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# The practice of arterial catheters in ICUs and nurses' perceptions of infection prevention: A multicentre cross-sectional study

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## Abstract

**Background:** Peripheral arterial catheters (AC) are increasingly used in intensive care units (ICUs). Arterial catheter-related bloodstream infection is a serious complication that can increase patients' morbidity and length of stay. Standardised infection prevention practices are important when using AC. However, the current practices regarding AC insertion, use and removal and the perceived infection prevention attitudes of nurses in ICUs are unknown.

**Methods:** This was a multicentre cross-sectional study; 20 tertiary general hospitals were selected with a stratified random method in Beijing, China, using a self-reported internet survey.

**Results:** A total of 981 valid questionnaires were collected. Overall, some infection prevention practices, such as AC insertion and disinfection of the blood sample hub, were generally consistent with clinical guidelines, whereas others were inconsistent: eye protection, skin antiseptic solution, dressing choice, blood sample collection and replacement of AC. More than 60% of participants mentioned occasionally or never having used eye protection. Only 6.0% of them stated using the chlorhexidine dressings. Among the participants, 80.6% reported that they replaced AC routinely rather than based on clinical indications, 64.2% self-rated that they did not routinely culture a catheter specimen after removal and 53.4% of participants positively agreed that AC could cause infection. Nurses with a higher education level were more likely to agree that an infection risk with AC exists (trend $\chi^2 = 5.456$, $p = 0.019$*).

**Conclusions:** Significant heterogeneity exists across hospitals in China in terms of antiseptic techniques and perception of infection prevention during AC insertion, use and removal. Critical care nurses' practices partially complied with guideline recommendations. Educational level was found to be a risk factor for their perceived infection prevention attitudes. Nurses with a lower education level underestimated the infection risk of AC. Future research may examine optimal preventive strategies for reducing infection.

## Keywords

Arterial catheter, bloodstream infection, intensive care units, nurses, survey

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## Introduction

Peripheral arterial catheters (AC) are increasingly used in the intensive care unit (ICU) and peri-operative settings. This monitoring system consists of three parts, namely vascular catheter (often inserted in a peripheral artery), pressure tubing circuit and transducer connected to an electronic monitor. AC are inserted in three out of four critically ill patients in intensive care units.[1] Inserting AC in critically ill patients can provide direct, fast and accurate blood pressure data, reduce pain caused by repeated puncture, decrease nurse workload and reduce the risk of needlestick injuries.[2,3] Although AC bring great convenience to clinical practice, there are many risks owing to

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improper aseptic techniques and infection prevention measures.

Catheter-related bloodstream infection (CRBSI) is one of the most serious complications of intravascular devices resulting in considerable morbidity, mortality and additional hospital cost.[4,5] The incidence of arterial catheter-related bloodstream infections (ACBSI) varied among different countries. In the United States, the incidence of ACBSI ranged from 0% to 4%,[4] while an Australian study indicated a rate of occurrence of 0.28% across 7-days duration for a group of patients.[6] A meta-analysis[7] showed that the pooled incidence of ACBSI was 3.40/1000 catheters or 0.96/1000 catheter-days, and it was often overlooked or underestimated. In China, the incidence of ACBSI was 3.3/1000 catheter-days which was higher than that of central venous catheter-related bloodstream infections (CVB-SI).[8] A previous study has shown that ACBSI increased the patients' length of ICU stays, mortality and healthcare costs.[9] Therefore, identifying the risk factors of ACBSI is important in clinical practice.

At present, there are several clinical practice guidelines (CPGs) instructing nurses to prevent infection in arterial or intravascular catheters. The most well-known CPGs are developed by the U.S. Centre for Disease Control and Prevention (CDC),[10] the National Institute for Health and Care Excellence (NICE),[11] the Asia Pacific Society of Infection Control (APSIC)[12] and the French Society of Intensive Care Medicine (SRLF).[1] These CPGs all provide evidenced-based recommendations for the insertion and maintenance of peripheral intravascular catheters. Yi W et al.[13] systematically searched the CPGs for AC and summarised the evidenced-based recommendations. Currently, although there is a growing body of evidence, its impact on clinical practice by nurses and whether a gap exists between evidence and clinical practice is not clear, which is worth discussing. In 2013, Reynolds et al.[14] surveyed the peripheral arterial catheter practices for blood gas sampling and infection prevention in operating rooms. Furthermore, this study only focussed on the infection prevention practice of arterial blood sampling. Until now, we have not found a related study which explored AC infection prevention practices of insertion, usage and removal in China. Moreover, whether ICU nurses are aware of or comply with the current guideline recommendations for AC is unknown.

### Aims

The study hypothesised a gap between clinical practice and guideline recommendations on AC-induced infection prevention measures. The aim of the study was to describe current ICU nursing practices of inserting, using and removing AC and to evaluate their perceptions regarding infection prevention. Additionally, the analysis included the relation between nurses' perceptions of infection prevention and their educational level, professional title, job title and working years.

## Materials and methods

### Study design and sampling

This was a descriptive, cross-sectional study. It was conducted in 20 tertiary general hospitals in Beijing, China, from March to May 2020. In this study, the stratified sampling method was used to select the hospitals. Firstly, the number of stratified sample hospitals in various levels was based on the ratio of each type of hospital to the total. The official appointment and registration platform recorded 77 tertiary general hospitals in Beijing, excluding specialised hospitals for rehabilitation, stomatology and psychiatry. Then, a random number table generated by a computer was used to select hospitals from all levels. Finally, 20 tertiary general hospitals were enrolled: 1 (5%) hospital was directly under the Ministry of Health, 4 (20%) hospitals were directly under the Beijing Municipal Administration, 4 (20%) were associated with sciences or medical colleges, 4 (20%) were armed-police or military hospitals, 2 (10%) were factory hospitals affiliated with the Ministry and 5 (25%) were county-level hospitals. The selected hospitals were located throughout Beijing, with strong geographical representation.

### Inclusion and exclusion criteria

The participant of this study were ICU nurses who worked in the selected hospitals. The inclusion criteria were registered nurses who had worked in an ICU more than 1 year and volunteered to participate. Nurses who were absent, studying or abroad for more than 3 months within the last year were excluded.

### Measures

This study used two data collection tools: demographic and job-related characteristics and a self-reported questionnaire consisting of 24 items divided into three parts. Demographic and job-related characteristics included age, gender, educational level, workplace, ICU working years, professional title and job title.

This study used the standard method to develop and test the questionnaire through an iterative process in three phases: (1) The preliminary draft of the questionnaire was developed by integrating the evidence from the guidelines, systematic reviews and the researchers' experience. (2) Two rounds of expert consultations were conducted with critical care experts to evaluate the test structure and content validity. (3) The psychometric testing through pre-investigation was conducted in a tertiary hospital. The final questionnaire included three parts. The first part (6 items) was about the

**Table 1.** Demographic characteristic of participants ($n = 981$).

| Characteristics | *n* | % |
|---|---|---|
| Work place | | |
| Department of critical care medicine | 611 | 62.3 |
| Cardiac surgery ICU (CSICU) | 180 | 18.3 |
| Neurological ICU (NICU) | 41 | 4.2 |
| Kidney care unit (UICU) | 39 | 3.9 |
| Respiratory ICU (RICU) | 33 | 3.4 |
| Geriatric internal medicine ICU (GIMICU) | 33 | 3.4 |
| Emergency intensive care unit (EICU) | 23 | 2.3 |
| Cardiac care unit (CCU) | 21 | 2.1 |
| Age (years) | | |
| ⩽30 | 607 | 61.9 |
| 31–40 | 330 | 33.6 |
| >40 | 44 | 4.5 |
| ICU working years (years) | | |
| ⩽5 | 396 | 40.4 |
| 6–10 | 309 | 31.5 |
| ⩾10 | 276 | 28.1 |
| Gender | | |
| Female | 879 | 89.6 |
| Male | 102 | 10.4 |
| Professional title | | |
| Registered nurse | 293 | 29.9 |
| Junior nurse | 513 | 52.3 |
| Supervisor nurse | 169 | 17.2 |
| Co-chief or chief nurse | 6 | 0.6 |
| Job title | | |
| Primary nurse | 853 | 87.0 |
| Nurse group leader | 99 | 10.1 |
| Head nurse | 29 | 2.9 |
| Education level | | |
| Secondary/college | 327 | 33.3 |
| Bachelor's degree | 650 | 66.3 |
| Master's degree or above | 4 | 0.4 |

nurses' practice and attitude to AC insertion. The second part (12 items) was about the use and replacement of dressings and pressure transducers. The last part (6 items) examined nurses' attitudes and practices regarding the time of AC removal. The internal consistency of the questionnaire was 0.80 and the content validity index was 0.93, indicating good reliability and validity.

### *Data collection*

Anonymous electronic questionnaires were distributed using WeChat (a Chinese app developed by Tencent Computer System). After receiving permission and active responses from each hospital, a liaison person, who was usually a head nurse, was designated to facilitate completing the survey. We set up each intelligent terminal so that it could only be filled out once. The completeness of the e-questionnaire was guaranteed by setting mandatory questions. Researchers could obtain the results from the electronic survey system platform directly after the participants filled out the questionnaire online.

### *Statistical analysis*

Data analysis was performed with SPSS 22.0 (SPSS Inc., Chicago, IL, USA). Continuous data were computed for descriptive statistics by mean, standard deviation and median and interquartile range percentage. Categorical data were presented as percentages. The chi-square test was performed to examine the relation between nurses' perception of infectious risks posed by AC and their educational level, professional title, job title and working years.

### *Ethical and research approvals*

This study was approved by the Peking University First Hospital Ethics Committee (2019-282). The questionnaire survey was anonymous. All participants provided informed consent before participating in the study and confidentiality was ensured. Participants had the right to refuse to participate. They were informed that the questionnaires were coded to categorise hospitals without identifying the individual's information who completed the questionnaire.

## Results

### *Sample characteristics*

The survey was completed by 981 of the 992 potential participants, giving a response rate of 98.9%. Participants were recruited from ICU wards at 20 hospitals and the average number of ICU beds was $17.26 \pm 9.77$. The demographic characteristics of the participants is presented in Table 1. The age of participants ranged from 20 to 53 years and the median age was 29 (26, 33.5 IQR = 7.5). Almost 62.3% worked in the Department of Critical Care Medicine and 89.6% were female.

### *Practice of AC insertion*

The antiseptic techniques used during AC insertion are shown in Table 2. About 45.2% and 41.1% of participants reported that AC were inserted by nurses and physicians, respectively. The use of maximum sterile barriers during AC insertion was reported by 72.4% respondents. In addition, more than 60% participants mentioned occasionally or never having used eye protection. Moreover, 31.6% of them stated that 2% chlorhexidine in 70% isopropyl alcohol was the preferred skin antiseptic solution during AC insertion.

### *Practice of using AC*

Of the participants, 60.2% reported to use the closed flush system and 39.2% the open system. Furthermore, 91.9% of

**Table 2.** The practice of antiseptic techniques during AC insertion.

| Variables | *n* | % |
|---|---|---|
| Arterial insertion personnel | | |
| Nurse | 443 | 45.2 |
| ICU Doctor | 403 | 41.1 |
| Anaesthesiologist | 68 | 6.9 |
| Technical personnel | 67 | 6.8 |
| Frequency of using maximum sterile barrier precautions | | |
| Always | 710 | 72.4 |
| Often | 158 | 16.1 |
| Occasionally | 71 | 7.2 |
| Never | 42 | 4.3 |
| Types of maximum sterility barrier precautions ($n=939$) | | |
| Mask | 909 | 92.6 |
| Cap | 898 | 91.5 |
| Sterile gloves | 851 | 86.7 |
| Sterile gown | 461 | 47.0 |
| Sterile drape | 784 | 79.9 |
| Frequency of eye protection used to prevent spatter | | |
| Always | 225 | 22.9 |
| Often | 155 | 15.8 |
| Occasionally | 458 | 46.7 |
| Never | 143 | 14.6 |
| Disinfection range during arterial catheter insertion | | |
| 5 cm × 5 cm | 54 | 5.5 |
| 8 cm × 8 cm | 117 | 11.9 |
| 10 cm × 10 cm | 347 | 35.4 |
| Beyond dressing coverage | 463 | 47.2 |
| Types of skin antiseptic solutions during AC insertion | | |
| Iodine volts | 479 | 48.8 |
| 2% chlorhexidine in 70% isopropyl alcohol | 310 | 31.6 |
| 1% to 2% tincture of iodine or iodine | 105 | 10.7 |
| 75% alcohol | 6 | 0.6 |
| Iodine volts | 26 | 2.7 |
| Alcohol and iodine volts | 55 | 5.6 |

Technical personnel is a different kind of person from doctor and nurse.

them self-rated using the sterile transparent semi-permeable membrane dressings and 6.0% used the chlorhexidine dressings. A total of 92.1% nurses stated that they always disinfect the blood sample hub when they collected blood samples (Table 3).

### *Practice of AC removal*

Of the participants, 791 (80.6%) reported that they replaced the AC routinely rather than based on clinical indications; 912(93%) of them self-rated to perform a daily evaluation of the appropriateness of maintaining AC in site. In addition, 480 (62.6%) participants mentioned that ICU physicians are the ones to do the daily evaluation. In the case of non-emergency catheterisation, respondents stated that the duration of the AC was 5–7 days (462 [47.1%]) or less than 4 days (266 [27.2%]). Moreover, 533 (54.3%) patients underwent emergency catheterisation in their department. Among them, 256 (46.3%) nurses replaced the catheter within 48 h and 277 (53.7%) replaced it after more than 48 h. Finally, 630 (64.2%) of the nurses self-rated that they did not routinely culture a catheter specimen after removal.

### *Perceived infection prevention*

The questionnaires indicated that 53.4% of the nurses positively agreed that AC insertion was associated with considerable risk of ACBSI. Of the participants, 93.7% expressed support for using maximum sterile barriers during AC insertion. Interestingly, nurses with a higher education level showed greater awareness and agreement with the infectious risk associated with AC (trend $\chi^2=5.456$, $p=0.019$; Table 4).

## Discussion

To the best of our knowledge, this study is the first cross-sectional study to estimate the current practices regarding AC and the perceived infection prevention attitudes regarding ACBSI in ICUs in China. This survey included 981 nurses from 20 hospitals, revealing significant heterogeneity in the practice of antiseptic techniques and perceived risk of infection. General nursing practices were consistent with the recommendations of the guidelines, such as AC insertion and disinfection of the blood sample hub. However, other practices, such as eye protection, skin antiseptic and dressing solution, collection of blood samples and AC replacement, were inconsistent. Another important finding was that nearly half of them thought AC could not cause ACBSI and this perception was influenced by nurses' educational level.

Regarding AC insertion, guidelines[10,15] recommended using a cap, mask, sterile gloves and small sterile fenestrated drape at the minimum during arterial insertion. The results indicated that 72.4% of participants applied a maximum sterile barrier during AC insertion and 93.7% supported this practice. It was better than the result of Cohen et al.[2] which showed that only 44% of clinicians used barrier precautions and 39% supported its mandatory use. In recent years, with the proposal of the maximum sterile barrier, ICU nurses have also realised its importance, but whether it is strictly implemented in practice should get the attention of managers. However, the use of eyewear was controversial. According to the INFUSION NURSING SOCIETY(INS) standard of PRACTICE (8th Edition)[16] and clinical decisions[17] developed by UpToDate, full barrier precautions should include eye protection to reduce the potential for catheter site infection and minimise the risk of disease transmission associated with blood splatter.

**Table 3.** The practice of antiseptic techniques during using of ACs ($n = 981$).

| Variables | n | % | Variables | n | % |
|---|---|---|---|---|---|
| Types of dressing | | | Time of replace the pressure transducer | | |
| Sterile transparent semi-permeable membrane dressing | 902 | 91.9 | 24 h | 55 | 5.6 |
| Chlorhexidine dressing | 58 | 6.0 | 48 h | 57 | 5.8 |
| Sterile gauze dressing | 14 | 1.4 | 96 h | 252 | 25.7 |
| Not sure | 7 | 0.7 | According to specification | 617 | 62.9 |
| Frequency of replace transparent dressing(without gauze) | | | The blood sample is collected from | | |
| 1–2 days | 143 | 14.6 | Heparin cap | 126 | 12.8 |
| 3–4 days | 433 | 44.1 | Stopcock positive pressure joint | 666 | 67.9 |
| 5–7 days | 346 | 35.3 | Positive pressure joint | 151 | 15.4 |
| Depending on circumstances | 59 | 6.0 | Other | 38 | 3.9 |
| Time of replace sterile gauze dressing gauze | | | Frequency of replacing the blood sample hub | | |
| 1–2 days | 695 | 70.9 | No replacement | 36 | 3.7 |
| 3–4 days | 204 | 20.8 | Every day | 204 | 20.7 |
| 5–7 days | 68 | 6.9 | Every 3 days | 130 | 13.3 |
| Depending on circumstances | 14 | 1.4 | Any time when contaminated with blood | 585 | 59.6 |
| Do you replace catheter site dressing routinely if the dressing becomes damp, loosened or visibly soiled | | | Replace with the pressure transducer | 26 | 2.7 |
| Always | 883 | 90.0 | Frequency of disinfecting the blood sample hub | | |
| Often | 88 | 9.0 | Always | 903 | 92.1 |
| Occasionally | 6 | 0.6 | Often | 53 | 5.4 |
| Never | 4 | 0.4 | Occasionally | 18 | 1.8 |
| Types of antiseptic to use when replacing dressings | | | Never | 7 | 0.7 |
| Iodine volts | 394 | 40.2 | Types of antiseptic for disinfecting blood sample hub ($n = 974$) | | |
| 2% chlorhexidine in 70% isopropyl alcohol | 394 | 40.2 | Iodine volts | 250 | 25.7 |
| 1%–2% tincture of iodine or iodine | 102 | 10.4 | 2% chlorhexidine in 70% isopropyl alcohol | 405 | 41.6 |
| 75% alcohol | 8 | 0.8 | 1%–2% tincture of iodine or iodine | 86 | 8.8 |
| Entoiodine | 83 | 8.4 | 75% alcohol | 180 | 18.5 |
| | | | Entoiodine | 53 | 5.4 |

However, in this survey, most nurses reported occasionally or never having used eye protection. Disseminating the concept of maximum sterile barriers through national standards, academic conferences and other measures is recommended for the future of nursing standards. On the other hand, Chlorhexidine 2% should be the preferred skin antiseptic solution.[11,18] In our study, only 31.6% of nurses stated using 2% chlorhexidine in 70% isopropyl alcohol, which is consistent with the study by Reynolds et al.,[14] where less than 50% of respondents used chlorhexidine to disinfect the skin. Besides, a systematic review showed that 1% chlorhexidine-alcohol reduced CRBSI risk better than 0.5% CHG-alcohol or 2% CHG-aqueous.[19] The Chinese health department should strengthen training on the type and function of disinfectants, developing standards to regulate their use in the future.

Regarding using AC, the use of chlorhexidine impregnated dressings is recommended, particularly in patients who are vulnerable to CRBSI or catheter colonisation.[1,20] In our study, only 6.0% of nurses selected chlorhexidine dressings. One possible reason was that there was currently no regulation on who must use chlorhexidine dressings. The high price of chlorhexidine dressings and it not yet being covered by medical insurance in China may be another reason. Unexpectedly, Jenks et al.[21] reported that TEGADERM chlorhexidine gluconate (CHG; developed by 3M) was associated with lower rates of catheter-related infection and it could save £77.26 per patient. Hence, barriers to use must be identified to strengthen the training and education of nurses and the cost for chlorhexidine dressings should be covered by national medical insurance. Another widespread use of AC in ICU was for frequent arterial blood gas (ABG) analysis.[2] There were risks of infection because of frequent blood sampling from AC.[3] That is, the strategies proposed by experts to allow a reduction of infection were disinfecting before accessing or manipulating open systems.[1] In this study, almost all the nurses disinfected the blood sample hub. It was better than the study of Reynolds et al.[14] which found that 47% of respondents reported 'never disinfected' access ports in

**Table 4.** Perception of infectious risks for arterial catheter infection and risk factors.

| Risk factors | Characteristics | Perception of infectious risks for arterial catheter infection | | | Trend $\chi^2$ value | *p*-Value |
|---|---|---|---|---|---|---|
| | | No | Maybe | Yes | | |
| Education level | College degree and below | 11 | 156 | 160 | 5.456 | 0.019 |
| | Bachelor's degree and above | 10 | 280 | 364 | | |
| Professional title | Registered nurse | 8 | 135 | 150 | 1.808 | 0.179 |
| | Junior nurse | 8 | 233 | 272 | | |
| | Supervisor nurse and above | 5 | 68 | 102 | | |
| Job title | Primary nurse | 18 | 382 | 453 | 0.544 | 0.461 |
| | Nurse group leader | 3 | 43 | 53 | | |
| | Head nurse | 0 | 11 | 18 | | |
| Working years (years) | <1 | 3 | 36 | 51 | 1.393 | 0.238 |
| | 1–5 | 4 | 152 | 150 | | |
| | 6–10 | 7 | 139 | 163 | | |
| | 11–20 | 7 | 90 | 136 | | |
| | >20 | 0 | 19 | 24 | | |

operating theatres. Furthermore, our findings also suggested that other procedures of arterial blood collection in China were not uniform, such as blood collection sites, replacement and disinfection of the blood sample hub. Most of the published guidelines have not mentioned this topic, except for the evidence summary by the Joanna Briggs Institute (JBI) which only provided some general recommendations.[22] Therefore, more studies and high-quality evidence are needed to help clinical nurses to use and maintain AC in the future.

Regarding AC removal, about 80% of respondents reported replacing AC routinely rather than based on clinical indications, which represents a significant deviation from the recommendations. According to the guidelines,[23,24] AC should be replaced when clinically necessary. One study showed that the discontinuation of scheduled replacement of AC every 5 days did not increase the risk of colonisation but decreased the risk of bloodstream infection.[25] Another interesting result was that more than 60% of the nurses reported that they would not routinely culture catheterisation specimens when AC were removed. This may be a main reason for the underestimation of ACBSI. In addition, doctors and nurses considered ACBSI as the last cause when a patient had symptoms of infection. Therefore, it is necessary to strengthen awareness of ACBSI among doctors and nurses.

Finally, it was seen that about nearly half of the nurses agreed that AC could not cause ACBSI. Only a quarter of the nurses estimated the rate of catheter infection per thousand days to be closest to 1%, which was consistent with the results of Cohen et al.[2] The results indicated that clinicians significantly underestimated the infectious risk posed by AC. We also found that nurses' educational level affected their perceptions of ACBSI. Nurses with higher education were more likely to agree that there was an infection risk with AC. A nurse with a high degree of education has received more comprehensive knowledge and is more aware of the importance of infection. However, working years, job title and professional title did not affect nurses' perceptions of ACBSI. When conducting AC infection training, a focus should be placed on nurses with lower educational levels.

### *Limitations and further research*

Our study has a few limitations. First, the results were based on self-reported questionnaires, which means that they may provide a perspective of clinical practice that is different from reality. As the data was based on a survey, the subjective nature of the respondents might have influenced the results. In the future, an observational study should be carried out to describe the phenomena more objectively. Second, we only enrolled nurses from tertiary general hospitals in Beijing because of limited time and economic reasons, which may limit the wider generalisability of the findings. However, this study included 20 hospitals and the result was still significant. Moreover, nurses and physicians may have different behaviours and attitudes regarding AC-related practices. Further research should include doctors from different hospitals in mainland China.

## Conclusions

This study indicated significant heterogeneity in the practice of antiseptic techniques and perceived risk of infection among different hospitals. There is a gap between practice and guidelines for infection prevention measures. Nurses significantly underestimated the infection risk posed by AC and those with different educational levels had varying

attitudes towards ACBSI. Standardised practice procedures and workplace training are needed to apply the best evidence to optimal preventive strategies regarding the prevention of ACBSI.

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