Impact of Radial Arterial Location on Catheter Lifetime in ICU Surgical Intensive Care

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OBJECTIVES: The use of arterial catheters is frequent in intensive care for hemodynamic monitoring of patients and for blood sampling, but they are often removed because of dysfunction. The primary objective is to compare the prevalence of radial arterial catheter dysfunction according to location in relation to the radiocarpal joint in intensive care patients.

DESIGN: Prospective randomized, controlled, single-center study.

SETTING: The surgical ICU of the university hospital of Poitiers in France.

PATIENTS: From January 2016 to April 2017, all patients over 18 years old admitted to the surgical ICU and requiring an arterial catheter were included.

INTERVENTIONS: Randomization into two groups: catheter placed near the wrist (within 4 cm of the radiocarpal joint) and catheter placed away the wrist. The primary endpoint was the prevalence of dysfunction. We also compared the prevalence of infection and colonization.

MEASUREMENTS AND MAIN RESULTS: One hundred seven catheters were analyzed (14 failed placements with no difference between the two groups, and 16 catheters excluded for missing data), with 58 catheters in near the wrist group and 49 in away the wrist group. We did not find any significant difference in the number of catheter dysfunctions between the two groups ($p = 0.56$). The prevalence density of catheter dysfunction was 30.5 of 1,000 catheter days for near the wrist group versus 26.7 of 1,000 catheter days for away the wrist group. However, we observed a significant difference in terms of catheter-related infection in favor of away the wrist group ($p = 0.04$). In addition, distal positioning of the catheter was judged easier by the physicians.

CONCLUSIONS: The distal or proximal position of the arterial catheter in the radial position has no influence on the occurrence of dysfunction. However, there may be an association with the prevalence of infections.

KEY WORDS: arterial catheter; catheter placement; catheters dysfunction; catheters infections; ultrasound

Arterial catheter (AC) placement is standard of care in ICUs (1). It allows continuous blood pressure monitoring or repeated blood sampling. Unfortunately, ACs often fail before end-of-use leading to blood sampling difficulties or distorted blood pressure with noninterpretable curve. A new AC is therefore necessary, exposing patients to rare but serious complications related to this procedure, as finger ischemia (2). The prevalence of early AC dysfunction varies across studies, occurring in up to 23% of catheters in the CLEAN study (3). A new AC placement is therefore necessary.

The radial access is the most commonly used for AC insertion as the radial pulse is the simplest one and as it exposes the patient to fewer infectious complications than the femoral approach (4, 5). The last 2 decades have seen the extensively development of ultrasound used for insertion of vascular catheters, becoming the gold standard, and since 2012, ultrasound-guided insertion

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KEY POINTS

Question: Can we reduce the prevalence of arterial catheter dysfunction by inserting them further from the wrist joint?

Findings: The position of the arterial catheter does not influence the occurrence of dysfunctions but the study shows that the location of the arterial catheter in the radial position can have an impact on the occurrence of catheter infection.

Meanings: This is the first study to focus on the position of the catheter on the radial arterial and which finds significant results on the prevalence of catheter infections.

of ACs is recommended (6, 7). Indeed, this technique improves the success rate from the first attempt and reduces both the number of punctures and time required to complete the procedure successfully, especially in specific circumstances frequent in intensive care such as obesity, edema, or anatomical variations (8, 9). Furthermore, ultrasound allows the radial artery to be approached along its entire length.

We hypothesized that the distance between AC insertion site and the radiocarpal joint influences the prevalence of catheter dysfunction and dressings adhesion and, therefore, catheters colonization and infection. The main goal of the present study was to compare the prevalence of AC dysfunctions in relation to catheter's position on radial artery. Secondary objectives include to compare catheter colonization and catheter infection and patients comfort.

PATIENTS AND METHODS

Study Design and Participants

We conducted a randomized, open-label study in one surgical ICU of the University Hospital of Poitiers. Patients over 18 years old requiring AC insertion in the radial position were included. The sampling is consecutive. Noninclusion criteria were expected death within 48 hours of insertion, AC insertion before admission to the ICU, or any contraindication to radial catheter placement (positive Allen test or Raynaud's syndrome).

Procedures were followed in accordance with the ethical standards of the responsible committee on human experimentation (approved by the Ethics Committee of the University Hospital of Poitiers 2015-A00676-43 Poitiers, France on September 2, 2016) and with the Helsinki Declaration of 1975 (ClinicalTrials.gov: NTC0345534). Patients or their relatives consent to participate in the trial.

A statistician not involved in either screening patients or in the assessment of outcomes provided a computer-generator number list. Randomization was carried out through balanced numbered and sealed envelopes. Patients were randomly assigned (1: 1) in permuted blocks of varying block sizes to one of the two treatment groups based on the distance between the insertion site and the radiocarpal joint. Masking of the participants and ICU staff was not feasible because of the study design. However, the microbiologists who tested the catheters and blood samples and the statisticians were masked to group assignment.

Procedures

Once the AC indication was decide and nonopposition to participate to the trial obtained, patients were assigned to either the control group (or near the wrist group NW group: AC inserted less than 4 cm from the radiocarpal joint) or the experimental group (or away the wrist group AW group: AC inserted more than 4 cm from the radiocarpal joint) (Photo). The radiocarpal joint was defined as the line between the tip of the palpable radial styloïd perpendicularly to the median axis of the hand and forearm. Operators inserting the catheters were either physicians or residents. All of them were trained in ultrasound-guided insertion of AC before starting the inclusions and trained to calculate the distance from the wrist for placement. The rate of UltraSound use was 100% between both groups. Catheter insertion and care followed French recommendations similar to Centers for Disease Control and Prevention recommendations (5). Briefly, the skin was disinfected with 2% alcoholic chlorhexidine (ChloraPrep, Becton Dickinson, Franklin Lakes, NJ) applied by moving back and forth for at least 30 seconds, starting at the catheter insertion site and then extending to the entire work area. Large sterile drapes were applied once the work area was dry. Catheters (20 gauges, 6 cm long, VYGON, Ref. 5118.908, Ecouen, France) were inserted by physicians using maximal barrier precautions (sterile gloves

and gown, masks and charlottes). After insertion, the catheters were sutured in place and were dressed with semi-permeable transparent dressings (Tegaderm, 3M, St. Paul, MN). Dressings were changed 24 hours after catheter insertion and then every 4 days or earlier if leaked, soiled or wet. The entire line (pressure sensor dome, extension) was permanently filled with nonheparinized physiologic saline solution. No immobilization of the wrist was performed. Manipulation of lines and three-way stopcocks was carried out using gauze moistened with 0.5% alcoholic chlorhexidine (Gifrer, Décines-Charpieu, France). Catheters were removed if no longer needed, if catheter failed or when a catheter-related infection was suspected. Catheter tips were cultured using a simplified quantitative broth (10).

Outcomes

The primary endpoint was the prevalence of catheter dysfunction leading to catheter removal. Catheter dysfunction was defined as the inability to perform blood sampling from the catheter and/or to obtain an interpretable blood pressure curve. Secondary endpoints were the number of attempts and time required to complete the procedure successfully, catheter colonization and infection rate, catheter occlusion rate, and staff' and patients' satisfaction.

Catheter colonization was defined as a quantitative catheter-tip culture eluate in broth showing at least one microorganism in a concentration of at least 1,000 colony-forming units/mL (10). Catheter-related sepsis without bacteremia was defined as a combination of: 1) fever (body temperature ≥ 38.5°C) or hypothermia (body temperature ≤ 36.5°C); 2) catheter colonization; 3) resolution of fever or hypothermia within 48 hours after catheter removal and without any change in antimicrobial therapy, or presence of pus at the catheter insertion site; and 4) no other source of infection identified. Catheter-related bloodstream infection (CR-BSI) was defined as a combination of: 1) fever (body temperature ≥ 38.5°C) or hypothermia (body temperature ≤ 36.5°C); 2) one or more positive peripheral blood cultures drawn 48 hours before or after catheter withdrawal; 3) isolation of the same organism (same species and same susceptibility pattern) from the colonized catheter, or from the catheter insertion site, or a blood culture differential time-to-positivity of 2 hours or more; and 4) no apparent source of bacteremia other than the catheter. In patients with bacteremia due to coagulase-negative *Staphylococci*, at least two positive cultures from separate blood samples were required. Catheter-related infections included either catheter-related sepsis without bacteremia or CR-BSI. A satisfaction questionnaire was completed by the patients (when the patient is able to respond) and healthcare providers using a 10-point numerical evaluation scale regarding comfort and easiness of the procedure.

Statistical Analysis

The number of catheters required to explore the hypothesis that catheters inserted away from the radiocarpal joint (experimental group) are significantly less likely to dysfunction than catheters inserted close to the radiocarpal joint (control group) was estimated before undertaking the study. From previous reports (3) and our own clinical experience, we estimated that 22% of catheters in the control group will malfunction. Random assignment of 174 evaluable catheters to each study group will detect a 50% reduction in the rate of catheter dysfunctions in the experimental group at 80% power and 5% bilateral significance.

The data were analyzed on an intention-to-treat basis. Demographic data were described as number and percentage, and median and interquartile range or mean and SD for quantitative and qualitative variables, respectively, and compared with the chi-square test and Fisher exact test or Mann-Whitney *U* test, as appropriate. The proportions of catheters free of colonization or dysfunction as a function of length of time in place were compared between groups using the log-rank test. Tests were two-tailed with a p value lower than 0.05 being considered significant. The statistical analyses were performed using MedCalc Software's Version 16.8.4 (MedCalc Software Ltd, Ostend, Belgium). This study is registered with ClinicalTrials.gov NCT03455348 and is closed to new participants.

RESULTS

Between January 2016 and April 2017, 137 patients were included in the study, 15 were excluded because of missing data, that is, 122 catheters. Among the 122

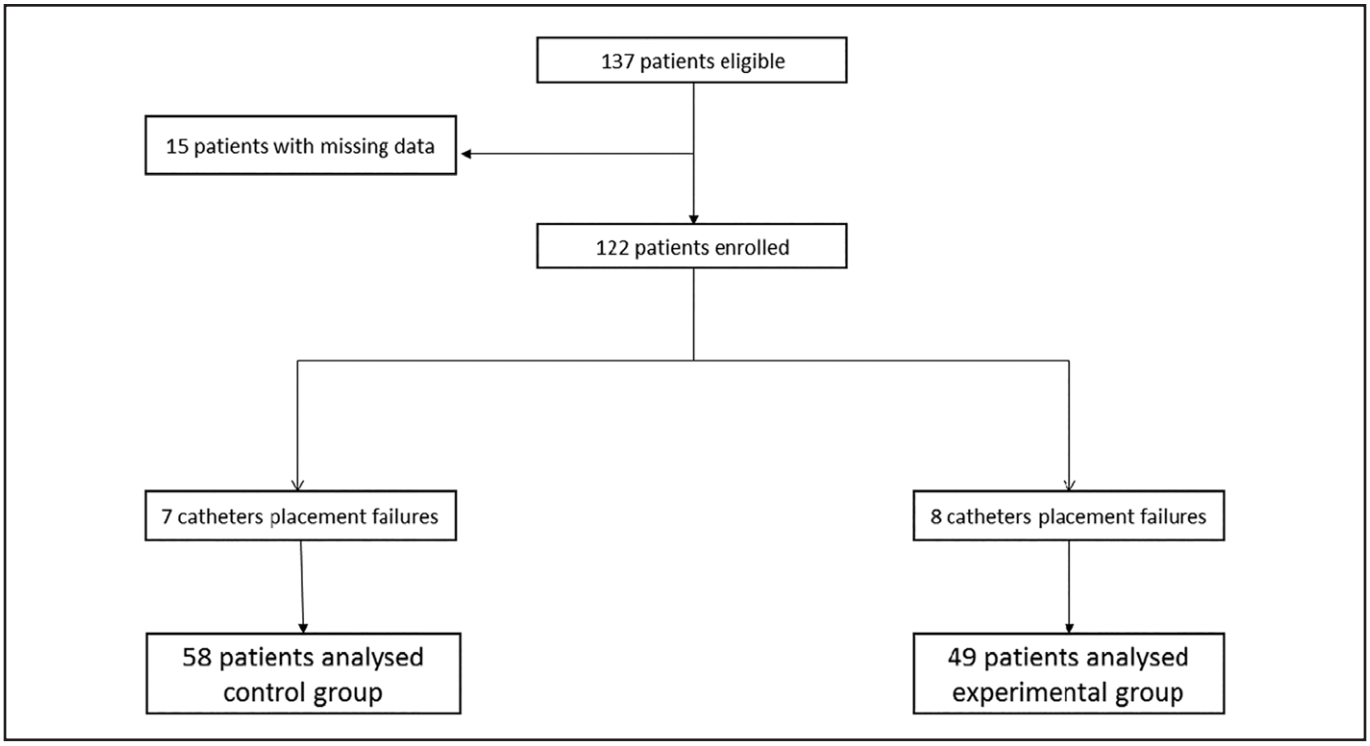

Figure 1. Flow chart.

catheters, 15 placement failures occurred (seven in control group and eight in experimental group). Thus, only 107 catheters were analyzed with 58 catheters in the control group and 49 in the experimental one (**Fig. 1**: the CONSORT diagram).

Table 1 summarizes the patients' characteristics. The two groups were comparable except the length of stay in intensive care medicine, which was significantly longer in control group, but no significant increase in the arterial catheterization duration (8.4 ± 0.9 d for control group and 6.9 ± 0.9 d for experimental group; p = 0.23), neither in norepinephrine exposure or edema.

Regarding primary outcome, the number of catheter dysfunctions were not significantly different between the two groups, with 15 dysfunctions in control group (23%) and nine dysfunctions in experimental group (16%) (p = 0.56) (**Fig. 2**). The prevalence density of dysfunction was 30.5 of 1,000 catheter days for control group against 26.7 of 1,000 catheter days for experimental group.

Regarding secondary outcomes, catheter-related infections were significantly more frequent in the control group with 4 (7%) documented infections compared with none in experimental group (0 [0%]) (hazard ratio = 4.9; 95% CI, 1.1–22.9; p = 0.04) (**Fig. 3**). The microorganism identified were all Gram-negative bacilli (*Proteus mirabilis*, *Serratia marcescens*, *Citrobacter koseri*, *Pseudomonas aeruginosa*).

In terms of colonization, no significative difference was found with 6 (10%) in the control group and 2 (4%) in the experimental group (p = 0.28).

Regarding the satisfaction, the medical staff was significantly better satisfied for catheter placement in the experimental group (p = 0.008). However, the quality of exposition, the length of the procedure and the number of attempts were not significantly different between groups (**Table 2**).

Similarly, the nurses' satisfaction with catheter care were significantly better in the experimental group (p = 0.039) and patients were also significantly more satisfied when the AC was placed farther from the wrist (p = 0.008).

DISCUSSION

This is the first randomized study comparing the prevalence of AC dysfunction in relation to position on the radial artery under ultrasound.

In our study, the placement of a radial AC far from the radiocarpal articulation does not to prevent AC dysfunctions. Indeed, the prevalence density of

TABLE 1.
Patient Characteristics

Patient Characteristics ($n = 122$)	Control Group ($n = 65$)	Experimental Group ($n = 57$)	p
Demographic data			
Age (yr)	56 (44–67)	54 (39–64)	0.41
Male sex, *n* (%)	50 (77)	38 (66)	0.21
Body mass index (kg/m^2)	26 (23–29)	25 (23–28)	0.4
Simplified Acute Physiology Score II at admission	30 (22–42)	33 (23–47)	0.67
Cardiovascular risk factor, *n* (%)	42 (65)	32 (56)	0.36
Data at admission			
Mean blood pressure (mm Hg)	84 (72–94)	83 (73–92)	0.83
Norepinephrine, *n* (%)	16 (25)	11 (19)	0.52
Edema, *n* (%)	15 (23)	15 (26)	1
Outcomes			
ICU length of stay, d	14 (6–24)	7 (4–17)	0.027
Hospital mortality, *n* (%)	5 (6)	3 (5)	1

Values are given in median (25th–75th percentiles).

dysfunction was 30.5 of 1,000 catheter days for control group against 26.7 of 1,000 catheter days for experimental group. However, this seems to affect the prevalence of catheter-related infections.

A major French randomized controlled trial published in 2012 by Günther et al (11) focused on the complications encountered by intravascular catheters, whether venous or arterial, in ICUs. This study encompassed 2,214 catheters including 512 AC. Regarding the latter, the first complication which was encountered was a material dysfunction of 12.9 of 1,000 catheter days spent wearing the AC, a lower figure than our previous results but still a significant prevalence. However, the study is not directly concerned with dysfunctions, and the number of catheters is greater than in our study. Furthermore, the use of ultrasonography is not mentioned and the position (radial or femoral) was not reported.

To our knowledge, only one French study has directly focused on the prevalence of AC dysfunctions (12). A total of 95 catheters were concerned (46 in radial position and 49 in femoral position). A dysfunction rate of about 17% was found just for catheters in radial position, which corresponds to our results. In this study, femoral catheters had a significantly lower rate of dysfunction than radial ones and the authors attributed this result to less frequent spontaneous movements of the thigh related to the wrist and/or a larger diameter of the catheters inserted in the femoral site. This last hypothesis seems more likely to us in view of the results of our study because the latter was also based on the hypothesis that repeated wrist movements played a part in the occurrence of dysfunctions, but the explanation is probably multifactorial.

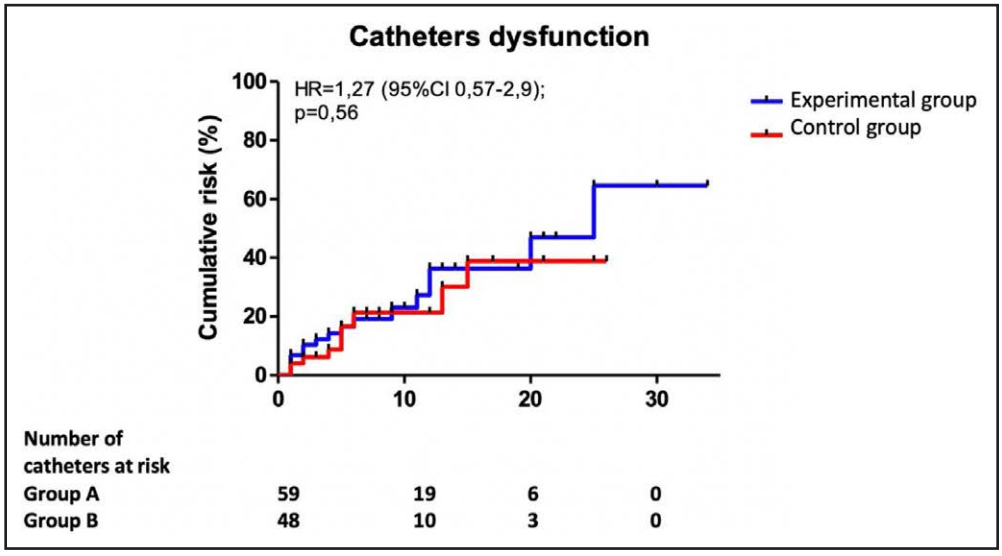

Figure 2. Cumulative risk of catheter dysfunction. HR = hazard ratio.

Two other studies reported a higher risk of dysfunction when the distance between the catheter insertion site and the radiocarpal joint increases (13, 14). Riachy et al (13), for example, showed each time the distance from the catheter

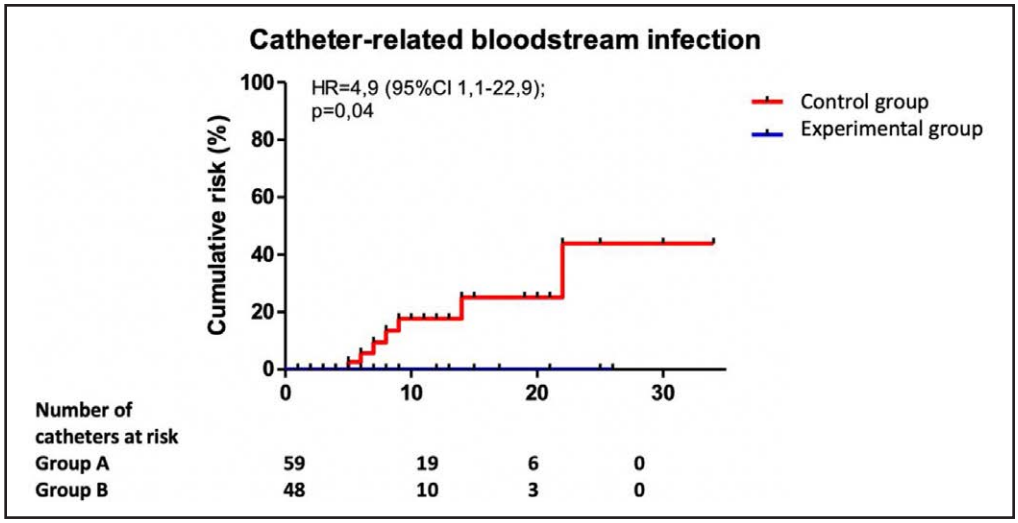

Figure 3. Cumulative risk of catheter-related infection. HR = hazard ratio.

TABLE 2. Outcomes

Outcomes ($n = 107$)	Control Group ($n = 58$)	Experimental Group ($n = 49$)	p
Catheter dysfunctions, *n* (%)	15 (23)	9 (16)	0.49
Catheterization duration, d, mean (SD)	6 (4–12)	4 (3–8)	0.21
Colonizations, *n* (%)	6 (10)	2 (4)	0.28
Infections, *n* (%)	4 (7)	0 (0)	0.12
Number of attempts	1 (1–2)	2 (1–2)	0.2
Exposure time, min	15 (10–20)	15 (10–20)	1
Physician satisfaction, VAS	6 (4–7)	9 (8–10)	0.008
Patient satisfaction, VAS	6 (5–9)	8 (7–10)	0.008
Nurse satisfaction, VAS	6 (6–8)	8 (7–9)	0.039

VAS = Visual Analog Scale.
Values are given in median (25th–75th percentiles).

insertion site to the wrist fold increased by 1 cm, the risk of dysfunction was multiplied by "2.07." And, Dysfunction catheters were 4.23 times more likely in patients with insertion sites 3 cm or higher above the bend of the wrist than in patients with lower sites (p = 0.01) in the trial by Kaye et al (14). However, none of them assessed the catheters' dysfunction as the main judgment criterion. In addition, the positioning technique was not specified, and none of these studies used ultrasound. We know that the placement of AC under ultrasound exposes to a decrease in the rate of complications (15). It can therefore be assumed that, in the absence of ultrasound, the placement of the catheter at a distance from the wrist is more difficult because the artery is less palpable. It therefore exposes the catheter to a higher risk of attempts and complications and, eventually, of dysfunction. In addition, the difficulty of placement can lead to infections, which are another serious complication of AC placement.

We know that catheter-related bacterial infections are associated with higher morbidity and mortality risks, longer hospital stays and an increase in the overall care cost (16).

It should be notified that in our study, the infection rate is significant (3.7% on all the catheters) compared with the results found in the literature. For example, in the study conducted by Günther et al (11), only one catheter-related infection was found out of the 512 included (0.2%) but the duration of the catheterization was not indicated and 80% of the patients were on antibiotics when the catheter was inserted.

Another randomized, prospective study (17) sought to analyze the prevalence, pathogenesis and risk factors associated with infections related to radial AC. Six hundred ninety-four of these were studied and the infection rate was 1.3% (or 1.3/1,000 d spent with the catheter on).

The prevalence of infections is therefore as low as in our study, but the catheterization duration is different: 3 days for this study but almost eight for ours. In addition, patients had lower severity scores. The longer the catheterization, the greater the risk of infection.

In our study, we found a link between infection and catheter position. Indeed, it appears that the further the catheter is from the wrist, the lower the risk of catheter-related infection is.

This is the first study to highlight such a link. We hypothesized that this decrease in the number of infection is primarily related to an easier insertion, even if it does not result in a shorter insertion time or a lower number of attempts, and to the fact that the catheters are easier to maintain, as the dressings are more occlusive and supposedly changed less often.

In a Spanish prospective, nonrandomized study (18), whose aim was to analyze the prevalence of AC-related bacteremia, the infection rate was close to 4% (3.5 infections/1,000 d spent wearing the catheter). The duration of the catheterization (close to 9 d) was an independent risk factor for catheter infection. These results are close to ours with the same duration of catheterization.

Despite the publication of the North American recommendations on the prevention of intravascular catheter infections published in 2011 by O'Grady et al (5), indicating that when all precautions are taken regarding catheter insertion, the risk of catheter-related infections is very low (0.41/1,000 d spent with the catheter on), the role of AC in infection may be underestimated, as in most studies this equipment is usually used for short periods of time (1 or 2 d) for patients running lower risk of infection and having lower severity scores.

Thus, as our results suggest, AC can be an important source of infection if the catheterization duration is significant, even those inserted in a radial position.

Finally, most of the studies do not mention the level of preparation of the operator. In our study, it was resident, which may have influenced the results and increased the prevalence of infections.

Regarding colonization, our study found a rate of 10% in the control group versus 4% in the experimental group but a nonsignificant difference. In the study by Khalifa et al (19), which investigated the length of stay and risk of colonization of peripheral ACs in critically ill patients, we found a colonization rate of 16%, which is higher than in our population. However, the disinfection protocol was not the same (povidone-iodine in the study of Khalifa et al [19] vs chlorhexidine in ours) and no catheters were placed under ultrasound.

Our study also highlights an interesting fact about catheter placement. Indeed, the feeling of satisfaction is higher among experimental group's operators, due to an easier insertion under ultrasound, the remote insertion of the wrist allowing the puncture to be performed at a more distant location from the ultrasound probe.

To our knowledge, this is the first study to focus on the feelings of medical and paramedical staff and patients' comfort, regarding the insertion of AC under ultrasound. Although placing AC at a distance from the wrist does not alter the prevalence of dysfunction, it appears to be beneficial to the patient, as well as to the medical and paramedical staff.

One study is interested in the placement of peripheral IV catheters and patient satisfaction. It also found greater patient satisfaction when using ultrasound than the traditional method (20).

However, our study shows its limitations. First, this research was monocentric and focused on surgical resuscitation patients only. Second, the use of the blind in the protocol was not feasible. Only the bacteriologist performing the analyses on the catheters was not aware of this research work. However, in the study, the definition of "catheter dysfunction" was not subject to interpretation (impossibility of sampling or interpretable blood pressure curve) and therefore, the results might not have a bias even in the absence of blind.

In addition, we did not provide any information on prior antibiotic therapy. However, in one of the two groups, a larger number of the patients who were on antibiotics could affect the results on colonization and infection rates. There may also be a significant loss of data, resulting in a loss of study power. Finally, the fact that most of the operators were residents in training should be taken into account. We tried to overcome this bias by training the residents to insert catheters under ultrasound thanks to a simulation method. In addition, they were expected to place about 20 catheters before they could take care of patients. Nevertheless, it can be argued that this fact reflects a daily reality in a hospital department such as ours.

CONCLUSIONS

This study is the first to compare the influence of the positioning of ACs in the radial position on the prevalence of dysfunctions. The results show that the distance between the AC and the radiocarpal joint does not influence the development of dysfunction. In addition, this study suggests that placing the catheter at a distance from the wrist could reduce the prevalence of

catheter-related infections. These results should be validated by a multicenter study which would be designed around this hypothesis.

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Dr. Marie drafted the work and made substantial contributions to the analysis and interpretation of data. Drs. Marie, Dahyot-Fizelier, and Kerforne designed the work, interpreted data for the work, critically revised the work for important intellectual content and gave final approval of the version to be published. All authors acquired data, critically revised the work for important intellectual content and gave final approval of the version to be published.

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