Prospective study of arterial and central venous catheter colonization and of arterial- and central venous catheter–related bacteremia in intensive care units*

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Objective: **To compare the rates of positive quantitative culture (PQC) of arterial catheter (AC) and central venous catheter (CVC) tips and of CVC- and AC-related bacteremia in intensive care unit patients undergoing placement of both ACs and CVCs.**

Design: **Prospective, descriptive survey. To control for a difference in the severity of patients having an AC or CVC, only patients having both an AC and a CVC were included.**

Setting: **An adult, nine-bed medical/surgical intensive care unit at a university teaching hospital.**

Subjects: **The analysis included 308 CVCs and 299 ACs inserted in 212 severely ill patients, with a mean ± SD Simplified Acute Physiology Score II of 52 ± 22 and an intensive care unit mortality of 33% (69 of 212).**

Interventions: **None.**

Measurements and Main Results: **The same insertion and maintenance procedures were used for both types of catheter. A PQC was defined by a catheter tip culture yielding $\geq 10^3$ colony forming units/mL. Catheter-related bacteremia was defined by a PQC and a blood culture positive for the same microorganism. The cumulative incidence (PQCs/number of catheters inserted) was 9.4% (29/308) for CVCs and 7.7% (23/299) for ACs ($p = .44$). Incidence density (PQCs/1,000 catheter days) was 12.0 for CVCs versus 9.3 for ACs. At the femoral site, there was no significant difference between CVCs and ACs in the cumulative incidences and incidence densities of PQCs. Two instances of catheter-related bacteremia were observed, one involving a CVC and one involving an AC.**

Conclusions: **Among severely ill patients with both CVCs and ACs, the epidemiology of PQCs of CVCs and ACs is comparable when the same infection control measures are used for the insertion and maintenance of both types of catheters. (Crit Care Med 2005; 33:1276–1280)**

KEY WORDS: infections; arterial; central venous catheter

Arterial catheters (ACs) are frequently used for continuous hemodynamic monitoring of and drawing blood samples from critically ill patients. These patients are often at increased risk of nosocomial infections because of their underlying disease, and catheter-related infection is one of the main severe complications of arterial or central venous catheterization (1–3).

Most reports on complications related to ACs have focused on mechanical problems. Recently a few investigators using standardized quantitative culture techniques have reported AC-related infections (4–7). One randomized study suggested that the use of sterile barrier precautions when inserting ACs without the use of a guidewire has no greater effect on decreasing colonization or infection than standard procedure, unlike with central venous catheters (CVCs) (7). The authors noted that the incidence of AC-related infectious complications was comparable to that of CVC-related infectious complications in the literature.

However, that study (7), like most other published reports (1, 5, 7–11), involved ACs only; thus, comparison of rates of AC- and CVC-related infections was not possible. A few studies have described infectious complications of CVCs and ACs that were placed in two different patient populations (4, 12). This makes comparison difficult because there may be differences in the severity of the patients' condition, and severity is a determining factor of risk of infection since the most critically ill patients are those whose CVCs and ACs are handled the most. To our knowledge there are no published reports comparing rates of positive quantitative culture (PQC) of CVCs and ACs or of CVC- and AC-related bacteremia in a patient group undergoing both types of catheterization. Our prospective study was designed to compare these rates of colonizations/infections in an intensive care unit (ICU) where the insertion and maintenance procedures used for ACs were the same as those for CVCs.

MATERIALS AND METHODS

Study Population. This prospective study was performed in a nine-bed medical/surgical ICU at the university teaching hospital of Clermont-Ferrand, France, between September 15, 2000, and December 31, 2002. All the patients admitted to the ICU during this period were eligible. All patients who required CVC and AC placement for a duration ≥48 hrs during their hospital stay were included in the study. Only the catheters placed and removed in the unit were analyzed, whether CVCs and ACs were in place at the same time or sequentially. All patients underwent placement of polyurethane single-lumen or multiple-lumen CVCs (from Seldiflex Plastimed, St. Leu-la-

***See also p. 1437.**

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Foret, France, during the period of September 15, 2000, through December 31, 2001, and from Arrow-Howes, Reading, PA, until December 31, 2002) and ACs (Leader Cath, Vygon, Ecouen, France). The CVCs and the ACs used in this study had no antibiotic or antiseptic properties. The Seldinger technique was used for catheter insertion. In our unit, CVCs are used to deliver medications and nutritional support and to measure central venous pressure. CVCs are never used for blood sampling. ACs are used to draw blood samples and to monitor arterial blood pressure.

For both CVCs and ACs, the indication for catheterization, the insertion site, and the number of CVC lumens were left to the discretion of the attending physician. CVCs were not tunneled and no guidewire-assisted changing of catheters was done for either CVCs or ACs. All of the CVCs and ACs were inserted at the bedside by the attending physicians. Catheter insertion and dressing of the insertion site were done according to our previously published ICU procedure (13), which requires the wearing of a cap, mask, gown, and sterile gloves for CVC and AC insertion. The puncture site was prepared with alcoholic solution of 0.5% chlorhexidine, and the surrounding areas were covered with sterile drapes. A sterile, occlusive, adhesive, transparent dressing (Tegaderm, 3M, London, ON, Canada) was applied. For both CVCs and ACs, occlusive dressings and intravenous tubes were routinely changed every 48 hrs by a nurse wearing a cap, mask, and sterile gloves. Informed consent was not required because all procedures were routine. The ethics committee of the hospital was nevertheless informed about the study and raised no objections.

Data Collection. We recorded demographic data including age and sex, Sepsis-related Organ Failure Assessment (SOFA) score (14), Simplified Acute Physiology Score (SAPS) II at 24 hrs (15), use of dialysis or mechanical ventilation for >48 hrs during hospital stay, workload as assessed by total daily omega score (16), length of ICU stay, and ICU mortality. We also recorded the type of catheter (venous or arterial), the number of lumens of the CVCs, insertion site, and duration of placement. All these data were entered in an Excel file.

The CVCs and ACs were not changed after a fixed insertion time but were removed when they were no longer needed or when the patient exhibited signs of infection (fever or sepsis) that had no other obvious cause. The CVCs and ACs used in patients who died were included. The skin surrounding the insertion site was carefully disinfected with chlorhexidine before catheter removal. The CVCs and ACs were removed under aseptic conditions. A 5-cm distal segment (tip) was collected in sterile containers from all catheters. All catheter tips were sent to the microbiology laboratory for quantitative culture.

Microbiology. All the samples were cultured by means of the simplified quantitative culture technique previously described by Brun-Buisson et al. (17). For patients exhibiting clinical signs of infection (fever, chill, hypotension, leukocytosis/leukopenia), peripheral blood samples were collected at the time of catheter removal and subsequently cultured. Standard microbiological methods were used to identify the colonizing/infecting organisms.

Definitions. A PQC was defined as a quantitative culture tip yielding $>10^3$ colony forming units/mL. Catheter-related bacteremia (CRB) was defined by isolation of the same phenotypic microorganisms from both peripheral blood and catheter tip in a culture growing $>10^3$ cfu/mL when there was no other overt source of the bacteremia except the catheter.

Statistical Analysis. PQC and CRB rates were expressed in terms of cumulative incidences and incidence densities. Cumulative incidence is expressed as percentage and incidence density as PQCs per 1,000 catheter days. Categorical variables were compared by the chi-square test or Fisher's exact test, and continuous variables were compared by analysis of variance or by Mann-Whitney test or Kruskall-Wallis test when necessary. The Kaplan-Meier test was used to compare the risk of PQCs over time between CVCs and ACs. Two-tailed p values $< .05$ were considered to indicate statistical significance. Analyses were performed with Epi Info 6 software (Centers for Disease Control and Prevention, Atlanta, GA).

RESULTS

Study Population. During the study period 800 patients were admitted to the ICU, of whom 647 had a stay >48 hrs. Of these, 450 had a CVC or AC in place for >48 hrs, and all catheters were inserted and removed during their ICU stay. In 86 patients, CVCs were placed without AC insertion; in 131 patients, ACs were placed without CVC insertion; and in 233 patients, both CVCs and ACs were placed. Of these 233 patients, 21 (9.0%) were excluded because CVC or AC culture results were not available (11 and 12 cases, respectively). Thus, the study involved 607 catheters (308 CVCs and 299 ACs) inserted in 212 patients—128 men and 84 women (sex ratio, 1.52)—with a mean ± SD age of 61.4 ± 17 yrs (median, 66 yrs), a median SOFA score at 24 hrs of 7, and a mean SAPS II at 24 hrs of 52 ± 22 (median, 50). Of the 212 patients, 119 (56%) had invasive mechanical ventilation >48 hrs and 79 (37%) had at least one dialysis session while in the ICU. For these 212 patients, the mean ± SD length of ICU stay was 17.2 ± 17.9 days (median, 10; range, 2–110), the mean omega score/day was 15.6 ± 7.3 (median, 14.8; range, 3.9–51), and the ICU mortality rate was 33% (69/212).

Catheterizations. Of the 308 CVCs, 19 (6%) were single-lumen, 23 (8%) were double-lumen, and 266 were triple-lumen (86%). The mean ± SD duration of CVC placement was 7.9 ± 4.9 days (median, 7 days), and it was longer for CVCs inserted at the subclavian site ($p = .005$). CVC-PQC was observed in 29 (9.4%) of 308 cases, with no significant difference in relation to the number of lumens ($p = .38$). The incidence density of PQC was 12 per 1,000 days of CVC use. There was no difference in the mean duration of CVC placement with or without PQC (7.9 ± 2.8 days [median, 8 days] vs. 7.9 ± 5.1 [median, 7 days; $p = .8$]). On the basis of the median duration of CVC placement, the PQC rate was higher for CVCs that remained in place >7 days than for those removed earlier (13.1% vs. 6.1%; $p = .04$). The rate of PQC was greater with internal jugular or femoral vein catheters than with those placed via the subclavian route (relative risk, 3.6 vs. 3.8; 95% confidence interval, 1.1–12 vs. 1.03–14.2; $p = .02$ vs. $p = .03$). The characteristics of the CVC catheterizations are shown in Table 1.

The 299 ACs were mostly placed in the radial site (68%). The mean ± SD duration of AC placement was 8.2 ± 5.3 days (median, 7 days), with a difference in AC catheterization duration according to the

Table 1. Characteristics of the 308 central venous catheterizations

Route	No. of CVCs (%)	Duration (Days), Mean ± SD	Cumulative Incidence: PQC-CVC/No. of CVCs (%)
Any	308 (100)	7.9 ± 4.9	29/308 (9.4)
Internal jugular	160 (51.9)	7.3 ± 4.5[a]	19/160 (11.9)[b]
Subclavian	92 (29.9)	9.0 ± 5.2	3/92 (3.3)
Femoral	56 (18.2)	7.5 ± 5.4	07/56 (12.5)

CVC, central venous catheter; PQC, positive quantitative culture.

[a] $p = .005$ (Kruskal-Wallis test) between internal jugular, subclavian, and femoral routes; [b] $p = .04$ (χ^2 test) between internal jugular, subclavian, and femoral routes.

insertion site ($p = .03$). AC-PQC was observed in 23 (7.7%) of 299 cases, with no significant difference according to the insertion site ($p = .65$). The PQC incidence density was 9.3 per 1,000 days of AC use. There was no difference in the mean duration of AC placement with or without PQC (9.8 ± 8.1 days vs. 8.1 ± 4.9 days; $p = .33$). On the basis of the median duration of AC placement, the PQC rate did not differ between ACs left in place >7 days and those removed before day 8 (7.9% vs. 7.5%; $p = .89$). The characteristics of the AC catheterizations are shown in Table 2.

Comparison of CVCs and ACs. There was no difference in catheterization duration between CVCs and ACs ($p = .70$). There was no difference in the cumulative incidence of PQC between CVCs and ACs or in the incidence density of PQC (relative risk, 1.22 vs. 1.29; 95% confidence interval, 0.73–2.07 vs. 0.75–2.23; $p = .45$ and $p = .41$). The cumulative incidence of PQC did not differ between CVCs and ACs in relation to the femoral site ($p = .59$); nor did the incidence density differ (16.7 per 1,000 days of CVC use vs. 12.8 per 1,000 days of AC use; $p = .78$). There was no difference between the rates of CVC-PQC and AC-PQC when the catheters were placed by a senior physician (20/191 [10.4%] vs. 15/163 [9.2%]; $p = .69$). Similarly, there was no difference between the rates when the catheters were placed by a resident (5/117 [7.7%] vs. 8/136 [5.9%]; $p = .57$).

In 114 patients, CVCs and ACs were inserted on the first day of ICU admission. The duration of catheterization was 7.3 ± 5.0 days (median, 7 days) for CVCs and 7.9 ± 4.9 (median, 7 days) for ACs ($p = .41$). There was no difference between CVCs and ACs in the cumulative incidence of PQC (7/114 [6.1%] vs. 9/114 [7.9%]; $p = .6$). The incidence density was 8.4 per 1,000 days of CVC use and 10.0 per 1,000 days of AC use ($p = .46$). Figure 1 shows an actuarial survival curve for PQCs of CVCs and ACs. The Kaplan-Meier test estimated that the risk of PQCs in relation to the duration of catheterization did not differ over time between CVCs and ACs ($p = .35$).

CVC-PQC or AC-PQC was observed for 42 of 212 patients. CVC-PQC was observed for 26 patients (12.3%) and AC-PQC for 22 patients (10.4%; $p = .54$). The incidence density of PQC per patient was 10.7 per 1,000 days of CVC use and 8.9 per 1,000 days of AC use ($p = .31$). SAPS II was 50.9 ± 22.0 for the 42 patients with CVC- or AC-PQC and 52.6 ± 22.0 for the 170 patients without CVC- or AC-PQC ($p = .71$). SAPS II was not different between the 26 patients with CVC-PQC and the 186 patients without CVC-PQC (47.7 ± 21.0 vs. 52.9 ± 22.0; $p = .34$). SAPS II was 53.3 ± 21.0 for the 22 patients with AC-PQC and 52.2 ± 22.0 for the 190 patients without AC-PQC ($p = .8$).

Thirteen of 212 patients had an ICU-acquired bloodstream infection. Of these infections, two were catheter-related: CVC-related bacteremia due to *Staphylococcus aureus* and AC-related bacteremia due to *Enterobacter* species. Thus, the cumulative incidence and incidence density of catheter-related bacteremia were, respectively, 0.32% and 0.40/1,000 days for CVCs and 0.33% and 0.41/1,000 days for ACs. However, since there were only two instances of catheter-related bacteremia, we cannot draw any meaningful conclusion about the rates of CVC- vs. AC-related bacteremia.

The causative germs isolated in the PQCs of the CVCs and ACs are given in Table 3. They were mainly Gram-positive cocci, with a predominance of coagulase-negative staphylococci. No *Candida* species organisms were isolated in the PQCs.

DISCUSSION

Our study shows that the epidemiology of PQCs of CVCs and ACs are comparable. The same results were observed with catheterizations of the femoral veins and arteries. We compared the epidemiology of PQCs of CVCs and ACs and of CVC- and AC-related bacteremia when the same infection control measures were applied for the insertion and removal of the two types of catheter. It might have been expected to find differences between the rates of CVC and AC infectious complications, because CVCs and ACs are disparate types and have different uses. CVCs are used to measure hemodynamic variables, to draw blood samples, and to deliver medications and nutritional support. ACs are used to monitor invasive arterial blood pressure and for drawing blood samples. It is noteworthy that in our unit, none of the CVCs were introducers—thus, at no time were pulmonary catheters placed through them—

Table 2. Characteristics of the 299 arterial catheterizations

Route	No. of ACs (%)	Duration (Days), Mean ± SD	Cumulative Incidence: PQC-AC/No. of ACs (%)
Any	299 (100)	8.2 ± 5.3	23/299 (7.7)
Radial	203 (68)	8.4 ± 5.5[a]	15/203 (7.4)[b]
Brachial	30 (10)	9.3 ± 4.4	2/30 (6.7)
Femoral	66 (22)	7.1 ± 4.6	6/66 (9.1)

AC, arterial catheter; PQC, positive quantitative culture.

[a] $p = .03$ (Kruskal-Wallis test) between radial, brachial, and femoral routes; [b] $p = .88$ (χ^2 test) between radial, brachial, and femoral routes.

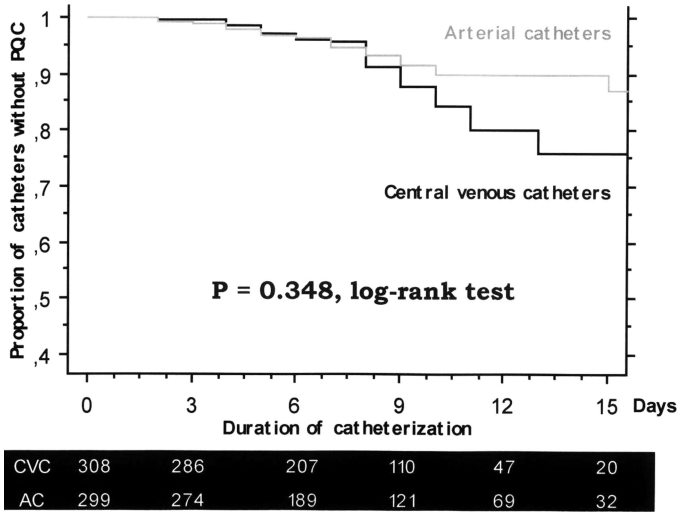

Figure 1. Proportion of central venous catheters and arterial catheters for which quantitative cultures were negative.

Table 3. Incidence of cultured microorganisms

Microorganism	No. of CVC Cultures	No. of AC Cultures
Gram-positive cocci	28	23
Staphylococcus epidermidis	11	12
Staphylococcus aureus	1	2
Enterococcus species	3	2
Other	3	7
Gram-negative bacilli	14	4
Pseudomonas aeruginosa	7	0
Enterobacter species	7	4
Total	42	27

CVC, central venous catheter; AC, arterial catheter.

Among severely ill patients with both central venous and arterial catheters, the epidemiology of positive quantitative cultures of the catheters is comparable when the same infection control measures are used for their insertion and maintenance.

and CVCs are never used for drawing blood samples.

To our knowledge, our work involves the largest series of ACs analyzed by a quantitative microbiological technique. We chose to use the quantitative culture method of Brun-Buisson (17) for the microbiological diagnosis of CVC and AC infections because it has the advantage of analyzing the intraluminal and extraluminal portions of the catheter. Using a diagnostic threshold to define PQC makes it possible to distinguish contamination from colonization. The technique has never been tested with ACs in validation studies; thus, we used it by extension to define PQC.

The incidence density of PQC of CVCs in our study (12.0 per 1,000 days of catheter use) is close to that reported by Rijnders et al. (18) in a systematic review of reports on CVC-related infections published between 1990 and 2002 (13.5 per 1,000 days of catheter use). The frequency of PQC of CVCs found in our study was close to that observed by our group in a previous work (13). In agreement with other studies, we found fewer PQCs when the CVC was inserted via the subclavian route than via the internal jugular or femoral routes (3, 19, 20), and we observed no difference in PQCs related to the jugular vs. femoral insertion sites (3). As in most other studies, Gram-positive cocci were the germs most commonly isolated in the PQCs of CVCs, with coagulase-negative staphylococci being predominant.

There have been few studies of AC-related infections. In addition, it is difficult to compare the findings because of the differences in study design, populations studied, duration of catheter placement, techniques of microbiological analysis, and the way in which results are expressed. Some study reports are purely descriptive (5, 6, 9, 11, 21), whereas other reports are of randomized trials assessing the risk of infection in relation to insertion site (10), routine changing of catheters (22), use of antiseptic solutions (4), or hygiene precautions on insertion (7).

These studies include catheterizations via the radial (4, 5, 7, 9–11), femoral (4, 6, 10, 11), or dorsalis pedis (5, 7) routes. The duration of catheter use varies between 4 and 16 days. Some study reports give no details on the culture techniques used (9, 10, 21). The varied nature of these reports probably accounts for the wide discrepancies in the frequency of infection, with cumulative incidence ranging between 0.4% and 43% and incidence density between 5 and 32 per 1,000 days of catheter use (4, 5, 9, 23). In our study, cumulative incidence was 7.7% and incidence density was 9.3 per 1,000 days of catheter use. The duration of arterial catheterization is shorter in our study than in all others reported except that of Martin et al. (5). This is probably due to the specificity of our study population, which underwent both venous and arterial catheterization. Like most authors, we observed no difference in the frequency of PQC of ACs between radial and femoral insertion sites (2, 10). In addition, in our study we found no differences in AC-PQC between the femoral and brachial sites ($p = .69$) or the femoral and upper extremity sites ($p = .63$).

The microorganisms isolated in the PQCs of ACs in our study did not differ from those usually found. As with CVC cultures, Gram-positive cocci were more common than Gram-negative bacilli, and among the Gram-positive cocci, coagulase-negative staphylococci were predominant.

Our study is original in that it takes into account the severity of the patients' condition in comparing the PQC rates of CVC and AC, because all patients had both types of catheter. Only Wester et al. (6) have studied jointly arterial and venous catheterization in the same patients, but they specifically studied vascular routes used for continuous arteriovenous hemodiafiltration, and the proportion of patients lost to follow-up was high. In most studies, catheter infection rates are more frequently observed in the most severely ill patients (24). In our study, patients with CVC-PQC or AC-PQC did not have higher SAPS II than patients without CVC-PQC or AC-PQC. This could be related to the case-mix of our study population, which comprised only patients who had both CVC and AC placement for >48 hrs. On the basis of the inclusion criteria of the study, our patient population was a subset of very severely ill patients, as demonstrated by the SAPS II values, the long ICU stay (median, 10 days), and the high ICU mortality rate (33%). The rates of catheter infectious complications may be different in ICU populations who have a lesser severity of illness, a shorter length of stay, and/or just one of the two catheters.

The number of cases of AC-related bacteremia in our study was low and comparable to that in most other reported studies (5, 7, 10, 25). The number of cases of CVC-related bacteremia (one for 308 CVCs) was similar to that in a previous study in which we found two instances of CRB among 230 CVC recipients (13). No conclusion can be drawn about CRB because of the small incidence of bacteremia.

CONCLUSIONS

In a subgroup of severely ill ICU patients who have both CVCs and ACs placed, when the same infection control procedures are applied for insertion and maintenance, the epidemiology of PQCs related to the two types of catheter is comparable.

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