International Journal of Nursing Sciences xxx (xxxx) xxx

HOSTED BY

Contents lists available at ScienceDirect

International Journal of Nursing Sciences

journal homepage: http://www.elsevier.com/journals/international-journal-of-nursing-sciences/2352-0132

Research Paper

Prevalence of central line-associated bloodstream infections in patients with cancer and subgroup analysis using propensity score matching: A nationwide multicenter study in Italy

Silvia Belloni [a, *], Cristina Arrigoni [a], Marco Alfredo Arcidiacono [b], Giovanni Boschi [b], Alessandro Leonetti [b], Maria Allevato [b], Orejeta Diamanti [c], Chiara Cardone [d], Daniele Girardi [e], Sergio Ferrante [e], Daniela Strada [e], Silvia Bonalumi [e], Elena Pisano [e], Paola Maisola [e], Giulia Villa [f], Arianna Magon [g], Gianluca Conte [g], Stefania Ducoli [e], Marco Fadda [e], Tedeschi Michele [e], Rosario Caruso [g, h]

[a] *Department of Public Health, Experimental and Forensic Medicine, Section of Hygiene, University of Pavia, Pavia, Italy*
[b] *Medical Unit, University Hospital of Parma, Parma, Italy*
[c] *Medical Unit, Veneto Institute of Oncology IOV – IRCCS, Padua, Italy*
[d] *Fondazione IRCCS Ca Granda Ospedale Maggiore Policlinico di Milano, Milan, Italy*
[e] *IRCCS Humanitas Research Hospital Rozzano, Milan, Italy*
[f] *Center for Nursing Research and Innovation, Vita-Salute San Raffaele University, Milan, Italy*
[g] *Health Professions Research and Development Unit, IRCCS Policlinico San Donato, San Donato Milanese, Milan, Italy*
[h] *Department of Biomedical Sciences for Health, University of Milan, Italy*

ARTICLE INFO

Article history:
Received 5 December 2024
Received in revised form
31 January 2025
Accepted 14 February 2025
Available online xxx

Keywords:
Cancer
Central line-associated bloodstream infection
Multiple correspondence analysis
Nursing
Propensity score matching

ABSTRACT

Objectives: This study aimed to analyze the prevalence of long-term central line-associated bloodstream infections (CLABSI) among hospitalized adults with cancer in Italy and compare the characteristics of patients who required long-term central venous access device (LCVAD) substitution due to prior CLABSI with those who had never experienced infections.

Methods: The study was conducted in hospitals across northern and central Italy using a multicenter, observational, cross-sectional design from March to September 2021. A total of 174 adults with cancer were included. Data were collected through electronic case report forms, including demographic, clinical, treatment-related, and catheter-related variables. Propensity score matching (PSM) was used to compare the characteristics of patients who underwent LCVAD substitution due to previous CLABSI with those who never experienced infections. Multiple correspondence analysis (MCA) was conducted to explore the patterns within matched subgroups.

Results: The prevalence of CLABSI was 3 %, and 5.2 % of patients required LCVAD substitution due to prior CLABSI. After applying PSM, the groups were successfully balanced for sex, age, presence of metastases, comorbidities, BMI, received treatments, corticosteroid therapy, ongoing antibiotics, hormone therapy, type of LCVAD, lumens, and utilization frequency. Hematologic cancer was more frequent in the CLABSI group (44.4 %) compared to the non-infective group (0), with a statistically significant difference ($P = 0.045$). MCA revealed potential patterns among matched subgroups but did not identify statistically significant associations: patients with previous LCVAD substitution were more frequently associated with a history of prior infections, ongoing antibiotic therapy, and unspecified primary lesion locations; conversely, patients who never experienced LCVAD-related infections tended to cluster around characteristics such as hormone therapy and corticosteroid therapy.

Conclusions: These findings emphasize the importance of continuous monitoring, individualized infection prevention strategies in oncology nursing practice. Future research with larger datasets is needed to validate these findings and develop tailored interventions to reduce CLABSI risks.

* Corresponding author.
E-mail address: sivia.belloni@unipv.it (S. Belloni).
Peer review under responsibility of Chinese Nursing Association.

https://doi.org/10.1016/j.ijnss.2025.02.011

Please cite this article as: S. Belloni, C. Arrigoni, M.A. Arcidiacono *et al.*, Prevalence of central line-associated bloodstream infections in patients with cancer and subgroup analysis using propensity score matching: A nationwide multicenter study in Italy, International Journal of Nursing Sciences, https://doi.org/10.1016/j.ijnss.2025.02.011

What is known?

- Central line-associated bloodstream infections (CLABSI) pose a significant risk to hospitalized patients with cancer and long-term central venous access device (LCVAD).
- Preventing CLABSI requires adherence to strict infection control protocols and close patient monitoring.

What is new?

- This study provided a point-prevalence estimate of CLABSI among hospitalized adults with cancer in Italy.
- Propensity scores matching analysis identified differences between patients who required LCVAD substitution due to previous CLABSI and those who never experienced infections, highlighting potential risk factors.
- Multiple correspondence analyses suggested associations between specific treatments (e.g., corticosteroids and hormone therapy) and CLABSI, reinforcing the need for targeted prevention strategies.

1. Introduction

Central line-associated bloodstream infection (CLABSI) is a burdensome and life-threatening phenomenon in healthcare systems and the most-costly healthcare-associated infection [1–3]. The Centers for Disease Prevention and Control (CDC) defined CLABSIs as laboratory-confirmed bloodstream infections where an eligible bloodstream infection (BSI) organism is identified that occurs during the indwelling or within 48 h after removal of the central line and is unrelated to another site of infection [4]. The literature defines central lines interchangeably as central venous access devices (CVADs) or central venous catheters (CVCs) [5,6]. According to the latest research, 10.6 central venous catheter-associated bloodstream infections occur every 1,000 central venous catheter days in hematologic and oncologic patients [7]. CLABSI is a significant cause of morbidity and mortality [8], increasing hospitalization duration, healthcare costs, and readmission rates [8,9]. It is associated with a higher risk of death ($OR = 2.75$, 95 %CI: 1.86–4.07) [8], prolonged hospital stays (47 days in CLABSI patients versus 22 days in non-CLABSI patients) [7], and increased likelihood of readmission ($OR = 1.36$, 95 %CI: 1.06–1.75) [9].

Patients with cancer commonly benefit from long-term central venous access devices (LCVADs), which are central venous accesses that remain inserted for more than six weeks [10]. The most common LCVADs utilized in oncology include Hickman-type tunnelled catheters, peripherally inserted central catheter (PICC), central lines, and fully implanted port-a-cath (PORT) [11]. These devices are pivotal in managing and treating patients with cancer as they allow for safe long-term delivery of chemotherapy and immunotherapy and the infusion of parenteral nutrition, blood products, antibiotics, and other therapies [12,13]. LCVAD minimizes patients' discomfort from frequent venepuncture and cannulation and prevents tissue damage from vesicant or irritant drugs. For these reasons, a recent guideline recommends long-term central catheters in patients with cancer undergoing active treatment [12]. Despite these benefits, CLABSI caused by LCVADs is common in vulnerable populations such as patients with cancer due to impaired immune competence caused by aggressive cancers or treatment-induced neutropenia [14,15]. A recent systematic review reported that a pooled occurrence rate of long-term CLABSI was roughly 8 % among hospitalized adults affected by solid and haematological tumours with a long-term central line [16]. However, the infection rate varies depending on the type of LCVAD inserted and the stage of treatment [17,18]. Coagulase-negative staphylococci are the most common organisms causing CLABSI in oncology settings (16.9 %) [19–21], followed by *Escherichia coli* (11.8 %) and Enterococcus faecium (11.4 %) [21]. CLABSIs are a severe complication in this patient population, causing delays in cancer treatment administration, prolonged antimicrobial therapies, admissions to intensive care units, and increased mortality [20].

CLABSIs are potentially preventable, and several measures could be implemented to reduce the incidence of CLABSI [22,23]. In some instances, prevention strategies may necessitate surveillance data, such as routinely incorporating clinical and organizational indicators to be further evaluated [24]. Prevalence surveys are a valuable and sustainable method for hospital-wide surveillance, particularly for specific objectives such as estimating and monitoring the burden of healthcare-associated infections (HAIs), identifying priorities for infection prevention and control and antimicrobial stewardship, enhancing HAIs' surveillance and infection prevention and control (IPC) measures, raising awareness at various levels, and evaluating regional or national interventions [25,26]. In particular, point-prevalence studies are manageable and relatively affordable, making them an effective benchmark for infection surveillance and control purposes [22,27]. A substantial body of evidence estimates the prevalence and risk factors of CLABSI among patients with cancer [16,28,29]. Some data on CLABSI were previously described in Italy, but these descriptions are not up-to-date [30]. Additionally, the available descriptions assess CLABSI as part of broader surveillance of HAIs, where CLABSI-specific data represent only a subset of findings rather than a focused investigation [30]. As a result, there is a lack of comprehensive, nationwide data specifically addressing CLABSI prevalence among patients with cancer and LCVADs. Understanding the prevalence and characteristics of CLABSI in hospitalized adults with cancer is essential for developing effective, evidence-based prevention strategies and improving patient outcomes. While prevalence data provide crucial insights into the burden of CLABSI, exploring patient- and treatment-specific characteristics remains equally important [16,28,29]. This knowledge could help identify high-risk subgroups, inform tailored interventions, and guide resource allocation in oncology settings.

Accordingly, this study aimed to describe the prevalence of CLABSI among hospitalized adult patients with cancer and to explore the characteristics of patients who underwent LCVAD substitution due to previous CLABSI, a clinically significant subgroup. While comparing current CLABSI cases with non-CLABSI patients would have been ideal, the small number of anticipated CLABSI cases in this study limited the feasibility of such an analysis. Instead, we focused on patients who had undergone LCVAD substitution due to prior CLABSI, as this group represents those who experienced significant CLABSI-related complications. This approach enables a more robust comparison and provides meaningful clinical insights into factors contributing to CLABSI outcomes.

LCVAD substitution is often necessitated by severe or recurrent infections, which may reflect distinct patient- or treatment-related factors [23]. Examining this group compared to patients who have never experienced infectious issues allows us to identify potential risk factors, patterns of care, and preventive strategies that could reduce CLABSI-related complications. Beyond complementing prevalence data, this comparison highlights the clinical context and patient journey following CLABSI, offering actionable insights for practice. Therefore, this secondary aim aligns with the overarching goal of improving CLABSI management. Identifying differences in demographics, treatments, and catheter-related variables between

these groups lays a foundation for future research to explore causality and develop individualized preventive strategies. These findings could potentially enhance nursing and clinical protocols, particularly for high-risk populations, ultimately improving patient safety and outcomes.

2. Methods

2.1. Study design

This was a multicenter cross-sectional study to determine the prevalence of CLABSI among hospitalized adult patients with cancer. Additionally, the study aimed to explore the characteristics of patients who underwent LCVAD substitution due to previous CLABSI, comparing them to patients who had never experienced central line infections. The study was reported according to the Guidelines for Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) [31].

2.2. Study settings and participants

The study involved seven hospitals in northern and central Italy and was conducted from March 2021 to September 2021. Hospitals were selected through convenience sampling, selecting public and university hospitals with diverse clinical specialities voluntarily agreeing to participate in the study. This study focused exclusively on oncology units, as these are the primary settings where LCVADs are managed for cancer treatment. Intensive care units, pediatric wards, and emergency departments were not included, as they serve distinct patient populations with different clinical workflows and catheter management protocols, which could introduce heterogeneity in the analysis.

All hospitalized patients with a cancer diagnosis who met the following criteria were enrolled: 1) $\geq$ 18 years old; 2) with at least one LCVAD, including PICC, fully implantable devices (i.e., PORT), or tunneled catheters, and excluding short-term CVCs or catheters inserted in the femoral or jugular veins; 3) with a central catheter in place for at least 48h or removed within the previous 48h [32]. Patients were excluded if they had cognitive impairments, severe mental disorders, or medical conditions that, in the investigator's judgment, significantly hampered their ability to cooperate or the feasibility of data collection.

The study focused on PICC, PORT, and tunneled devices due to their widespread use in long-term oncological care and unique management challenges. These devices are designed for prolonged therapies, such as chemotherapy and supportive treatments. Short-term CVCs and catheters placed in the femoral or jugular veins were excluded because they are typically used in temporary or emergency settings. Including these devices would not align with the study's aim to evaluate infection risk and management in long-term treatment scenarios. This exclusion ensured that the findings directly relate to patients undergoing sustained oncological care.

2.3. Sample size

The sample size was estimated using the standard formula for prevalence studies [33]: $n = Z^2_{\alpha/2} \times P \times (1\text{-}P)/E^2$. Where n represents the required sample size, $Z_{\alpha/2}$ corresponds to a 95 %*CI* (1.96), P is the estimated proportion of CLABSI in the adult population with cancer (8 %) [16], and E is the margin of error (5 %). Given these parameters and an expected dropout rate of 10 % [34], we estimated a minimum required sample size of 124 subjects to ensure reliable identification of the phenomenon under study.

2.4. Measures

2.4.1. Sociodemographic and clinical data

Sociodemographic data included age and sex. Patient clinical profiles included primary cancer type, presence of metastases, comorbidities, BMI, current cancer treatments (received treatment), and ongoing treatment modalities. Information on the characteristics of central venous catheters included the catheter insertion type (PICC, PORT, or tunneled), number of lumens, history of previous LCVAD use, and frequency of LTVAD utilization. Additional sections recorded information about outcomes, including CLABSI occurrence and LCVAD substitutions due to previous CLABSI. These variables were selected based on findings from an earlier systematic review of risk factors for CLABSI [16].

2.4.2. Primary outcome

The primary outcome of this study was the prevalence of CLABSI among hospitalized adults with cancer. The case definition for CLABSI was applied according to the CDC guidelines [32], regardless of the local procedures involved in CLABSI diagnosis. In detail, CLABSI was identified using the following criteria: 1) a recognized pathogen was cultured from one or more blood samples taken from the patient; 2) the patient had a fever (>38°*C*), shivers, or hypotension, as well as signs and symptoms and positive laboratory results unrelated to an infection at another site and 3) a positive blood culture with the same microorganism was discovered in the catheter tip.

In cases where patients had multiple catheterizations with consecutive positive cultures of the same microorganism, only the first positive result was diagnosed as CLABSI. Electronic patient medical records and microbiology databases were used to determine whether a patient had a CLABSI infection. If no certified CVC infection was found in the medical records, a CLABSI was assumed to be absent. We considered only laboratory results that were already available during data collection.

2.4.3. Secondary outcomes

The secondary outcomes of this study were to compare the characteristics of patients who underwent LCVAD substitution due to previous CLABSI with those who had never experienced LCVAD-related infections. This comparison aimed to explore potential differences in demographic, clinical, and treatment-related factors between the two groups, providing insights into patient- and treatment-specific characteristics associated with CLABSI. We employed Propensity Score Matching (PSM) to reduce confounding and ensure balanced comparisons between patients who had undergone LCVAD substitution due to previous CLABSI and those without LCVAD-related infections. PSM was chosen because it allows for creating well-matched groups based on observed covariates, minimizing bias in observational studies where randomized control trials are not feasible. This study estimated propensity scores using logistic regression, with LCVAD substitution due to previous CLABSI as the outcome variable (see data analysis). This matching process allowed us to compare the two groups while reducing bias from confounding variables, ensuring that observed differences in outcomes were less likely to be influenced by pre-existing differences between the groups.

2.5. Data collection

The ideal data collection time for a point prevalence multicenter study is a single day for all involved hospitals [35]. However, this was not feasible due to varying document preparation and ethical approval timelines across hospitals and the restrictions and workforce challenges caused by the COVID-19 pandemic. Therefore, each

hospital independently collected point-prevalence data on a designated day after ethical approval. Data collection across all sites was completed over seven months.

Each site's principal investigator selected the data collection day and assigned a trained research nurse to oversee the process. The principal investigator trained research nurses on the study's purpose, procedures, data to be collected, and the use of the data collection instruments. Informed consent was obtained from each participant after providing detailed information about the study, including their rights, purpose, procedures, potential risks, and confidentiality assurances. Participation was entirely voluntary, and patients could withdraw their consent at any time during the study.

Data were recorded using an electronic case report form (eCRF) designed according to the study protocol and regulatory requirements. Access to the eCRF was secured with personal usernames and passwords, and only authorized personnel could access the data. A panel of five experts—a research methodology expert, a central lines expert, an oncology clinical nurse specialist, a study coordinator, and an oncologist—developed the eCRF based on accuracy, clarity, feasibility, and informativeness principles. Data anonymity was ensured through the use of unique numerical codes for participants, making it impossible to trace individual identities.

2.6. Data analysis

Statistical analyses were conducted using R with relevant libraries, including MatchIt, cobalt, ggplot2, dplyr, FactorMineR, factorextra, and writexl. The significance level was set at $\alpha = 0.05$, and all tests were two-tailed. Categorical data were expressed as number (n) and percentage (%), normally distributed continuous data as mean and standard deviation (*SD*), but non-normally distributed as the mean and interquartile range (*IQR*). The primary point prevalence was reported as a proportion of people who had a CLABSI over the total number of people at a particular time. Missing data were assessed at the variable level and were deleted pairwise.

A comparison was made between a subgroup of patients who underwent LCVAD substitution due to previous CLABSI and those who had never experienced LCVAD-related infections. Given the imbalance in subgroup sizes, Absolute Standardized Difference (*ASD*) was used for comparisons and applied to both proportion and continuous variables.

Characteristics with an $ASD > 0.2$ were used to determine propensity scores for matching, aiming to provide exploratory insights into possible patterns or differences between these two subgroups [36]. Not all variables with $ASD > 0.2$ were included in the matching model. To prevent overfitting and maintain statistical feasibility, only clinically relevant variables with substantial imbalances were selected. This approach ensured an optimal trade-off between balancing covariates and retaining sufficient sample size for analysis.

A logistic regression model was used to estimate the propensity scores based on covariates with $ASD > 0.2$ (i.e., age, sex, primary cancer type, presence of metastases, comorbidities, BMI, and treatment-related variables) [36], 1:1 nearest-neighbour algorithm without replacement, with a calliper width of 0.2 standard deviations of the logit of the propensity score [37]. An $ASD > 0.2$ is generally considered indicative of imbalance between the two groups, necessitating adjustment to achieve comparability in propensity score matching. *P (Group)* referred to the probability of experiencing LCVAD substitution due to previous CLABSI, β_0 is the intercept, and the other β are referred to the coefficients for the respective covariates:

$$\text{logit}(P(\text{Group})) = \beta_0 + \beta_1 \cdot \text{Covariate}_1 + \beta_2 \cdot \text{Covariate}_2 + \ldots + \beta_k \cdot \text{Covariate}_k$$

Given the small sample size, matching each individual tumor type separately would have led to excessive fragmentation and loss of statistical power. Instead, primary tumor type was treated as a categorical variable to capture broader oncological differences while maintaining adequate subgroup sizes. The balance of covariates between the matched groups was evaluated using variance ratios, empirical cumulative distribution function (eCDF) means, eCDF max, and standardized pair distances. Variance ratios were assessed across all covariates, with values between 0.8 and 1.25 indicating a good balance [38]. However, small sample sizes could naturally result in variance ratios exceeding the 0.8−1.25 threshold [38]. The standardized mean differences (*SMDs*) were also calculated, with values below 0.2 considered indicative of negligible imbalance [38]. The eCDF mean and eCDF max were used to quantify differences in the cumulative distribution functions of covariates between groups, with smaller values indicating better matching. The standardized pair distances provided further evidence of the adequacy of the matching process by demonstrating similarity in the covariates across matched pairs.

The balance of covariates before and after matching was assessed to ensure the groups were comparable. Given the limited sample size, comparisons between the matched subgroups were performed using exact tests where possible. As no significant group differences were anticipated as a result of the propensity score matching procedure, we explored the behaviour of the variables within each matched subgroup employing a Multiple Correspondence Analysis (MCA) based on all the covariates. This approach aimed to highlight how the behaviours of the variables tend to differ to generate hypotheses for future research.

2.7. Ethical considerations

An independent local ethics committee approved the study protocol at each site (No. 766/20, 22 September 2020). The Declaration of Helsinki Ethical Principles and Good Clinical Practices outlines data collection, management, analysis, and interpretation procedures. Data were de-identified during data collection and analysed in aggregate to maintain the confidentiality and anonymity of information.

3. Results

3.1. Characteristics of the participants and the prevalence of long-term central line-associated bloodstream infections

The study included 174 hospitalized adults with cancer, with a mean age of 61.90 years ($SD = 13.52$) and a nearly equal distribution of males (45.4 %) and females (54.6 %). Gastrointestinal cancers (43.1 %) and hematologic cancers (24.1 %) were the most common primary cancer types, followed by breast cancer (10.9 %) and lung cancer (8.0 %). 43.1 % of patients had metastases, and 41.4 % had one or more comorbidities. The median BMI was 16.2 kg/m^2. Regarding treatments, 52.3 % of patients received chemotherapy, 14.4 % received supportive therapy, and 6.9 % received immunotherapy. Corticosteroid therapy and ongoing antibiotic use were reported in 42.5 % and 22.4 % of patients, respectively. Hormone therapy was administered to 5.9 % of the cohort. For LTVADs, 47.7 % of patients used PICC, 46.6 % used PORT, and 5.7 % used tunneled device. Most (92.5 %) had single-lumen catheters, with frequent utilization reported in 96.6 % of patients.

The primary prevalence of CLABSI was observed in 5 patients

(2.9 %). Secondary outcomes included LCVAD substitution due to previous CLABSI in 9 patients (5.2 %) and other previous central catheter-related infections in 5 patients (2.9 %). Detailed sample characteristics are presented in Appendix A.

3.2. Comparison between patients who had experienced a previous CLABSI leading to LCVAD substitution and those who had never experienced infective issues

The comparison between patients who experienced LCVAD substitution due to previous CLABSI ($n = 9$) and those who never experienced LCVAD-related infections ($n = 146$) revealed several differences, as summarized in Appendix B.

Balanced variables included sex (*ASD* = 0.012, 44.4 % vs. 55.6 %), age (*ASD* = 0.132, 60.11 ± 13.89 years vs. 61.90 ± 13.26 years), and metastasis status (*ASD* = 0.198, 55.6 % of CLABSI patients had metastases vs. 45.7 % in the non-infective group). Imbalanced variables included BMI (*ASD* = 0.381, 15.0 kg/m^2 vs. 16.1 kg/m^2), hematologic cancer (*ASD* = 0.546, 44.4 % vs. 19.9 %), supportive therapy (*ASD* = 0.559, 33.3 % vs. 11.0 %), corticosteroid therapy (*ASD* = 0.842, 11.1 % vs. 46.2 %), tunneled catheters (*ASD* = 0.235, 11.1 % vs. 4.8 %), single-lumen catheters (*ASD* = 0.403, 100.0 % vs. 92.5 %), and frequent utilization of LTVADs (*ASD* = 0.237, 100.0 % vs. 97.2 %).

3.3. Propensity score matching procedure

After propensity score matching, the balance between covariates in the treatment and control groups improved significantly. The variance ratios for ongoing antibiotic therapy fell between 0.8 and 1.25, while the other covariates exceeded this range, but the matching was deemed successful in the context of small matched groups and considering eCDF metrics. Accordingly, the eCDF means and maxima indicated that the covariates were well-balanced, and the standardized pair distances supported the adequacy of the matching process. Detailed results of the balance metrics are provided in Appendix C.

3.4. Comparisons between subgroups after the propensity matching procedure

The comparison between patients who experienced LCVAD substitution due to previous CLABSI ($n = 9$) and matched patients who never experienced LCVAD-related infections ($n = 9$) revealed notable differences in specific characteristics while other characteristics were well-balanced, as summarized in Table 1. It is important to note that while *ASD* values are reported post-matching for transparency in small sample sizes, *ASD* alone is not a reliable indicator of balance. Instead, *P*-values provide a more stable measure for assessing differences between groups after matching.

There were no significant differences between the groups regarding sex distribution, mean age, BMI, or comorbidities, indicating successful matching for these variables. Both groups also had similar proportions of patients with single-lumen catheters and reported frequent utilization of LTVADs, highlighting the adequacy of the matching process.

The matching process ensured balance among several variables, making the two groups comparable. No significant differences were observed in sex distribution ($P = 1.000$, *ASD* = 0), mean age ($P = 0.931$, *ASD* = 0.098), BMI ($P = 0.863$, *ASD* = 0.436), comorbidities ($P = 0.343$, *ASD* = 0.470), single-lumen catheters ($P = 1.000$, *ASD* = 0), and frequent utilization of LTVADs ($P = 1.000$, *ASD* = 0). These results indicate that the two groups were well-matched on these variables, ensuring comparability. Primary cancer type ($P = 0.045$) showed notable variation: breast cancer was significantly more frequent in the control group (55.6 %) compared to the CLABSI group (11.1 %); hematologic cancers were present only in the CLABSI group (44.4 %), while the control group had no cases; gastrointestinal cancers were comparable between the two groups (44.4 % vs. 33.3 %); brain cancer was present in the control group (11.1 %) but absent in the CLABSI group. Some variables differed between the two groups descriptively but were not statistically significant. The CLABSI group had a higher proportion of patients with metastases (55.6 % vs. 33.3 %, $P = 0.637$) and fewer patients receiving corticosteroid therapy (11.1 % vs. 44.4 %, $P = 0.294$). Regarding treatments, chemotherapy was more frequent in the CLABSI group (44.4 % vs. 22.2 %), while supportive/palliative therapy was more common in the control group (55.6 % vs. 33.3 %). Other treatment-related variables, including immunotherapy, hormone therapy, and ongoing antibiotic use, did not significantly differ between the groups. Additionally, tunneled catheters were slightly more frequent in the control group (33.3%) compared to the CLABSI group (11.1 %), though this difference was not statistically significant.

Appendix D illustrates an MCA biplot, highlighting the differences between the matched subgroups. The dimension axes represent the principal components of the MCA, with dimension 1 accounting for 14.1 % and dimension 2 accounting for 13.7 % of the variance, respectively. The biplot visually represents how the behaviours of various patient characteristics differ between the two groups. Each point represents an individual patient, color-coded by group: blue for those without substitution and red for those with substitution (the blue ellipse corresponds to the group with no substitution, while the red ellipse corresponds to the substitution group). The ellipses encapsulate the 95 %*CI* for the groups, showing the concentration and spread of the data points.

Variables are plotted as vectors, indicating their contribution to the variance in the data. Patients in the substitution group (those who underwent LCVAD replacement due to prior CLABSI) were more frequently associated with previous infections, ongoing antibiotic therapy, and unspecified primary lesion locations. These characteristics suggest that prior infectious events and antibiotic exposure may be linked to the need for catheter replacement. Conversely, patients in the no-substitution group (those who never experienced LCVAD-related infections) were more closely associated with hormone therapy and corticosteroid therapy. While MCA showed that the replacement group was more often associated with previous infections, this does not imply that these patients had recorded prior infections. Instead, it suggests that their clinical profiles aligned with those of patients with prior infections in the dataset, likely due to similarities in treatment history and risk factors.

4. Discussion

To our knowledge, this was the first multicenter point-prevalence study to analyze the prevalence of long-term CLABSI among hospitalized adult patients with cancer in Italy and their clinical characteristics in the last years. As a secondary endpoint—essentially with an exploratory value—we compared the characteristics of patients who had previously experienced a CLABSI that resulted in LCVAD substitution to those who had never experienced infections with central lines. Our investigation provided a snapshot of the epidemiological distribution of patients with cancer using LCVADs in northern and central Italy hospitals. The majority of the patients had a mean age of 61 years, were female, and had gastrointestinal cancers, followed by hematologic malignancies. Although our study could reflect the epidemiological distribution of patients with cancer in Italy, which reports colorectal cancer as the second most frequent in women [39,40], the

Table 1
Comparisons between patients who experienced LCVAD substitution due to previous CLABSI and matched patients who never experienced LCVAD-related infections.

Characteristics	LCVAD substitution due to previous CLABSI ($n = 9$)		Patients who have never experienced LCVAD-related infections ($n = 9$)		*ASD*	*P*
	n	%	*n*	%		
Sex						
Male	4	44.4	4	44.4	0	1.000
Female	5	55.6	5	55.6		
Age (years) (*Mean ± SD*)	60.11	13.89	61.67	15.97	0.098	0.931
Primary cancer						
Breast	1	11.1	5	55.6	0.581	0.045
Gastrointestinal	4	44.4	3	33.3		
Brain	0	0	1	11.1		
Hematologic	4	44.4	0	0		
Metastasis						
Yes	5	55.6	3	33.3	0.447	0.637
No	4	44.4	6	66.7		
Comorbidities						
0	6	66.7	3	33.3	0.470	0.343
1	1	11.1	4	44.4		
> 1	2	22.2	2	22.2		
BMI (kg/m^2) (*Median, IQR*)	15	15.00, 18.50	17.3	13.5, 19.45	0.436	0.863
Received Treatments						
Other/Disease-related treatment	1	11.1	0	0	0.425	0.233
Supportive therapy	3	33.3	5	55.6		
Chemotherapy	4	44.4	2	22.2		
Immunotherapy	1	11.1	2	22.2		
Corticosteroid Therapy						
Yes	1	11.1	4	44.4	0.744	0.294
No	8	88.9	5	55.6		
Ongoing antibiotics						
Yes	1	11.1	0	0	0.485	0.206
No	8	88.9	9	100		
Hormone Therapy						
Yes	1	11.1	2	22.2	0.298	1.000
No	8	88.9	7	77.8		
LCVAD						
Tunneled	1	11.1	3	33.3	0.327	0.620
PICC	5	55.6	3	33.3		
PORT	3	33.3	3	33.3		
Lumens						
Single-lumen	9	100	9	100	0	1.000
LTVAD frequent utilization						
Yes	9	100	9	100	0	1.000
Previous LTVAD						
Yes	0	0	1	11.1	0.485	1.000
No	0	0	8	88.9		

Note: ASD = Absolute Standardized Difference. IQR = Interquartile Range. PICC = Peripherally Inserted Central Catheter. PORT = Port-a-Cath. LTVAD = Long-Term Venous Access Device. CLABSI = Central Line-Associated Bloodstream Infection. LCVAD = Long-Term Central Venous Access Device. NA: Comparison not performed.

hospital-specific oncological referral specialties undoubtedly impacted our distribution.

Overall, we found a CLABSI prevalence of 3 %. These results are slightly lower than those of a recent meta-analysis that indicated hospitalized adult patients with cancer and LCVAD had a roughly 8 % (95 %*CI*: 4 %–14 %) pooled occurrence risk of developing a CLABSI [16]. However, the meta-analysis data reflects an international perspective and includes retrospective and prospective cohort studies, the most appropriate research methodology for detecting a phenomenon occurrence rate [41]. Further, our findings align with existing literature on protective and preventive factors that may influence CLABSI prevalence. In our sample, most patients were female, a factor previously associated with lower CLABSI risk [42].

Additionally, we observed a low percentage of comorbidities, which is consistent with previous studies suggesting that fewer underlying conditions may reduce infection susceptibility [28]. The mean BMI in our cohort was relatively low, which is in line with evidence indicating that lower BMI may be a protective factor against CLABSI [43]. Moreover, many patients had single-lumen catheters, a catheter type known to be associated with a lower risk of infection compared to multi-lumen devices [16,29]. These observations reinforce prior research findings, supporting our results' robustness within the broader clinical context.

The propensity score analysis was estimated by modeling the outcome (i.e., CLABSI) as a function of the previous LCVAD placement given the observed covariates, based on the assumption that outcome differences may be due to preexisting differences that are not under consideration [44]. This approach ensures that the groups are comparable based on the observed characteristics [44,45]. In addition to the propensity score matching, we conducted an MCA to explore the behavior of the variables within each matched subgroup. This analysis aimed to highlight how the behaviors of the variables tend to differ between the groups, generating hypotheses for future research [46].

It is crucial to emphasize that reaching non-statistical significance after PSM was the intended outcome, as it confirms that the groups were successfully balanced. The goal of this study was to generate exploratory insights rather than to test for significant differences post-matching. Future studies with larger samples will

be needed to validate these findings and further explore potential CLABSI risk factors. While PSM was instrumental in addressing the secondary aim of comparing subgroups (patients with prior CLABSI requiring LCVAD substitution vs. those without infections), it was not feasible to apply PSM to study factors influencing CLABSI prevalence. This limitation stems from the small number of CLABSI cases observed ($n = 5$), which precludes robust subgroup matching and introduces risks of overfitting and unreliable statistical conclusions. Furthermore, balanced covariates and sufficient variability across groups are essential for valid causal analysis, both of which were constrained in this study due to the limited sample size and homogeneity in baseline characteristics. These considerations underscore the exploratory nature of our findings and highlight the need for larger, longitudinal studies to investigate better causal factors influencing CLABSI prevalence.

Similarly, conducting univariate and multivariate regression analyses to identify risk factors influencing CLABSI prevalence was impossible due to the small sample size. Regression modeling requires sufficient events-per-variable ratios to produce reliable and generalizable results. With only five CLABSI cases, including multiple covariates would result in overfitting and statistically unstable estimates. These limitations emphasize the need for larger datasets with more CLABSI cases, allowing advanced statistical analyses to explore causal factors better.

Future research should address these limitations by incorporating larger datasets with more CLABSI cases. This would enable the application of advanced statistical analyses, such as multivariate regression and causal modeling, to identify key risk factors and inform evidence-based prevention strategies. The insights gained from this study lay a foundation for developing tailored interventions, such as patient-specific infection control protocols, that may reduce the burden of CLABSI in oncology settings. Moreover, the clinical utility of PSM demonstrated in this study emphasizes its value as a methodological tool for balancing covariates and addressing confounding, particularly in observational studies with limited sample sizes.

MCA allowed us to identify potential patterns and interactions that may not be immediately apparent through traditional statistical methods by visualizing the relationships and contributions of various covariates [47]. However, while the matching procedure was essential to balance the covariates between the groups, it is important to note that this approach may have also masked some differences while adding caution to the analysis. The rigorous matching process ensures that the comparisons are fair and reduces the potential for confounding variables. Still, it can also lead to a reduction in observable variability, potentially concealing true differences between the groups. This approach was appropriate within the framework of exploratory analysis, as the study was primarily designed to estimate prevalence, and caution was preferred over the need to discover patterns.

However, even within the context of exploratory and hypothesis-generating analysis, some hints of underlying differences warrant further investigation. For instance, the MCA indicated potential associations between certain treatments (hormone therapy and corticosteroids) and the subgroup of patients who had experienced LCVAD substitution due to previous CLABSI, which, although not statistically significant in this study, could be explored in larger, more targeted studies to uncover meaningful patterns. This relationship seems particularly important among patients with haematological malignancies after allogeneic hematopoietic stem cell transplantation [48]. The clinical implications of these findings suggest that tailored strategies could be developed to mitigate the risk of CLABSI in vulnerable patient populations [2]. Future research with larger, more targeted studies is needed to confirm these patterns, develop evidence-based interventions to improve patient outcomes, and consider longitudinal trajectories over time. More precisely, future studies should focus on larger datasets with more CLABSI cases, balanced covariates, and greater variability across groups to allow the application of PSM or other advanced statistical methods to investigate causal factors influencing CLABSI prevalence. While our study's primary aim was descriptive and hypothesis-generating, these limitations are a foundation for more targeted research efforts in this critical area.

The findings of this study have several important implications for nursing practice, particularly in oncology settings. Nurses play a crucial role in preventing, detecting, and managing CLABSI among patients with LCVADs [49]. Identifying potential risk factors, such as previous infections and certain treatments (e.g., antibiotic therapy), underscores the need for vigilant monitoring and targeted preventive measures [28]. Nurses should be aware of these risk factors and implement stringent infection control protocols to minimize the risk of CLABSI [50,51]. Additionally, the exploratory nature of our findings suggests that individualized care strategies, considering patient-specific risk profiles, could enhance clinical outcomes. For instance, patients with a history of infections or those receiving corticosteroid therapy might benefit from more frequent monitoring and proactive interventions. Furthermore, education and training programs for nursing staff should emphasize the importance of adhering to evidence-based guidelines for managing central lines and preventing CLABSI [52]. Although PSM was not feasible for analyzing factors influencing prevalence due to sample size constraints, the exploratory subgroup analysis provided valuable insights into potential risk factors. These insights, such as the role of corticosteroid or hormone therapy, could guide future clinical strategies and research to mitigate CLABSI risk in oncology settings.

It is important to clarify that the observed association between the non-replacement group and corticosteroid/hormone therapy does not imply a protective effect against CLABSI. This association may stem from differences in baseline clinical characteristics, treatment regimens, or patient disease severity, rather than a direct role of these therapies in infection prevention. Thus, these findings should not be interpreted as evidence supporting the use of corticosteroids or hormone therapy as a preventive measure for CLABSI. Further research is needed to explore these associations in larger, more diverse populations and assess whether additional confounding variables influence this relationship.

5. Limitations

This study has several limitations that should be noted. First, point prevalence studies fail to accurately detect a phenomenon's occurrence rate. However, point prevalence surveys are helpful for quickly estimating the burden of a disease. Second, the study was conducted in a small number of hospitals in a geographically restricted area, resulting in a small sample size. However, based on the sample size calculation, we exceeded the minimum number of subjects required to reach statistically acceptable results and accurate estimations of parameters while remaining manageable and cost-effective. Third, while PSM was successfully applied for subgroup analysis to address the secondary aim, its use for investigating influencing factors for CLABSI prevalence was not feasible due to the small number of CLABSI cases observed ($n = 5$). The limited sample size, coupled with the lack of variability in baseline characteristics and the challenge of achieving balanced covariates, precluded robust subgroup matching and causal inference. This limitation underscores the need for larger datasets with more CLABSI cases to enable such analyses in future research. Fourth, the clinical and microbiological procedures for detecting infections were diverse among hospitals, leading to the potential risk of

overestimation or underestimation of the outcome. Fifth, our investigation did not collect information about the microorganisms involved in the CLABSI. This limit was consistent with informing about the CLABSI incidence about the sample characteristics rather than providing microbiological information worthy of more in-depth investigations. Sixth, additional risk factors of the sample could have been described, such as the comorbidity index, the nutritional status, and the performance status, which are highly relevant in the population with cancer concerning the incidence of CLABSI. However, our goal was to provide a first cross-sectional snapshot of the phenomenon in the Italian setting so that more in-depth research might be planned using longitudinal designs that allowed us to correlate particular characteristics with the CLABSI incidence. Lastly, given that the diagnosis of CLABSI requires particular procedures to ensure the infection is detected, some cases could not be intercepted; we must consider underestimating the phenomenon. Overall, as explained in our hypothesis and secondary aim, we specifically selected patients with previous CLABSI to analyze differences in patient characteristics and explore potential risk factors associated with long-term catheter-related infections. This allowed us to compare those who required LCVAD replacement due to previous CLABSI with those who never had infections, providing insights into patient risk profiles and possible preventive strategies, but with limited possibility to generalize the insights.

The main results of this study are the prevalence and clinical information obtained, while the comparative analyses have an exploratory value. Differences in specific disease patterns could emerge after matching, but this requires further investigation. The main focus of the study is epidemiological, and within the limits that the analyses conducted beyond the description of prevalence are exploratory, they should be interpreted with caution.

6. Conclusions

This study determined that the prevalence of CLABSI in hospitalized adults with cancer in Italy is 3 %, emphasizing the importance of continuous surveillance and prevention efforts. Point-prevalence studies are critical in tracking CLABSI trends over time and increasing awareness among healthcare stakeholders about its impact and preventability. As part of the secondary aim, the PSM analysis highlighted potential differences between patients requiring LCVAD substitution due to previous CLABSI and those who never experienced infections, generating hypotheses for future research. While exploratory, these findings suggest that patient- and treatment-related characteristics may influence CLABSI risk, reinforcing the need for vigilant monitoring and individualized preventive strategies in clinical practice. Standardized infection control protocols and tailored interventions remain essential to mitigating CLABSI risk and improving patient outcomes. Future research, particularly using larger datasets, is needed to confirm these associations and develop targeted, evidence-based strategies that enhance the quality of care for oncology patients.

CRediT authorship contribution statement

Silvia Belloni: Conceptualization, Validation, Methodology, Data curation, Writing - original draft, Software, Formal analysis, Supervision, Project administration. **Cristina Arrigoni**: Writing - review & editing. **Marco Alfredo Arcidiacono**: Investigation, Data curation, Writing - review & editing. **Giovanni Boschi**: Investigation, Data curation, Writing - review & editing. **Alessandro Leonetti**: Investigation, Data curation, Writing - review & editing. **Maria Allevato**: Investigation, Data curation, Writing - review & editing. **Orejeta Diamanti**: Investigation, Data curation, Writing - review & editing. **Chiara Cardone:** Investigation, Data curation, Writing - review & editing. **Daniele Girardi**: Investigation, Data curation, Writing - review & editing. **Sergio Ferrante**: Investigation, Data curation, Writing - review & editing. **Daniela Strada**: Investigation, Data curation, Writing - review & editing. **Silvia Bonalumi**: Supervision, Writing - review & editing. **Elena Pisano**: Supervision, Funding acquisition, Writing - review & editing. **Paola Maisola**: Supervision, Project administration, Writing - review & editing. **Giulia Villa**: Investigation, Data curation, Writing - review & editing. **Arianna Magon**: Investigation, Data curation, Writing - review & editing. **Gianluca Conte**: Investigation, Data curation, Writing - review & editing. **Stefania Ducoli**: Supervision, Project administration, Writing - review & editing. **Marco Fadda**: Supervision, Funding acquisition, Writing - review & editing. **Tedeschi Michele**: Conceptualization, Methodology, Validation, Supervision, Project administration, Writing - review & editing. **Rosario Caruso**: Conceptualization, Methodology, Formal analysis, Data curation, Writing - original draft, Software, Supervision, Validation.

Funding

This study is part of a project that has received funding from the 5x1000 Humanitas funds. The Humanitas Research Foundation is a non-profit organization that operates at the University Research and Teaching Center of the Humanitas Clinical Institute in Rozzano. None of the researchers received income from the funding or had any role with the institution. The Foundation was not involved in the design nor the conduct of the study and will not benefit in any form from the investigation results. The publication fee for this work was covered by the Italian Ministry of Health's Ricerca 'Corrente' funding to IRCCS Humanitas Research Hospital.

Declaration of competing interest

The authors declare that they have no competing interests.

Acknowledgments

The authors acknowledge the work of the Italian Association of Oncology Nurses (AIIAO) for supporting the project's coordination. The association was not involved in the design nor the conduct of the study and will not benefit in any form from the investigation results. Thank you to Michele Tedeschi, who was the clinical trial manager of the promoting centre, for having supported this project. A great thank you to the head nurses of each involved hospital, Lorena Passadori, Katia Morstabilini, Luca Piacenza, Alfonso Sollami, Corrado Gervasi, Katia Morstabilini and Pietrina Monni, for having authorized the study's implementation. We would like to thank Daniela Donizetti, Simona Semplici, Elena Garofalo, Monica Corrada, Monica Caracava Martinez and Rosalia Ceriani for their support in coordinating the data collection of this research project. We express our gratitude to Diego Fenaroli, Chiara Cortinovis, Jazmin Vargas, Debora Caldara, and Francesca Piretti, who played a significant role in successfully contributing to data collection for this research project.

Appendices. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijnss.2025.02.011.

References

[1] Leeman H, Cosgrove SE, Williams D, Keller SC. Assessing burden of central line-associated bloodstream infections present on hospital admission. Am J Infect Control 2020;48(2):216–8. https://doi.org/10.1016/j.ajic.2019.08.010.
[2] Malek AE, Raad II. Preventing catheter-related infections in cancer patients: a review of current strategies. Expert Rev Anti Infect Ther 2020;18(6):531–8. https://doi.org/10.1080/14787210.2020.1750367.
[3] Zimlichman E, Henderson D, Tamir O, Franz C, Song P, Yamin CK, et al. Health care-associated infections: a meta-analysis of costs and financial impact on the US health care system. JAMA Intern Med 2013;173(22):2039–46. https://doi.org/10.1001/jamainternmed.2013.9763.
[4] Haddadin Y, Annamaraju P, Regunath H. Central line–associated blood stream infections. StatPearls Publishing; 2022.
[5] Moir D, Bodenham A. A narrative review of long-term central venous access devices for the intensivist. J Intensive Care Soc 2018;19(3):236–46. https://doi.org/10.1177/1751143717741249.
[6] Cavanna L, Citterio C, Nunzio Camilla D, Orlandi E, Toscani I, Ambroggi M. Central venous catheterization in cancer patients with severe thrombocytopenia: ultrasound-guide improves safety avoiding prophylactic platelet transfusion. Mol Clin Oncol 2020;12(5):435–9. https://doi.org/10.3892/mco.2020.2010.
[7] Baier C, Linke LN, Eder M, Schwab F, Chaberny IF, Vonberg RP, et al. Incidence, risk factors and healthcare costs of central line-associated nosocomial bloodstream infections in hematologic and oncologic patients. PLoS One 2020;15(1):e0227772. https://doi.org/10.1371/journal.pone.0227772.
[8] Ziegler MJ, Pellegrini DC, Safdar N. Attributable mortality of central line associated bloodstream infection: systematic review and meta-analysis. Infection 2015;43(1):29–36. https://doi.org/10.1007/s15010-014-0689-y.
[9] Chovanec K, Arsene C, Gomez C, Brixey M, Tolles D, Galliers JW, et al. Association of CLABSI with hospital length of stay, readmission rates, and mortality: a retrospective review. Worldviews Evid Based Nurs 2021;18(6):332–8. https://doi.org/10.1111/wvn.12548.
[10] Galloway S, Bodenham A. Long-term central venous access. Br J Anaesth 2004;92(5):722–34. https://doi.org/10.1093/bja/aeh109.
[11] Taxbro K, Chopra V. Appropriate vascular access for patients with cancer. Lancet 2021;398(10298):367–8. https://doi.org/10.1016/S0140-6736(21)00920-X.
[12] Sousa B, Furlanetto J, Hutka M, Gouveia P, Wuerstlein R, Mariz JM, et al. Central venous access in oncology: ESMO clinical practice guidelines. Ann Oncol 2015;26(Suppl 5):v152–68. https://doi.org/10.1093/annonc/mdv296.
[13] Fiorini J, Venturini G, Conti F, Funaro E, Caruso R, Kangasniemi M, et al. Vessel health and preservation: an integrative review. J Clin Nurs 2019;28(7–8):1039–49. https://doi.org/10.1111/jocn.14707.
[14] Lipitz-Snyderman A, Sepkowitz KA, Elkin EB, Pinheiro LC, Sima CS, Son CH, et al. Long-term central venous catheter use and risk of infection in older adults with cancer. J Clin Oncol 2014;32(22):2351–6. https://doi.org/10.1200/JCO.2013.53.3018.
[15] Zembower TR. Epidemiology of infections in cancer patients. Infectious Complications in Cancer Patients 2014:43–89. https://doi.org/10.1007/978-3-319-04220-6_2. Cham: Springer International Publishing.
[16] Belloni S, Caruso R, Cattani D, Mandelli G, Donizetti D, Mazzoleni B, et al. Occurrence rate and risk factors for long-term central line-associated bloodstream infections in patients with cancer: a systematic review. Worldviews Evid Based Nurs 2022;19(2):100–11. https://doi.org/10.1111/wvn.12574.
[17] Akhtar N, Lee LD. Utilization and complications of central venous access devices in oncology patients. Curr Oncol 2021;28(1):367–77. https://doi.org/10.3390/curroncol28010039.
[18] Wong CC, Choi HC, Lee VH. Complications of central venous access devices used in palliative care settings for terminally ill cancer patients: a systematic review and meta-analysis. Cancers 2023;15(19):4712. https://doi.org/10.3390/cancers15194712.
[19] Luft D, Schmoor C, Wilson C, Widmer AF, Bertz H, Frei R, et al. Central venous catheter-associated bloodstream infection and colonisation of insertion site and catheter tip. What are the rates and risk factors in haematology patients? Ann Hematol 2010;89(12):1265–75. https://doi.org/10.1007/s00277-010-1005-2.
[20] McDonald MK, Culos KA, Gatwood KS, Prow C, Chen HD, Savani BN, et al. Defining incidence and risk factors for catheter-associated bloodstream infections in an outpatient adult hematopoietic cell transplantation program. Biol Blood Marrow Transplant 2018;24(10):2081–7. https://doi.org/10.1016/j.bbmt.2018.04.031.
[21] See I, Freifeld AG, Magill SS. Causative organisms and associated antimicrobial resistance in healthcare-associated, central line-associated bloodstream infections from oncology settings, 2009-2012. Clin Infect Dis 2016;62(10):1203–9. https://doi.org/10.1093/cid/ciw113.
[22] MacPhail A, Dendle C, Slavin M, McQuilten Z. Hospital-acquired bloodstream infections in patients with cancer: current knowledge and future directions. J Hosp Infect 2024;148:39–50. https://doi.org/10.1016/j.jhin.2024.03.002.
[23] Sikka G, Farooq S, Patel B, Prada RA. Strategies to prevent central line-associated bloodstream infections (CLABSIs). Infection Prevention in the Intensive Care Setting. Cham: Springer International Publishing; 2024. p. 15–31. https://doi.org/10.1007/978-3-031-67062-6_3.
[24] Murray J, Cohen AL. Infectious disease surveillance. International Encyclopedia of Public Health 2017:222–9. https://doi.org/10.1016/b978-0-12-803678-5.00517-8. Amsterdam: Elsevier.
[25] Golfera M, Toscano F, Cevenini G, DE Marco MF, Porchia BR, Serafini A, et al. Predicting healthcare-associated infections: are point of prevalence surveys data useful? J Prev Med Hyg 2022;63(2):E304–9. https://doi.org/10.15167/2421-4248/jpmh2022.63.2.1496.
[26] Puro V, Coppola N, Frasca A, Gentile I, Luzzaro F, Peghetti A, et al. Pillars for prevention and control of healthcare-associated infections: an Italian expert opinion statement. Antimicrob Resist Infect Control 2022;11(1):87. https://doi.org/10.1186/s13756-022-01125-8.
[27] Humphreys H, Smyth EM. Prevalence surveys of healthcare-associated infections: what do they tell us, if anything? Clin Microbiol Infect 2006;12(1):2–4. https://doi.org/10.1111/j.1469-0691.2005.01273.x.
[28] Alshahrani KM, Alhuwaishel AZ, Alangari NM, Asiri MA, Al-Shahrani NA, Alasmari AA, et al. Clinical impacts and risk factors for central line-associated bloodstream infection: a systematic review. Cureus 2023;15(6):e40954. https://doi.org/10.7759/cureus.40954.
[29] Lafuente Cabrero E, Terradas Robledo R, Civit Cuñado A, García Sardelli D, Hidalgo López C, Giro Formatger D, et al. Risk factors of catheter- associated bloodstream infection: systematic review and meta-analysis. PLoS One 2023;18(3):e0282290. https://doi.org/10.1371/journal.pone.0282290.
[30] Zotti CM, Messori Ioli G, Charrier L, Arditi G, Argentero PA, Biglino A, et al. Hospital-acquired infections in Italy: a region wide prevalence study. J Hosp Infect 2004;56(2):142–9. https://doi.org/10.1016/j.jhin.2003.10.001.
[31] von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP, et al. The strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. Bull World Health Organ 2007;85(11):867–72. https://doi.org/10.2471/blt.07.045120.
[32] Zarb P, Coignard B, Griskeviciene J, Muller A, Vankerckhoven V, Weist K, et al. The European Centre for Disease Prevention and Control (ECDC) pilot point prevalence survey of healthcare-associated infections and antimicrobial use. Euro Surveill 2012;17(46):20316. https://doi.org/10.2807/ese.17.46.20316-en.
[33] Cochran WG. Sampling techniques. 2. ed. New York: Wiley; 1963 [Nachdr.].
[34] Bellary S, Krishnankutty B, Latha MS. Basics of case report form designing in clinical research. Perspect Clin Res 2014;5(4):159–66. https://doi.org/10.4103/2229-3485.140555.
[35] Sharma S, Mudgal S, Thakur K, Gaur R. How to calculate sample size for observational and experiential nursing research studies? Natl J Physiol Pharm Pharmacol 2019;1. https://doi.org/10.5455/njppp.2020.10.0930717102019.
[36] Stuart EA. Matching methods for causal inference: a review and a look forward. Stat Sci 2010;25(1):1–21. https://doi.org/10.1214/09-STS313.
[37] Lunt M. Selecting an appropriate caliper can be essential for achieving good balance with propensity score matching. Am J Epidemiol 2014;179(2):226–35. https://doi.org/10.1093/aje/kwt212.
[38] Austin PC. An introduction to propensity score methods for reducing the effects of confounding in observational studies. Multivariate Behav Res 2011;46(3):399–424. https://doi.org/10.1080/00273171.2011.568786.
[39] AIOM. I numeri del cancro in Italia 2024. https://www.aiom.it/i-numeri-del-cancro-in-italia/. [Accessed 30 January 2025].
[40] AIRC. Incidenza Tumori Italia: Le statistiche del Cancro | AIRC 2024. https://www.airc.it/cancro/informazioni-tumori/cose-il-cancro/numeri-del-cancro. [Accessed 30 January 2025].
[41] Dekkers OM, Vandenbroucke JP, Cevallos M, Renehan AG, Altman DG, Egger M. COSMOS-E: guidance on conducting systematic reviews and meta-analyses of observational studies of etiology. PLoS Med 2019;16(2):e1002742. https://doi.org/10.1371/journal.pmed.1002742.
[42] Dube WC, Jacob JT, Zheng ZD, Huang YJ, Robichaux C, Steinberg JP, et al. Comparison of rates of central line-associated bloodstream infections in patients with 1 vs 2 central venous catheters. JAMA Netw Open 2020;3(3):e200396. https://doi.org/10.1001/jamanetworkopen.2020.0396.
[43] Wang Y, Xiang Q, Wu JY, Xiao N, Chen J. Obesity and the risk of catheter-related bloodstream infection: a systematic review and meta-analysis. Antimicrob Resist Infect Control 2022;11(1):141. https://doi.org/10.1186/s13756-022-01166-z.
[44] Martens EP, Pestman WR, de Boer A, Belitser SV, Klungel OH. Systematic differences in treatment effect estimates between propensity score methods and logistic regression. Int J Epidemiol 2008;37(5):1142–7. https://doi.org/10.1093/ije/dyn079.
[45] Stuart EA, Lee BK, Leacy FP. Prognostic score-based balance measures can be a useful diagnostic for propensity score methods in comparative effectiveness research. J Clin Epidemiol 2013;66(8 Suppl):S84–90.e1. https://doi.org/10.1016/j.jclinepi.2013.01.013.
[46] Kamalja K, Khangar NV. Multiple correspondence analysis and its applications. Electron J Appl Stat Anal 2014;10:432–62.
[47] Costa PS, Santos NC, Cunha P, Cotter J, Sousa N. The use of multiple correspondence analysis to explore associations between categories of qualitative variables in healthy ageing. J Aging Res 2013;2013:302163. https://doi.org/10.1155/2013/302163.
[48] Kameda K, Kimura SI, Akahoshi Y, Nakano H, Harada N, Ugai T, et al. High incidence of afebrile bloodstream infection detected by surveillance blood culture in patients on corticosteroid therapy after allogeneic hematopoietic stem cell transplantation. Biol Blood Marrow Transplant 2016;22(2):371–7. https://doi.org/10.1016/j.bbmt.2015.09.019.
[49] Sakharkar S, Sharma R, Mude DV, Kasturkar P, Wankhede P, Gomase K, et al.

Prevention and nursing management for central line associated blood stream infection. J Pharm Res Int 2021:32–8. https://doi.org/10.9734/jpri/2021/v33i52a33555.

[50] Esposito MR, Guillari A, Angelillo IF. Knowledge, attitudes, and practice on the prevention of central line-associated bloodstream infections among nurses in oncological care: a cross-sectional study in an area of southern Italy. PLoS One 2017;12(6):e0180473. https://doi.org/10.1371/journal.pone.0180473.

[51] Arrigoni C, Grugnetti AM, Caruso R, Gallotti ML, Borrelli P, Puci M. Nursing students' clinical competencies: a survey on clinical education objectives. Ann Ig 2017;29(3):179–88. https://doi.org/10.7416/ai.2017.2145.

[52] Foka M, Nicolaou E, Kyprianou T, Palazis L, Kyranou M, Papathanassoglou E, et al. Prevention of central line-associated bloodstream infections through educational interventions in adult intensive care units: a systematic review. Cureus 2021;13(8):e17293. https://doi.org/10.7759/cureus.17293.