 1981)	*p*
Arterial catheter/patient	1.9 (1–14)	2.0 (1–14)	1.9 (1–12)	.71
Duration of catheterization, days (per catheter)	5 (3–7)	4 (3–6)	5 (3–7)	<.0001
Colonized catheters, n (%)	505 (15.6)	180 (14.2)	325 (16.4)	.10
Arterial catheter–related bloodstream infection, n (%)	29 (0.9)	18 (1.4)	11 (0.6)	.01
Colonization incidence density (per 1,000 days of catheter)	30.32 (27.79–33.08)	31.32 (27.07–36.25)	29.79 (26.72–33.21)	.11
Arterial catheter–related bloodstream infection incidence density (per 1,000 days of catheter)	1.74 (1.21–2.51)	3.13 (1.97–4.97)	1.01 (0.56–1.82)	<.0001

The numbers of arterial catheters per patient are expressed as means (minimum–maximum). The duration of catheterization are expressed as median of days per catheter (interquartile range). The *p* values refer to the comparison of the period before 2000 vs. after 2000. Incidence densities are expressed with their 95% confidence intervals.

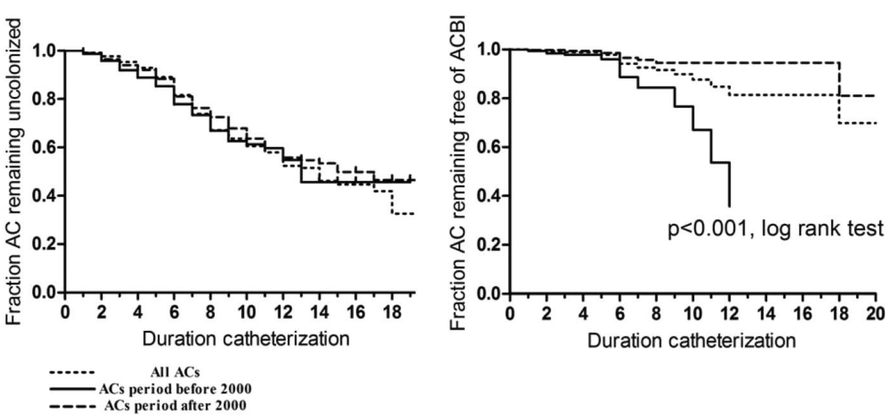

Figure 1. Proportion of arterial catheters (*ACs*) that remained uncolonized (*left*) and free from AC-related bloodstream infections (*ACBIs*) (*right*) over the duration of catheterization.

Table 3. Microbiology of arterial catheter colonizations and arterial catheter-related bloodstream infections

Microorganisms	Arterial Catheter Colonization (% of Colonized Catheters)	Arterial Catheter-Related Bloodstream Infection (% of Arterial Catheter-Related Bloodstream Infection)
Gram–positive *cocci*		
Coagulase–negative staphylococcus	285 (56)	8 (28)
Staphylococcus aureus	32 (6)	9 (31)
Others	51 (10)	1 (3)
Gram–negative *bacilli*		
Pseudomonas aeruginosa	61 (12)	1 (3)
Enterobacter sp.	42 (8)	4 (14)
Others Enterobacteriaceae	91 (18)	9 (31)
Others	12 (2)	1 (3)

Total exceeds 505 for colonizations and 29 for infection because some arterial catheters were colonized or infected with more than one pathogen.

pathogen was *Staphylococcus aureus* (31%). Gram-positive bacteria represented 60% (12 of 20) of the pathogens involved in ACBI episodes before 2000 but only 50% (six of 12) after 2000, whereas the involvement of Gram-negative bacteria increased from 40% (eight of 20) to 50% (six of 12) during the same time period.

Risk Factors for ACBI

In univariate analysis, the Simplified Acute Physiology Score II score (HR, 1.04 [1.02–1.06] per 1-point increment; $p <$ .0001) and the Acute Physiology and Chronic Health Evaluation II score (HR, 1.09 [1.05–1.13] per 1-point increment; $p <$ .0001) were associated with an increased risk of ACBI, whereas the period after 2000 (HR, 0.30 95% CI, 0.14–0.67; p = .003) was associated with a decreased risk of ACBI.

These results remained unaltered in multivariate analysis: Simplified Acute Physiology Score II score (HR, 1.04; 95% CI, 1.02–1.06; p = .0002) and provisional replacement strategy (being in the period after 2000; HR, 0.35; 95% CI, 0.16–0.78; p = .008).

Sensitivity Analysis

When the analysis was restricted to the patients whose ICU stays exceeded 5 days, the following parameters remained independently associated with the risk of ACBI: Simplified Acute Physiology Score II score (HR, 1.03; 95% CI, 1.01–1.05; p = .002) and provisional replacement strategy (HR, 0.31; 95% CI, 0.14–0.72; p = .007).

DISCUSSION

The aim of the present study was to characterize the infectious complications related to ACs in a large population of surgical ICU patients and to evaluate whether a policy based on expert recommendations to avoid systematic changes of AC would decrease the rate of infections. In this series, the incidence densities were 30.32 (27.79–33.08) per 1,000 catheter-days for colonization and 1.74 (1.21–2.51) per 1,000 catheter-days for ACBI. Despite a common belief that ACs become infected less frequently than central venous catheters, these incidences are similar to those reported for central venous catheters (2, 5, 6). In the period before 2000 (systematic replacement strategy every 5 days), there seemed to be an increased risk of ACBI. Previous studies have reported that there is no benefit to scheduled replacement of ACs (7, 8). However, these studies included relatively small sample sizes, and the lack of observed differences between systematic and nonsystematic replacement could have been attributable to insufficient statistical power (7, 8). More recently, Khalifa et al (9) reported an increased risk of colonization in ACs that were in place for ≥10–14 days, whereas Lucet et al (10) published similar results for ACs that remained in place for ≥8 days. However, these reports are not consistent with those by Blot et al (11) and Koh et al (5); those studies suggest that the instantaneous risk of catheter infections is stable over time.

Because of the lack of consistent results, the experts did not provide any formal recommendations regarding the replacement of ACs that are required to remain in place for ≥5 days (2). The present study suggests that systematic replacement of ACs on day 5 not only was ineffective but also was associated with an increased risk of ACBI. Different hypotheses may be proposed to explain such results. First, the risk of colonization might be constant over time (5, 11). Second, other factors might contribute to the increased ACBI risk in cases of systematic replacement. During prolonged ICU stays, patient conditions, such as edema and vasoconstriction, may render catheterization more difficult and may lead to increased numbers of arterial punctures. Multiple vascular punctures and vessel wall injuries are known to promote the development of local infections (12–14). This situation likely occurred more frequently in patients who underwent systematic replacement of ACs. Furthermore, the cutaneous flora (type and number of microorganisms) and the immunologic status of patients are likely to be modified throughout the ICU stay (15). However, because systematic replacement policies were not associated with a significant increase in the total number of catheters per patient in our series, we cannot conclude that the increased ACBI risk was only related to multiple catheterizations. Nevertheless, considering a median number of two catheters per patient in our series, it is likely that the avoidance of systematic replacement resulted in a longer duration for the first catheter and a short duration for the second. It is then likely that the shorter exposure to the second catheter could have resulted in an overall reduction in the ACBI risk. However, considering the usually accepted pathogenesis of catheter infection, it is somehow difficult to explain the fact that colonization incidence density was comparable between the two periods. It is currently thought that colonization precedes ACBI. A decrease in ACBI should then be mirrored by a decrease in colonization. However, this pathogenesis hypothesis might be incomplete. For example, at a same colonization rate, a higher incidence of ACBI could be related to more underlying arterial injuries. Although we took great care to remove ACs in sterile conditions, we cannot exclude that some ACs could have been contaminated, thereby affecting the measurement of AC colonization incidence density.

We used a povidone-iodine alcoholic solution for skin disinfection, which may have resulted in the increased risk of infection as compared to chlorhexidine-based disinfection. Chlorhexidine has been shown to significantly reduce the risk infection as compared to povidone-iodine solutions (16). However, we used a povidone-iodine alcoholic solution because alcohol is known to have a synergistic effect with both chlorhexidine and with povidone-iodine (17). In only one randomized study (18) that was published after the completion of our study, the use of chlorhexidine-based solutions was found to reduce the incidence of catheter colonization as compared to 5% alcoholic povidone-iodine solutions.

Finally, although Gram-positive-related infections remained dominant, we observed a rather high incidence of Gram-negative bacteria, especially after 2000. This observation is consistent with previous investigations that showed an increased incidence of Gram-negative–related bacteriemia among hospitalized patients over the past decade (19). The reasons for this trend remain unknown, but the importance of more effective strategies for controlling the emergence and transmission of methicillin-resistant *Staphylococcus aureus* strains has been highlighted.

This study has some limitations. First, because our control group was historical, the present study should be considered as a prepost quasi-experimental study. Therefore, the results might be affected by any modifications in the patients' characteristics or changes to the care protocols between the two periods. However, no major changes in our standards of care occurred during the study period. Furthermore, adjustment of baseline covariates did not alter the results obtained in the univariate analysis. Second, the study focused on bloodstream infections and did not take into account local infections. However, Rello et al (20) have demonstrated that only bloodstream infections influence prognosis and costs. Third, because a part of our population had short ICU stays, the difference in the duration of catheterization between the two study periods was limited. However, the reduction in the ACBI risk associated with avoidance of systematic replacement was confirmed in the subgroup of patients who spent ≥5 days in the ICU. Finally, we did not record the site of AC insertion. Several studies (10, 21) have reported that the AC insertion site, the femoral compared to the radial, affects the ACBI risk. Because we did not change our standards of care between the two periods (the femoral site accounted for two-thirds), it is unlikely that the site of CA insertion could have accounted for the observed differences between the two study periods.

In conclusion, systematic replacement policies seemed to be associated with an increased risk of AC-related infections, providing supporting evidence for the updated 2002 Centers for Disease Control guidelines that advise against replacement of ACs on a scheduled basis (2).

REFERENCES

1. Lorente L, Villegas J, Martín MM, et al: Catheter-related infection in critically ill patients. *Intensive Care Med* 2004; 30:1681–1684
2. O'Grady NP, Alexander M, Dellinger EP, et al: Guidelines for the prevention of intravascular catheter-related infections. Centers for Disease Control and Prevention. *MMWR Recomm Rep* 2002; 51(RR-10):1–29
3. Cleri DJ, Corrado ML, Seligman SJ: Quantitative culture of intravenous catheters and other intravascular inserts. *J Infect Dis* 1980; 141:781–786
4. Andersen PK, Gill RD: Cox's regression model for counting processes: A large sample study. *Ann Stat* 1982; 10:1100–1120
5. Koh DB, Gowardman JR, Rickard CM, et al: Prospective study of peripheral arterial catheter infection and comparison with concurrently sited central venous catheters. *Crit Care Med* 2008; 36:397–402
6. Polderman KH, Girbes AR: Central venous catheter use. Part 2: Infectious complications. *Intensive Care Med* 2002; 28:18–28
7. Eyer S, Brummitt C, Crossley K, et al: Catheter-related sepsis: prospective, randomized

study of three methods of long-term catheter maintenance. *Crit Care Med* 1990; 18: 1073–1079
8. Furfaro S, Gauthier M, Lacroix J, et al: Arterial catheter-related infections in children. A 1-year cohort analysis. *Am J Dis Child* 1991; 145:1037–1043
9. Khalifa R, Dahyot-Fizelier C, Laksiri L, et al: Indwelling time and risk of colonization of peripheral arterial catheters in critically ill patients. *Intensive Care Med* 2008; 34: 1820–1826
10. Lucet JC, Bouadma L, Zahar JR, et al: Infectious risk associated with arterial catheters compared with central venous catheters. *Crit Care Med* 2010; 38:1030–1035
11. Blot F, Estphan G, Boughaba A, et al: Is routine changing of peripheral arterial catheters justified? *Clin Microbiol Infect* 2008; 14:813–815
12. Cobb DK, High KP, Sawyer RG, et al: A controlled trial of scheduled replacement of central venous and pulmonary-artery catheters. *N Engl J Med* 1992; 327:1062–1068
13. Donlan RM, Costerton JW: Biofilms: survival mechanisms of clinically relevant microorganisms. *Clin Microbiol Rev* 2002; 15: 167–193
14. Safdar N, Kluger DM, Maki DG: A review of risk factors for catheter-related bloodstream infection caused by percutaneously inserted, noncuffed central venous catheters: implications for preventive strategies. *Medicine (Baltimore)* 2002; 81:466–479
15. Lukaszewicz AC, Grienay M, Resche-Rigon M, et al: Monocytic HLA-DR expression in intensive care patients: interest for prognosis and secondary infection prediction. *Crit Care Med* 2009; 37:2746–2752
16. Chaiyakunapruk N, Veenstra DL, Lipsky BA, et al: Chlorhexidine compared with povidone-iodine solution for vascular catheter-site care: A meta-analysis. *Ann Intern Med* 2002; 136:792–801
17. Parienti JJ, du Cheyron D, Ramakers M, et al: Alcoholic povidone-iodine to prevent central venous catheter colonization: A randomized unit-crossover study. *Crit Care Med* 2004; 32:708–713
18. Mimoz O, Villeminey S, Ragot S, et al: Chlorhexidine-based antiseptic solution vs alcohol-based povidone-iodine for central venous catheter care. *Arch Intern Med* 2007; 167: 2066–2072
19. Albrecht SJ, Fishman NO, Kitchen J, et al: Reemergence of gram-negative health care-associated bloodstream infections. *Arch Intern Med* 2006; 166:1289–1294
20. Rello J, Ochagavia A, Sabanes E, et al: Evaluation of outcome of intravenous catheter-related infections in critically ill patients. *Am J Respir Crit Care Med* 2000; 162(3 Pt 1): 1027–1030
21. Lorente L, Santacreu R, Martin MM, et al: Arterial catheter-related infection of 2,949 catheters. *Crit Care* 2006; 10:R83