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

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

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Declaration of competing interest

The author declared no conflict of interest.

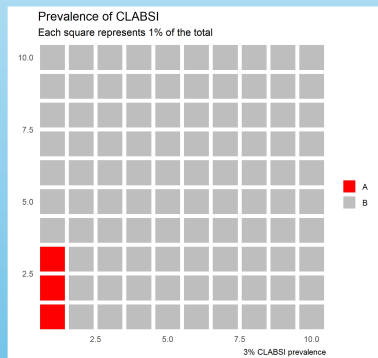
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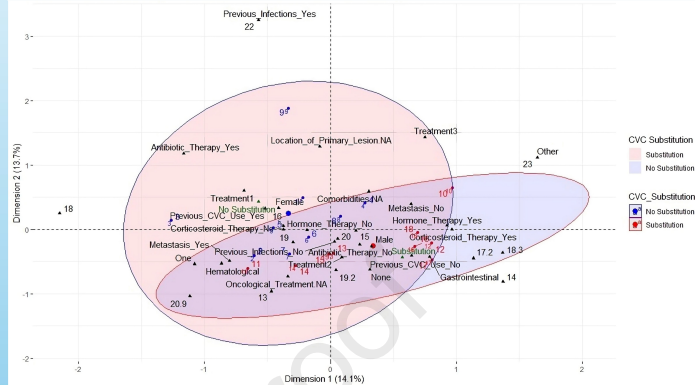
The prevalence of long-term central line-associated bloodstream infections in adult patients with cancer: A nationwide multicenter cross-sectional study in Italy

AIM: This multicenter point-prevalence study aimed to analyze the prevalence of long-term central line-associated bloodstream infections (CLABSI) among hospitalized adult cancer patients in Italy and their clinical characteristics. A secondary objective was to compare the characteristics of patients who had previously experienced CLABSI, resulting in long-term central venous access device (LCVAD) substitution, to those who had never experienced infections with central lines.

Methods: The study involved patients from hospitals in northern and central Italy. To address the secondary objective, propensity score matching and multiple correspondence analysis (MCA) were used to balance covariates between groups and explore the behavior of the variables within each matched subgroup.



Results



Implications for Practice: The study highlights the importance of vigilant monitoring and targeted preventive measures in oncology nursing practice to reduce the risk of CLABSI. Based on the exploratory analyses, individualized care strategies and adherence to evidence-based guidelines for managing central lines are crucial.

Conclusion: The main result was the prevalence of CLABSI among hospitalized adult cancer patients in Italy. The exploratory analyses suggested potential patterns associated with patients who had experienced LCVAD substitution due to a CLABSI. Future research has to confirm the emerging patterns.

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

Abstract

Objectives: This multicenter point-prevalence study aimed to analyse 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 point-prevalence design from March to September 2021. Adults with cancer and LCVADs were included. Propensity score matching (PSM) was used to compare patients who underwent LCVAD substitution due to previous CLABSI with those who never experienced infections. Data were collected through electronic case report forms, including demographic, clinical, treatment-related, and catheter-related variables. Multiple correspondence analysis (MCA) explored patterns within matched subgroups.

Results: The study included 174 adults with cancer and LCVADs. The prevalence of CLABSI was 3%, and 5.2% of patients required LCVAD substitution due to prior CLABSI. PSM analysis compared patients with prior CLABSI ($n = 9$) to matched controls without infections ($n = 9$) and found no significant differences in age, sex, comorbidities, or body mass index. 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.

Conclusions: This study provides an updated estimate of CLABSI prevalence among hospitalized adults with cancer in Italy and highlights potential differences in patient characteristics associated with prior CLABSI requiring LCVAD substitution. These findings emphasize the importance of continuous monitoring, individualized infection

prevention strategies, and adherence to evidence-based protocols in oncology nursing practice. Future research with larger datasets is needed to validate these findings and develop tailored interventions to reduce CLABSI risks.

Keywords: Central line-associated bloodstream infection; Cancer; Propensity score matching; Multiple Correspondence Analysis; Nursing

What is known?

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

What is new?

- This study provides 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.
- Exploratory 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 Control and Prevention (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 hours 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 last 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 catheters (PICCs), central lines, and fully implanted port-a-cath (PORTs) [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 HAI surveillance and infection prevention and control measures (IPC), 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) ≥ 18 years old; 2) with at least one LCVAD, including PICCs, fully implantable devices (i.e., PORTs), 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 48 hours or removed within the previous 48 hours [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 PICCs, PORTs, 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]: $n = Z_{\alpha/2}^2 \times P \times (1-P) / E^2$. 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, body mass index (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 ($> 38^{\circ}\text{C}$), 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 Statistical 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. Statistical 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. For proportions, the approach was as follows, where p are the proportions per group:

$$ASD = \frac{|\hat{p}_1 - \hat{p}_2|}{\sqrt{\hat{p}(1 - \hat{p})}}$$

For numeric variables, the approach was as follows, where $\bar{X}$ values were the means and s^2 the variances:

$$ASD = \frac{|\bar{X}_1 - \bar{X}_2|}{\sqrt{\frac{s_1^2 + s_2^2}{2}}}$$

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].

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]. $P(\text{Group})$ 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:

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

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]. The standardized mean differences (SMDs) were also calculated, with values below 0.1 considered indicative of negligible imbalance [38]. The eCDF mean, and eCDF max was 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 conducted data collection, management, analysis, and interpretation procedures. Data were de-identified during data collection and analysed in aggregate to maintain confidentiality and anonymity of information.

3. Results

3.1 Characteristics of the participants and CLABSI prevalence

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/m². 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 PICCs, 46.6% used PORTs, and 5.7% used tunneled devices. 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 Table 1.

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 Table 2.

The groups were comparable in terms of demographic characteristics, with sex ($ASD = 0.012$) and age ($ASD = 0.132$) showing minimal differences, indicating a well-balanced distribution. Additionally, the two groups' chemotherapy and immunotherapy treatments were relatively balanced, suggesting no significant differences in these exposures. Frequent utilization of LTVADs was also comparable, with 100% in the CLABSI group versus 97.2% in the non-infective group ($ASD = 0.237$), indicating a high level of similarity in catheter usage patterns.

Conversely, some characteristics demonstrated noticeable imbalances between the groups. Hematologic cancers were more common in the CLABSI group (44.4%) compared to the non-infective group (19.9%), with an ASD of 0.546, highlighting a significant difference in cancer type distribution. Differences were also noted for metastasis status ($ASD = 0.198$) and BMI ($ASD = 0.381$), though these were less pronounced. Regarding treatment-related factors, supportive therapy was more frequent in the CLABSI group (33.3%) compared to the non-infective group (10.96%), with an ASD of 0.559. A substantial difference was observed in corticosteroid therapy, which was administered to only 11.1% of patients in the CLABSI group versus 46.2% in the non-infective group ($ASD = 0.842$). Among LCVAD characteristics, tunneled catheters were slightly more common in the CLABSI group (11.1% vs. 4.8%, $ASD = 0.235$), while single-lumen catheters were used exclusively in the CLABSI group (100%) compared to 92.5% in the non-infective group, with an ASD of 0.403.

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 to 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 A.

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 3.

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.

However, differences were observed in primary cancer types ($P = 0.045$), with breast cancer being significantly more prevalent in the control group (55.6%) compared to the CLABSI group (11.1%). Hematologic cancers, on the other hand, were present only in the CLABSI group (44.4%). Although not statistically significant, the CLABSI group showed a higher proportion of patients with metastases (55.6% vs. 33.3%) and fewer patients receiving corticosteroid therapy (11.1% vs. 44.4%).

Regarding treatments, chemotherapy was more common in the CLABSI group (44.4% vs. 22.2%), while palliative therapy was more frequent in the control group (55.6% vs. 33.3%). Other treatment-related variables, including immunotherapy, hormone therapy, and ongoing antibiotic use, did not differ significantly 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 A 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. The plot reveals that variables such as “previous infections” and “antibiotic therapy” are more associated with the substitution group, while the absence of hormone therapy and corticosteroids align more closely with the no substitution group. This differentiation helps understand the underlying patterns and differences between the two groups, generating hypotheses for future research.

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 have a mean age of 61, 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 hospital-specific oncological referral specialties undoubtedly impacted our distribution.

Overall, we found a CLABSI prevalence of 2-3%. 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].

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 serve as 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.

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 prevalence 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.

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.

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Table 1. Characteristics of the participants ($n = 174$).

Characteristics	Categories	n (%)
Sex	Male	79 (45.4)
	Female	95 (54.6)
Age (years) (<i>Mean $\pm$ SD</i>)		61.90 $\pm$ 13.52
Primary cancer	Breast	19 (10.9)
	Gastrointestinal	75 (43.1)
	Brain	2 (1.1)
	Lung	14 (8.0)
	Genital	7 (4.0)
	Urinary	4 (2.3)
	Sarcoma	3 (1.7)
	Skin	3 (1.7)
	Thymus	1 (0.6)
	Hematologic	42 (24.1)
	Uncertain	4 (2.5)
Metastasis	Yes	75 (43.1)
	No	99 (56.9)
Comorbidities	0	102 (58.6)
	1	41 (23.6)
	> 1	31 (17.8)
BMI (kg/m ²) (<i>Mean, IQR</i>)		16.2 (15.00, 18.2)
Received treatments	Other disease-related treatment	29 (16.7)
	Supportive therapy	25 (14.4)
	Chemotherapy	91 (52.3)
	Immunotherapy	12 (6.9)
	Chemotherapy + immunotherapy	9 (5.2)
	Radiotherapy	3 (1.7)
	Surgery	5 (2.9)
Ongoing treatment modality	Corticosteroid therapy	74 (42.5)
	Ongoing antibiotics	39 (22.4)
	Hormone therapy	10 (5.8)
	None	51 (29.3)
LCVAD	Tunneled	10 (5.7)
	PICC	83 (47.7)
	PORT	81 (46.6)
Lumens	Single-lumen	161 (92.5)
	Double-lumen	13 (7.5)
LTVAD frequent utilization ^a	Yes	168 (96.6)
	No	6 (3.4)
Previous LTVAD ^b	Yes	29 (16.7)
	No	145 (83.3)
Outcomes	CLABSI	5 (2.9)
	Other catheter-related infections	14 (2.9)
	LCVAD substitution due to previous CLABSI	9 (5.2)
	No infection	146 (83.9)

Note: ^a Frequent utilization refers to daily or near-daily catheter use for chemotherapy or supportive care treatments. ^b Previous LTVAD refers to patients who had used a long-term venous access device before the

current one. IQR = interquartile range. PICC = peripherally inserted central catheter. PORT = port-a-cath. CLABSI = central line-associated bloodstream infection. LCVAD = long-term central venous access device.

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Table 2. Comparisons between patients who experienced LCVAD substitution due to previous CLABSI and 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 = 146)		ASD
	n	%	n	%	
Sex					
Male	4	44.4	64	43.8	0.012
Female	5	55.6	82	56.2	
Age (years) (<i>Mean ± SD</i>)	60.11 ± 13.89		61.9 ± 13.26		0.132
Primary cancer					
Breast	1	11.1	17	11.6	0.016
Gastrointestinal	4	44.4	68	46.6	0.043
Brain	0	0	2	1.4	0.166
Lung	0	0	13	8.9	0.442
Genital	0	0	6	4.1	0.293
Urinary	0	0	3	2.1	0.204
Sarcoma	0	0	3	2.1	0.204
Skin	0	0	2	1.4	0.166
Thymus	0	0	1	0.7	0.117
Hematologic	4	44.4	29	19.9	0.546
Uncertain	0	0	2	1.4	0.170
Metastasis					
Yes	5	55.6	64	45.7	0.198
No	4	44.4	82	54.3	
Comorbidities					
0	6	66.7	83	56.8	0.203
1	1	11.1	37	25.3	0.375
> 1	2	22.2	26	17.8	0.110
BMI (kg/m ²) (<i>Mean, IQR</i>)	15	15.00, 18.50	16.1	14.55, 18.80	0.381
Received Treatments					
Other/Disease-related treatment	1	11.1	26	17.82	0.191
Supportive therapy	3	33.3	16	10.96	0.559
Chemotherapy	4	44.4	78	53.42	0.180
Immunotherapy	1	11.1	10	6.85	0.149
Chemotherapy + immunotherapy	0	0	9	6.16	0.362
Radiotherapy	0	0	3	2.05	0.205
Surgery	0	0	4	2.74	0.237
Corticosteroid Therapy					
Yes	1	11.1	67	46.2	0.842
No	8	88.9	79	53.8	
Ongoing antibiotics					
Yes	1	11.1	31	21.4	0.281
No	8	88.9	115	78.6	
Hormone therapy					
Yes	1	11.1	8	5.5	0.204

No	8	88.9	138	94.5	
LCVAD					
Tunneled	1	11.1	7	4.8	0.235
PICC	5	55.6	66	45.2	0.208
PORT	3	33.3	73	50	0.343
Lumens					
Single-lumen	9	100	135	92.5	0.403
Double-lumen	0	0	11	7.5	0.404
LTVAD frequent utilization					
Yes	9	100	141	97.2	0.237
No	0	0	5	2.8	

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.

Table 3. 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 (<i>n</i> = 9)		Patients who have never experienced LCVAD-related infections (<i>n</i> = 9)		ASD	<i>P</i>
	<i>n</i>	%	<i>n</i>	%		
Sex						
Male	4	44.4	4	44.4	0.000	NA
Female	5	55.6	5	55.6		
Age (years) (<i>Mean ± SD</i>)	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) (<i>Mean, IQR</i>)	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	0.000	NA
LTVAD frequent utilization						
Yes	9	100	9	100	0.000	NA

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.

What is known?

- CLABSI poses a significant risk to hospitalized cancer patients with long-term central venous access devices (LCVADs).
- Preventing CLABSI requires adherence to strict infection control protocols and close patient monitoring.

What is new?

- This study provides a point-prevalence estimate of CLABSI among hospitalized adult cancer patients in Italy.
- Exploratory analyses highlighted potential associations between treatments (e.g., corticosteroids and hormone therapy) and CLABSI, though these findings require further investigation.

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 and 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.

Declaration of competing interest

The authors declare that they have no competing interests.