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Impact of sterile gloving during proximal manipulation of central line catheter hub: the multicenter observational study CleanHandPROX

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Abstract

Background Patients with central lines face an increased risk of developing bacteremia. Preventing late-onset catheter-related infections relies on implementing various measures during manipulations of the catheter hub of central lines (e.g., during connections, disconnections, blood withdrawals, pulsed rinses, or injections performed at the first connection after the central catheter). French guidelines include**,** among these measures, the requirement to put on sterile gloves immediately before proximal manipulation to help prevent contamination of the catheter hub during preparation. To our knowledge, no study has reported compliance with wearing sterile gloves during these manipulations, nor the impact of not wearing sterile gloves on the cleanliness of the fingers of healthcare workers (HCWs) just before manipulating the connectors.

Methods We conducted a two-part study to assess compliance with sterile gloving and to provide direct microbiological evidence of bacterial contamination on HCWs' hands immediately before the manipulation of central lines when sterile gloving is not used. First, the use of sterile gloves was observed during proximal manipulations of central lines using a standardized grid. Second, we examined the microbial flora present on the fingers of each observed HCW just before proximal manipulation.

Results A total of 260 HCWs from 35 healthcare institutions were observed during proximal manipulation. The HCWs were distributed into three groups: 188 used sterile gloves (72%), 23 used nonsterile gloves (9%), and 49 did not wear gloves (19%). The swabbing of the fingertips revealed microbial cultures from 72 samples (28%). A total of 97 microorganisms were identified, all of which are well-recognized agents responsible for catheter-related bacteremia, predominantly coagulase-negative *staphylococci* (n = 36) and *Bacillus* sp. (n = 31). Fingertip contamination was lower for HCWs wearing sterile gloves (27/188; 14%) than for those wearing nonsterile gloves (12/23; 52%) or not wearing gloves (33/49; 67%) ($p < 0.001$). The contaminants were similar across the three groups.

Conclusions Our data support the positive impact of sterile gloving in ensuring clean fingertips during proximal manipulation of central lines, a key measure in preventing late-onset catheter-related bacteremia. The contamination

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of sterile gloves in one out of seven HCWs highlights the need for a clean care environment and minimal contact with the patient's skin and surroundings during proximal manipulation.

Keywords Central lines, Proximal manipulation, Central venous catheter, Peripherally inserted central catheter, Implantable catheter ports, Asepsis, Sterile gloving, Improvement of practices

Introduction

The placement of central venous intravenous catheters is a routine medical procedure in patients with fragile health conditions. Following catheter contamination, central line-related bloodstream infections can lead to increased mortality rates, extended hospital stays, and increased hospitalization costs. In 2023, the French National Survey Network (Surveillance et Prévention des Infections Associées aux Dispositifs Invasifs, SPIADI network) reported the highest incidence rates of central line-related bacteremia in hematological, oncological, and intensive care units, and eight out of ten central catheter-related bacteremias occurred more than seven days after catheter placement in these units [1]. Investigating catheter-related bacteremia due to coagulase-negative *staphylococci*, several studies have provided evidence that the catheter hub is an important portal for microorganisms causing catheter-related bacteremia. These studies demonstrated that the same strains were isolated from both the catheter hub and the blood culture [2–5]. In the case of long-term central catheters (e.g., CVCs, PICCs and ICPs), if strict asepsis is not maintained during catheter hub manipulations (e.g., manipulations of the external end of the catheter or its prolongator, to which the infusion tubing connects), microorganisms from the skin flora of HCWs may be introduced into the line through the catheter hub connectors closest to the central catheter. These microorganisms can then migrate endoluminally and enter the bloodstream, leading to late-onset infections [2].

Preventing late-onset catheter-related infections depends on implementing a bundle of measures during connections, disconnections, blood withdrawals, or pulsed rinses, referred to as proximal manipulations, performed on the connectors of the central line closest to the central catheter. Contrary to the guidelines from the CDC [6] and the WHO [7], French guidelines state the necessity of using sterile gloves during central line proximal manipulations to ensure a sufficiently high level of asepsis [8]. The French guidelines include, among these measures, the requirement to put on sterile gloves immediately before proximal manipulation to help prevent contamination of the catheter hub with microorganisms collected on the HCWs' hands during preparation [8].

To our knowledge, no study has reported compliance with wearing sterile gloves during proximal manipulations of central lines, nor the impact of wearing sterile gloves on the cleanliness of the fingers of HCWs just before manipulating the catheter hub. Therefore, our primary study objective was to assess the use of sterile gloves during central line proximal manipulations and to identify discrepancies between the recommended best practices and actual compliance. Our second objective was to provide direct microbiological evidence of bacterial contamination on HCWs' hands immediately before the manipulation of central lines.

Materials and methods

Context and study design

Since 2019, the French Ministry of Health has mandated that all hospitals in France require their local infection prevention teams to implement the 2022–2025 National Strategy for Infection Prevention and Antibiotic Resistance. Within this initiative, the reduction of catheter-related infections is a primary focus. Reducing catheter-related infections is a key focus of this initiative. The national SPIADI network supports local infection control teams in their efforts to monitor and prevent catheter-related infections in their facilities. In this context, the SPIADI team invited infection control teams from hospitals across France to join the study. From January to June 2023, at each participating center, we examined the proximal manipulations of lines associated with long-term central catheters to assess compliance with expected sterile gloving practices. This assessment was conducted through direct observation of HCWs performing proximal manipulations, combined with discussions with the observed HCWs and the infection control team to understand why sterile gloving was not consistently practiced when necessary. Additionally, we analyzed the microbial flora on the fingers of each observed HCW just before they performed these manipulations. By combining observations of HCWs' gloving practices with a study of the microbial flora on their fingertips just before proximal manipulation, we assessed the impact of the different practices (sterile gloving, non-sterile gloving, and non-gloving) on finger cleanliness just before manipulating the catheter hub.

Observational study

At each participating center, the infection control team leader selected the ward(s) for the study and conducted

the observations. The recommendation was to select a specific entity (such as a hospital, department, or unit) and observe graduate or student HCWs performing proximal manipulation of a central line in adult patients within that area, based on their availability or accessibility. Each HCW was observed only once during the study, which was intentional by design.

Observations were made on various randomly selected HCWs. A standardized grid (Supplementary Fig. 1) was used to record observations, documenting practices from the beginning to the end of the procedure. This included assessing hand hygiene (hand washing or alcohol-based hand rubbing) at the start of the procedure, verifying prerequisites (such as exposed forearms, short nails, and no jewelry), evaluating the conformity of gestures if applicable (seven steps, i.e., palm to palm, palm of one hand against the back of the opposite hand and vice versa, fingers interlaced, back of the fingers against the opposite palm, left thumb rotated in the right hand and vice versa, fingertips of the left hand and vice versa, and finally, the wrists), recording glove usage (presence or absence of gloves and timing of gloving if applicable), and noting connector disinfection (type of antiseptic solution used). The completed observation sheets were sent to the national level for analysis. The results were used to evaluate practices. Special emphasis was placed on sterile gloving, which was expected for these manipulations (Supplementary Fig. 2). Regarding the responses given by HCWs to the observers when questioned about their non-compliance, the study of these responses mainly involved analyzing the distribution of the proposed answers. For other responses, descriptive analysis was conducted manually. Detailed findings related to the manipulation process, including the selection of antiseptics for connector disinfection, the types of dressings used, compliance with antiseptic contact duration, HCW attire, and patient attire, are documented in the 2023 SPIADI national report. This report is available in French and can be downloaded from the SPIADI network's website [9].

Microbiological study

Local infection control teams used sterile Amies transport media (Mast, Copan-Brescia, Italy) to swab the fingertips and palms of HCWs' hands immediately before they performed proximal manipulation, following a standardized procedure. All ten fingertips and both palms were swabbed for each HCW. The fingertips and palms of HCWs' hands were swabbed in all cases. If the hands were not gloved, the bare skin of the fingertips and palms was swabbed. If the hands were gloved, the gloved fingertips and palms were swabbed instead. Supplementary Figure 2 illustrates exact timing of the swabbing. The swabs were kept at room temperature and then sent to the national laboratory. Upon arrival, they were labeled and paired with the corresponding observation sheets. Each swab sample was placed in Trypcase Soy Broth TSB-T (bioMérieux, Marcy l'Etoile, France) and incubated at 37 °C for 24 h. After this incubation period, 50 µl of the broth was spread onto Trypticase Soy sheep blood agar (bioMérieux, Marcy l'Etoile, France) [10, 11]. These plates were incubated at 37 °C under aerobic conditions for 48 h, and all visible microbial colonies were identified using MALDI-TOF technology (Bruker Daltonics, France). The microbiological data provided an overview of the contamination levels on HCWs' fingers just before manipulation. Additionally, these data, combined with observational data on practices, was entered into an Excel spreadsheet to analyze the correlation between the presence of microorganisms on the fingers and compliance with sterile gloves use among HCWs. Since proximal manipulations should adhere to the same standards across different departments, we did not differentiate the observation results based on the origins of the HCWs.

Statistical analysis

For categorical variables, Pearson's chi-squared test was used to compare groups. All analyses were two-tailed, and a p-value < 0.05 was considered significant. Stata version 10.0 software (Stata Corp., College Station, TX, USA) was used for statistical analysis.

Results

A total of 35 French hospitals participated in the study: two university and regional hospitals, 16 general hospitals, seven hemodialysis centers, six short-stay clinics, two oncology centers, one home care center, and one rehabilitation center (Supplementary Fig. 3). The number of observations varied between 1 and 36 depending on the center (median value: 5; IQR: 5). A total of 260 HCWs were observed, of whom 254 (98%) were nurses and six were doctors (2%). The HCWs were diverse and distributed as follows: 115 in hemodialysis units (44%), 61 in intensive care units (23%), 53 in short-stay medical units (20%), 13 in rehabilitation care units (5%), 11 in home care centers (4%), and five in surgical departments (2%). The proximal manipulations observed consisted of 143 connections (55%), 60 disconnections (23%), 24 blood withdrawals (9%), 12 pulsed rinses (5%), 11 injections (4%) and 10 other diverse manipulations (4%).

Prevalence of sterile glove use

While HCWs' hands should be gloved with sterile gloves, 188 out of the 260 HCWs (72%) complied with this requirement (Table 1). Among the remaining HCWs,

Table 1 Gloving practices among the 260 HCWs

Practice	N observations (%) and timing of gloving		
	Before preparation of the materials	Immediately before proximal manipulation	All
Sterile gloves	35	153	188 (72)
Non sterile gloves	6	17	23 (9)
No gloves			49 (19)
N HCWs	41 (16)	170 (65)	260

23 wore nonsterile gloves (9%), and 49 manipulated the central lines without gloving their hands (19%). Most of the HCWs who wore gloves put them on just before the proximal manipulation, as requested by the current French guidelines. Of the 72 HCWs who did not wear sterile gloves, 60 explained their practices (83%). Most HCWs cited habitual practice as the reason (32; 53%), 14 (23%) stated that sterile gloving was not mandatory in their healthcare institution, 6 (10%) deemed the guideline useless, 4 (7%) were unaware of this guideline, and 4 (7%) believed their manipulation was not proximal.

Contamination of the HCWs' fingertips just before proximal manipulation

Each manipulation observation was followed by microbiological sampling of the HCWs' fingertips, regardless of whether they were gloved. Of the 260 swabs analyzed, 72 (28%) revealed the presence of at least one microorganism, with various microorganisms cultivated from the swabs in 24 cases (9%). The 97 microorganisms identified (Table 2) were all from the skin flora, with half belonging to the resident flora (49; 50.5%), such as non-*aureus staphylococci* and *Micrococci*. The remaining identified microorganisms typically belong to the transient human skin flora and include bacteria such as *Moraxella*, *Enterococci*, *Acinetobacter*, and non-*aeruginosa Pseudomonas*, as well as a significant portion originating from the environment, including *Bacillus cereus* and *non-cereus* species.

We investigated the correlation between the presence of microorganisms on fingers and gloving practices among HCWs before proximal manipulation. The proportion of HCWs with contaminated fingertips was significantly lower in the sterile glove group (14% in the sterile glove group vs. 52.2% in the non-sterile glove group and 67.3% in the no-glove group), and this difference was statistically significant ($p < 0.001$) (Table 3). However, the proportion of HCWs with contaminated fingertips was similar in the non-sterile glove group and in the no-glove group ($p = 0.215$).

Among the HCWs wearing sterile gloves, glove contamination was not influenced by compliance with hand hygiene. The contamination rates were 9% for the 53 HCWs (5/53) who were not compliant with hand hygiene opportunities, 18% for the 62 HCWs (11/62) who were compliant with only one hand hygiene practice, and 15% for the 73 HCWs (11/73) who were compliant with both hand hygiene practices ($p = 0.438$). Finger contamination was also not influenced by compliance with hand hygiene practices in the other two groups of HCWs, i.e., the group of HCWs wearing non-sterile gloves ($p = 0.208$) and the group of HCWs not wearing gloves ($p = 0.418$).

In addition, when considering separately the HCWs who were compliant with both hand hygiene gestures, those who performed one, or those who were non-compliant with both gestures, in each of these three groups, finger contamination was consistently lower for HCWs wearing sterile gloves compared to those wearing non-sterile gloves or not wearing gloves ($p < 0.001$).

Table 2 Microorganisms identified on the fingertips of the 260 HCWs

Human skin flora	Identified microorganisms	N (%)
Resident flora (n = 49)	*S. epidermidis*	18 (19)
	Other coagulase negative *staphylococci*	18 (18,5)
	Micrococcus sp	3 (3)
	Corynebacterium sp	3 (3)
	Actinomyces sp	1 (1)
	Brevibacterium and other Gram + *Bacilli*	3 (3)
	Yeasts and filamentous fungi	3 (3)
Transient flora of human origin (n = 10)	*Enterococci*	2 (2)
	Acinetobacter sp	1 (1)
	Moraxella sp	3 (3)
	Pseudomonas sp (non-*aeruginosa*)	4 (4)
Environmental origin (n = 38)	*Bacillus cereus*	11 (11)
	Bacillus non-*cereus*	27 (28)

Table 3 Fingertips contamination according to gloving and hand hygiene practices among the 260 HCWs

	Contamination according to observed gloving practices (%)			
	No gloves	**Non sterile gloves**	**Sterile gloves**	**All**
N HCWs	49	23	188	260
With 2 compliant hand hygiene gestures	24	7	73	104
With 1 compliant hand hygiene gesture	17	11	62	90
With no compliant hand hygiene gesture	8	5	53	66
N fingertips contamination (%)	33 (67)	12 (52)	27 (14)	72 (28)
With 2 compliant hand hygiene gestures	14 (58)	5 (71)	11 (15)	30 (29)
With 1 compliant hand hygiene gesture	13 (76)	6 (54)	11 (18)	30 (33)
With no compliant hand hygiene gesture	6 (75)	1 (20)	5 (9)	12 (18)

The microorganisms identified on the fingertips slightly differed regardless of the conditions (hands not gloved, gloved with non-sterile or sterile gloves) (Table 4). Microorganisms from the resident flora were more frequently found on the fingers of HCWs who performed the proximal manipulation with bare hands (33% of HCWs vs. 26% of HCWs with non-sterile gloves, and 8% of HCWs with sterile gloves; $p < 0.001$).

The microorganisms identified on the fingertips of HCWs wearing sterile gloves were similar, regardless of whether the gloves were donned before the preparation of the patient and materials or immediately before proximal manipulation (Table 5).

Discussion

Our study, carried out in 35 diverse French hospitals, provides new insights into gloving practices during proximal manipulations of central lines.

When catheters are in place for extended periods and are manipulated without sufficient rigor, the catheter hub likely plays a major role in allowing microorganisms to gain access and migrate endoluminally until they reach the bloodstream, potentially causing late-onset catheter-related bloodstream infections [2–5]. Rigourous asepsis, particularly proper hand hygiene during central line manipulations, is a well-recognized factor in preventing these infections.

The primary objective of our study was to observe current practices and verify compliance with French recommendations regarding the use of sterile gloves during proximal manipulations of central lines. After direct observation of a substantial number of proximal central line manipulations, we identified a concerning trend in practices. Three out of ten HCWs do not wear sterile gloves during the procedure, with some working without gloves (two in three) or with non-sterile gloves (one in three). If proximal manipulations of central lines are not effectively performed in a sterile environment, sterile gloves are intended to contribute to achieving ultra-clean fingers for opening the central line. The HCWs not wearing sterile gloves are not convinced of the necessity of using these devices. For them, the use of sterile gloves is associated with the placement of central catheters or surgical contexts, and wearing sterile gloves is only relevant

Table 4 Origin of the microorganisms based on gloving practices for HCWs with contaminated fingertips

	Contaminants according to observed gloving practices			
	No gloves	**Non sterile gloves**	**Sterile gloves**	**All**
N HCWs	49	23	188	260
N HCWs with contaminated fingertips	33	12	27	72
N HCWs (%) with fingertips contaminated by				
Resident flora	16 (33)	6 (26)	16 (8)	38 (15)
Transient flora	22 (45)	10 (43)	13 (7)	45 (17)
N microorganisms (%) belonging to	44	19	34	97
Resident flora	23	11	15	49
Transient Flora of	21	8	19	48
- Human origin	3	3	4	10
- Environmental origin	18	5	15	38

Table 5 Origin of the microorganisms according to the timing of donning sterile gloves

	N observations according to the timing of donning sterile gloves (%)		
	Before preparation of the materials	**Immediately before proximal manipulation**	**All**
N HCWs wearing sterile gloves	35	153	188
N HCWs with contaminated fingertips	5	22	27
N microorganisms (%) belonging to	6	28	34
Resident flora	1	14	15
Transient flora of	5	14	19
- Human origin	2	2	4
- Environmental origin	3	12	15

in a sterile environment (sterile field or operating room). HCWs who do not wear sterile gloves also consider sterile gloves to be wasted when used at the patient's bedside, due to immediate contamination upon contact with connectors and lines. However, this situation should not arise during proximal manipulations, as guidelines specify that HCWs handle connectors and lines with sterile compresses, and gloved fingers should not directly touch connectors or lines.

Enhancing the level of asepsis during proximal manipulations of central lines is a crucial priority in the prevention of central catheter-related bloodstream infections. To our knowledge, there was a lack of data demonstrating how the hands of HCWs performing proximal manipulations of central lines may be contaminated immediately before manipulation, especially when gloving practices are suboptimal throughout the procedure. In a previous study aimed at examining the impact of hand hygiene on fingertip cleanliness during the placement of a short peripheral catheter [12], we conducted a microbiological analysis of HCWs' fingers just before catheter insertion. This study first demonstrated the importance of hand hygiene practices to ensure very clean hands during invasive procedures. Moreover, we used the microbiological results to develop an educational tool for professionals placing catheters. The impact study of this educational tool showed that the microbiological results significantly enhanced HCWs' understanding of the prevention messages conveyed by the tool. Therefore, in the present study, we chose to replicate a microbiological analysis of HCWs' fingertips, this time just before proximal manipulation. The goal was to produce data showing the impact of wearing sterile gloves during these manipulations, which can then be used, after the study, as an educational tool to promote best practices during proximal manipulations. Examining the microbial flora present on the fingertips of HCWs immediately before proximal manipulation, while taking into account gloving practices, we first showed that the major nosocomial pathogens associated with catheter-related bloodstream infections, such as *Staphylococcus aureus* and *Enterobacterales* [1], were not found on the fingertips of the HCWs, regardless of whether they wore sterile gloves. Notably, we did not identify common microorganisms associated with late-onset central catheter-related bacteremia, such as *Staphylococcus aureus, Escherichia coli*, *Klebsiella*, *Enterobacter* and *Pseudomonas aeruginosa* (Supplementary Fig. 4). This indicates that a rather high level of asepsis was applied by all the observed HCWs. However, microorganisms belonging to the human skin flora, including resident species (e.g., *S. epidermidis* and other coagulase-negative *Staphylococci*) and those belonging to the transient skin flora and mostly originating from the environment (e.g., *Bacillus*), were detected on the fingertips of three out of ten HCWs. These microorganisms are involved in more than 50% of late-onset catheter-related bloodstream infections [1], suggesting that the microorganisms present on the fingertips may contribute to the occurrence of at least a portion of catheter-related infections.

Combining the microbiological data with the data obtained from direct observation of HCWs manipulating the lines, we found that the presence of microorganisms on the fingertips was influenced by compliance with gloving during the procedure. Our findings underscore the importance of wearing sterile gloves to ensure the highest level of finger cleanliness during line manipulation, and demonstrate the relevance of French recommendations regarding the use of sterile gloves for these common procedures.

However, achieving zero risk cannot be guaranteed, as evidenced by the presence of microorganisms on the fingers of one out of seven HCWs who wore sterile gloves. These data indicate that sterile gloving is just one component of a bundle of preventive measures for catheter-related bloodstream infections. Several hypotheses can

be proposed to explain finger contamination despite compliant gloving, including contamination from gloves through contact with the patient's skin or the care environment. The presence of microorganisms with a high ability to survive in the environment, such as *Acinetobacter*, *Enterococci, Bacillus cereus* and non-*cereus*, on the fingertips underscores the importance of maintaining a clean environment around the patient and being attentive to avoid touching the environment during the procedure.

We do not advocate for routine microbiological studies of finger contamination among HCWs. However, we consider the findings from this specific study valuable for utilization in training sessions, as they effectively illustrate how HCWs' fingers can become contaminated when HCWs do not wear sterile gloves. To facilitate behavioral change, HCWs must recognize the risks and understand the mechanisms of microorganism transmission during patient care [13, 14]. Following this study, we developed an educational tool named CleanhandPROX, which is tailored to the context of central-line proximal manipulations and specifically designed to assist HCWs in performing these manipulations in comprehending the importance of adhering to glove usage recommendations. This tool consists of concise educational sessions incorporating data acquired from observations and microbiological analyses. It also includes instructional videos demonstrating various manipulation scenarios, showcasing both correct procedures and common errors. We believe that training HCWs with this educational tool will lead to a significant improvement in adherence to proper glove usage during central line manipulations. The tool includes a technical guide to assist infection control teams in organizing educational sessions, a slideshow presenting microbiological data, three short videos, and a poster to announce the educational sessions in the wards (Supplementary Fig. 5). All parts of the tool are available for free download on the spiadi.fr website.

Our study has several limitations. The microbiological analysis was conducted using a single culture medium (Trypticase Soja sheep blood agar), which may have limited the growth of fastidious bacteria present on the hands of HCWs. However, we performed an enrichment phase in broth for the samples before isolation on agar. In addition, since the objective of the study was to detect the microorganisms typically responsible for catheter-related bloodstream infections, our results demonstrated that this objective was achieved.

Conclusion

Regarding hand hygiene, and particularly the use of sterile gloves during proximal manipulations of lines associated with central catheters, the study shows that the current practices are not optimal. The non-compliance of HCWs could explain at least part of the occurrence of late central line-associated bloodstream infections. Training aimed at reducing gaps between practices and recommendations must be implemented in the field. The microbiological study we conducted provides evidence in favor of using sterile gloves to achieve maximum finger cleanliness during proximal manipulations. We encourage field teams to use these results to reinforce best practice recommendations. This approach may significantly help improve compliance with glove usage.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13756-024-01467-5.

Additional file 1.

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Author contributions

ASV designed the study, and contributed to the analysis of the results. SDS carried out the microbiological study and analyzed the microbiological data. MF was a major contributor to the operational implementation of the study and field data collection and analyzed the observational data. NVDM designed and coordinated the study, contributed to the interpretation of the data and wrote the manuscript. Each member of the CleanHandPROX collaboration group carried out in his healthcare institution, observed the HCWs, and collected the microbiological samples. All the authors have read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author N. van der Mee-Marquet upon reasonable request. The educational tool is available using this link https://www.spiadi.fr/tools?tab=1

Declarations

Ethics approval and consent to participate

All experiments were performed in accordance with relevant guidelines and regulations**.** The study was carried out within the framework of the National Agency Santé Publique France and the National Program for the Prevention of

Healthcare-associated Infections (national Health Strategy 2022–2025), which advocates for regular evaluation of healthcare professionals' practices by local infection control teams. All work related to this program was authorized by the CNIL (National Commission on Informatics and Liverties; file 2212596 dates March 27, 2019). The protocol for the CleanHandPROX study was approved on March 8, 2022, by an ethics committee/institutional review board during a meeting of the scientific council of Santé Publique France, which is responsible for overseeing the implementation of the SPIADI program. The implementation of the study was monitored by the scientific committee overseeing the SPIADI program (January 17, 2023). At the local level, participation in the study required written commitment from the hospital director and the infection control team leader. The commiment charters were collected at the national level by the SPIADI team. In the departments where the study was conducted, the observed professionals were informed about the study (observational component, microbiological component). Informed consent was obtained from all observed professionals and all subjects for whom the central line proximal manipulation was observed and/or their legal guardian(s).

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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