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Appropriate selection of vascular access devices in the hospitalized patient: a prospective observational pilot study

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Abstract

Introduction Vascular access devices (VADs) play a critical role in clinical practice, facilitating the administration of medications, fluid therapy, and parenteral nutrition. Nevertheless, improper selection of VADs can result in various complications, escalate healthcare costs, and significantly impact patients' experience. This study seeks to evaluate the appropriateness of VAD selection in contemporary clinical practice.

Methods A prospective observational pilot study was conducted between September 1st and December 31st, 2023, in two medical wards at Careggi University Hospital, Florence, Italy. Data on VAD type, insertion, maintenance, and complications were collected. The primary outcome was the appropriate selection of central VADs (CVADs) and peripheral VADs (PVADs) as recommended by the most recent international guidelines and consensus documents.

Results A total of 322 VADs were inserted in the considered period, out of which 23 (7.1%) were CVADs and 299 (92.9%) were PVADs. Peripherally Inserted Central Catheter (PICC, $n = 10$; 43.5%) was the most represented CVAD, followed by ports ($n = 6$; 26%), Centrally Inserted Central Catheters (CICC, $n = 4$; 17.4%), and Femorally Inserted Central Catheters (FICC, $n = 3$; 13%). Short peripheral cannulas (SPC) were the most represented PVADs ($n = 257$; 86%), followed by long peripheral cannulas (LPC) (32; 10.7%), and midline (MC) ($n = 10$; 3.3%). CVADs were appropriate in 82.6% of cases, whereas PVADs' appropriateness fell to 43.1%. Overall, 47 VAD failures were observed: 6 (26.1%) CVADs and 41 (13.7%) PVADs.

Conclusion This study found a high prevalence of inappropriate VAD selection in hospitalised patients, especially among PVADs, although with no increased risk of complications. Further studies are needed to address effective strategies for improving the selection of VADs.

Keywords Vascular access devices, Catheterization, Peripheral, Catheterization, Central venous, Patient safety, Clinical decision-making, Hospitalised patients

Introduction

Vascular access devices (VADs) are essential components in the management of hospitalized patients, with approximately 90% of inpatients requiring a VAD for the safe administration of medications, fluids, electrolytes, parenteral nutrition, and blood products [1]. Even in outpatient settings, VADs play a crucial role in ensuring prolonged therapies such as chemotherapy and antibiotic therapy. However, they are not free from complications [2].

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VAD-associated complications are various, including mechanical complications at insertion, thrombosis, infection, phlebitis, occlusion, and dislocation, negatively impacting outcomes and increasing the workload for healthcare staff [3]. Complications arise not only from an improper VAD insertion and management but also from an inappropriate VAD selection. Selecting the most appropriate VAD for the intended use is then fundamental to ensuring optimal patient care, improving safety, and reducing costs [4, 5]. Appropriate VAD selection is particularly relevant in the DIVA (Difficult Intra-Venous Access) patient, who are at higher risk of complications, including multiple attempts of cannulation and exploitation of peripheral vein tissue, and at need of more invasive VAD [6]. Clinically, various strategies have been implemented to enhance the appropriateness of VAD, including algorithms of choice, hospital policies, and, obviously, training [7]. Nevertheless, the actual application of these strategies remains lacking, as does the evaluation of VAD appropriateness in the real world.

The present study aimed to evaluate the appropriateness of VAD selection in the medical wards of a tertiary care hospital.

Material and methods

Study design

This was a prospective, observational, single-centre pilot study to provide preliminary estimates of appropriateness rates and to inform sample size calculations for a subsequent interventional study. It was conducted over four months, between September 1st and December 31st, 2023, in two internal medicine wards at Careggi University Hospital in Florence, Italy. The study was approved by the local Ethics Committee (Comitato Etico di Area Vasta Toscana Centro; CEAVC reference no. 22706/BIO, 18 April 2023). Written informed consent was obtained from all participants before their inclusion. The study was conducted and reported in accordance with STROBE recommendations [8].

Study population

In this study, VAD appropriateness was defined as the correctness of device selection based on the patient's therapeutic needs, as recommended by two international reference documents: the ERPIUP Consensus (World Congress of Vascular Access—WoCoVA) and the Infusion Therapy Standards of Practice (Infusion Nurses Society—INS) [9, 10].

Based on these documents, it was considered inappropriate:

- The use of PVAD for administering solutions that are not fully compatible with the peripheral route.

- The use of a non-power injectable certified VAD for the administration of contrast medium
- Keeping a CVAD in place for more than 48 h when not needed (i.e., for the infusion of peripherally compatible solutions in patients with preserved peripheral veins). Use of a port for the infusion of peripherally compatible solutions for more than 48 h was also considered inappropriate (as for authors' hospital policy).
- Maintaining a CVAD placed in emergency conditions for more than 48 h.

These four scenarios of inappropriateness were identified as they represent frequent and clinically relevant situations of suboptimal VAD selection or management in daily practice. These scenarios were also selected because they are objectively identifiable and reliably measurable, thus suitable for a pilot observational study.

Appropriateness was assessed by two trained nursing students using predefined criteria derived from the ERPIUP and the INS documents, as no validated scoring system for vascular access appropriateness currently exists. In cases of uncertainty, senior VAT members were consulted. Assessors were not blinded to either the device type or outcomes, as this was necessary for proper evaluation of appropriateness and potential complications.

CVAD's intraprocedural complications and PVAD's failure rates were also collected.

Eligible patients were those admitted to the participating medical wards with an indication for a vascular access device (VAD). Patients below 18 years of age were excluded from the study.

In the authors' hospital, policies on the selection and use of VADs have been in place since 2014 and updated every five years.

Definitions and VAD types

A patient was defined "DIVA (Difficult Intra-Venous Access)" in case of the absence of visible or palpable veins; history of previous difficulties; multiple attempts; practitioner's expectation of difficult intra-venous access [11].

Emergency insertion refers to cases where full sterility or protocol compliance might be compromised.

VADs were defined according to the terminology recently proposed by the World Congress of Vascular Access (WoCoVA) – the NAVIGATE project [12] – which defined central vascular access devices (CVADs) as centrally inserted central catheter (CICC), peripherally inserted central catheter (PICC), femorally inserted central catheter (FICC), port and tunnelled-cuffed catheter (Tc); and peripheral vascular access devices (PVADs) as short peripheral cannulas (SPC, <6 cm long), long

peripheral cannulas (LPC, 6–15 cm long), and midline catheter (MC, 15–25 cm long).

In this study, the following VADs from different manufactures were used: LPCs (BD®; BBraun® Vygon®); single and double lumen midlines (Health Line®); 2 or 3 lumens CICC (Amecath®; Arrow®); single lumen and double lumens PICCs (BD®; Health Line®; Vygon®); 4.5, 5 and 6.5 Fr ports (BBraun®; Vygon®).

Data collection

Data were collected using REDCap® (Research Electronic Data Capture), a web application developed by Vanderbilt University for building and managing online surveys and databases. Patients' demographics, type of VAD, reason for insertion, duration, complications, and adherence to best practice guidelines were recorded.

Patients were enrolled at the time of device insertion, as determined independently by the prescribing physician, in accordance with the clinical practice of the medical ward. Before enrolment, informed consent was obtained from all patients. The observation period ended when the patient was discharged from the ward. No further follow-up assessments were scheduled beyond this point.

Statistical analysis

Descriptive statistics were used to analyse the data. Categorical variables were presented as absolute and relative

frequencies, while continuous variables were expressed as mean and standard deviation or median and inter-quartile range. Comparative analyses will be performed in the VAT 2 study to assess any differences in appropriateness rates between patients managed with and without a VAT oversight.

Results

Patients' demographic characteristics

A total of 322 devices from 161 patients were analysed, including 86 females (53.42%) and 75 males (46.58%). The median body mass index was 24.45 kg/m² (IQR: 21.95–27.70 kg/m²), while the median age was 73 (61–79 yrs). A rate of 15.5% of patients was found to be DIVA, whereas 136 were non-DIVA. The distribution of the number of VAD insertions differed between DIVA and non-DIVA patients: 32.0%, 36.0%, and 32.0% of DIVA patients received 1, 2, or ≥3 VADs, respectively, compared to 50.7%, 27.9%, and 21.3% in the non-DIVA group (Chi-square test, $p=0.216$) (Figs. 1 and 2; Table 1).

Appropriateness of CVADs

A total of 23 out of 322 VADs (7.1%) were CVADs. Ten PICCs were inserted, accounting for 43.5% of all CVADs, with a median dwell time of 6.5 days (IQR 5–8). Four CICCs were inserted, representing 17.4%

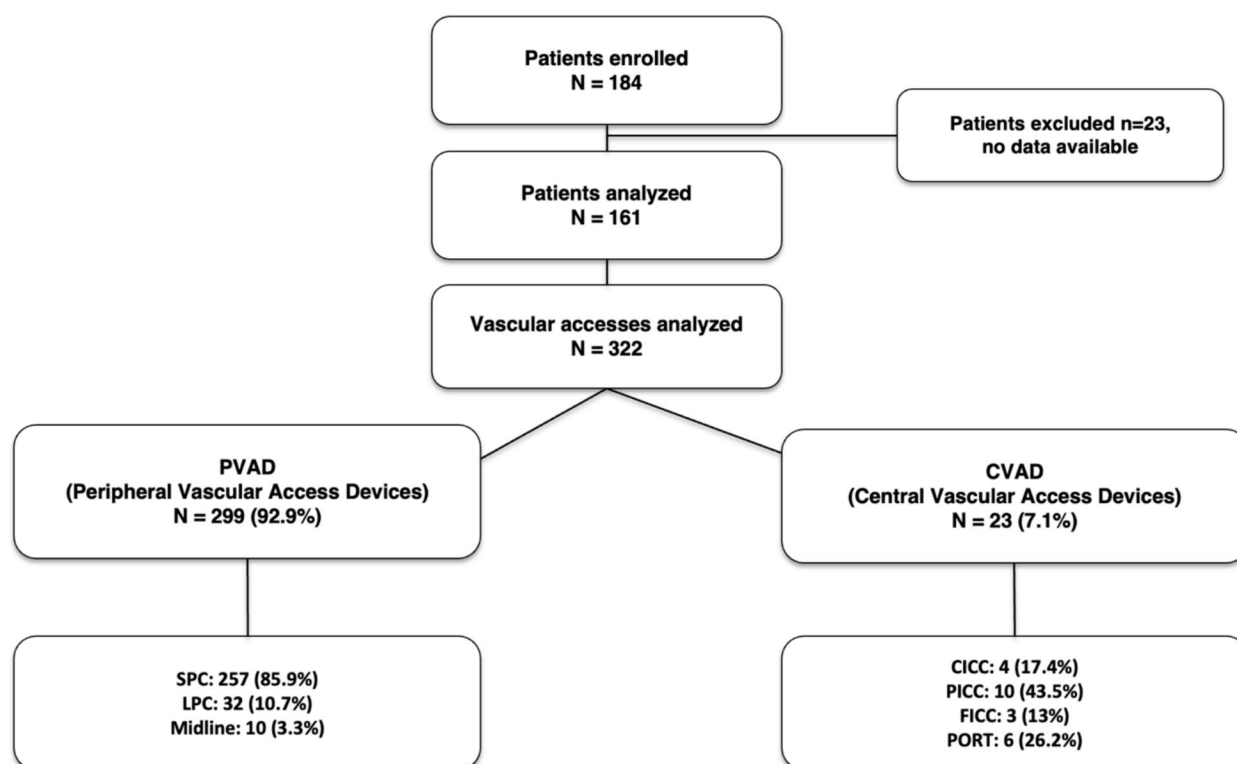


Fig. 1 Flowchart of patients enrolled and VADs inserted

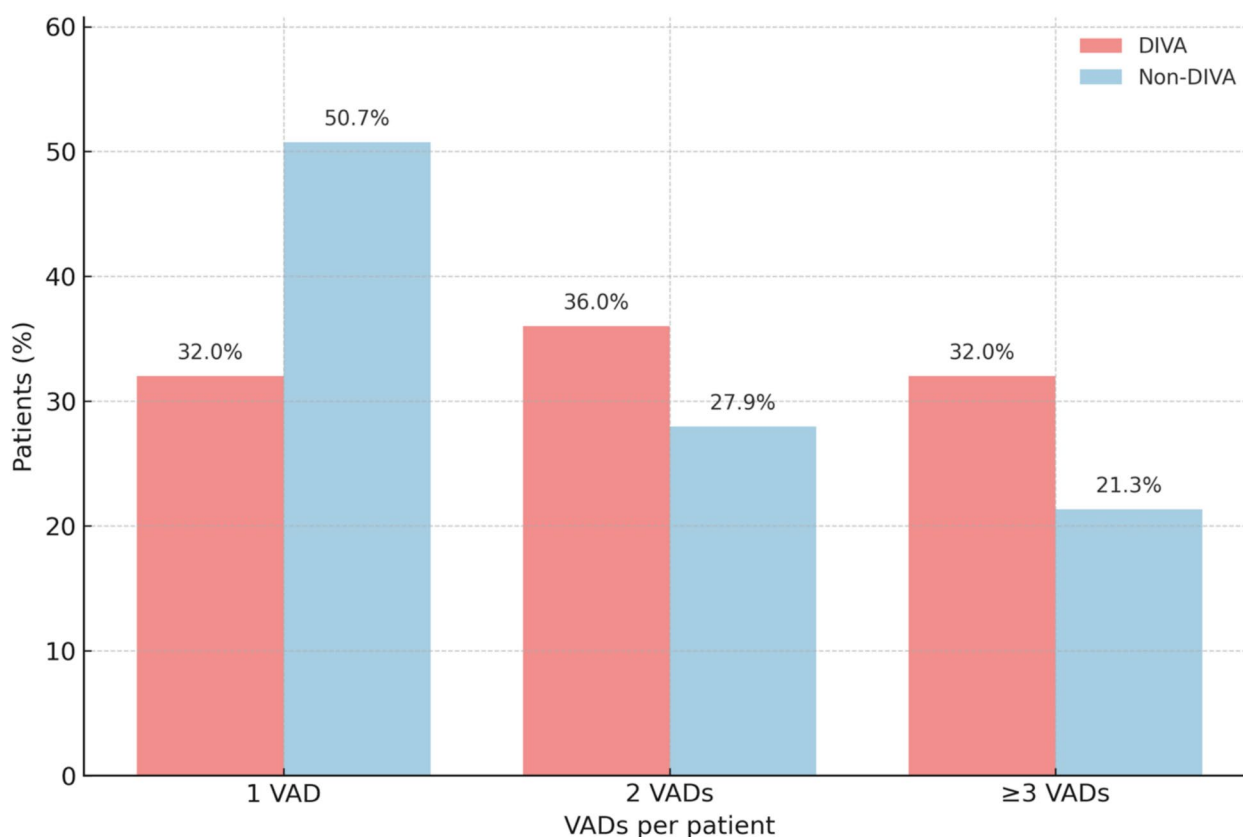


Fig. 2 Distribution of VAD placement per DIVA and non-DIVA patients

Table 1 DIVA and non-DIVA patients by the number of VADs inserted

Group of patients	1 VAD n (%)	2 VADs n (%)	≥ 3 VADs n (%)	Total patient n
DIVA	8 (32.0)	9 (36.0)	8 (32.0)	25
Non-DIVA	69 (50.7)	38 (27.9)	29 (21.3)	136

of CVADs, with a median dwell time of 7 days (IQR 4–9). Three FICC (13% of CVADs) were inserted, with a median dwell time of 12 days (IQR 10–17.5). Six ports (26.2%) were implanted.

Among CVADs, 82.6% were appropriate and 17.4% were inappropriate. One CICC was appropriate (25%) and 3 inappropriate (75%). PICC and FICC showed the highest appropriateness rates ($n=10$; 100%; and $n=3$; 100% respectively). Five ports (83.3%) were appropriate, while 1 (16.7%) was inappropriate. A detailed representation of CVAD's appropriateness is shown in Table 2 and Fig. 3.

Clinical indications for CVAD included chemotherapy ($n=14$; 60.9%), fluid therapy ($n=10$; 43.5%), pain management ($n=10$; 43.5%), antibiotic therapy ($n=5$; 21.7%),

transfusions ($n=6$; 26.1%), contrast medium for diagnostic procedures ($n=3$; 13.0%), total parenteral nutrition ($n=2$; 8.7%), and vasoactive amine administration ($n=2$; 8.7%).

Appropriateness of PVADs

A total of 299 out of 322 VADs (92.8%) were PVADs, out of which 129 (43.1%) were appropriate; conversely, 170 (56.9%) were inappropriate. Out of 299 PVADs, 257 (85.9%) were short peripheral catheters (SPC), 32 (10.7%) were long peripheral catheters (LPC), and 10 (3.3%) were midline catheters (MC).

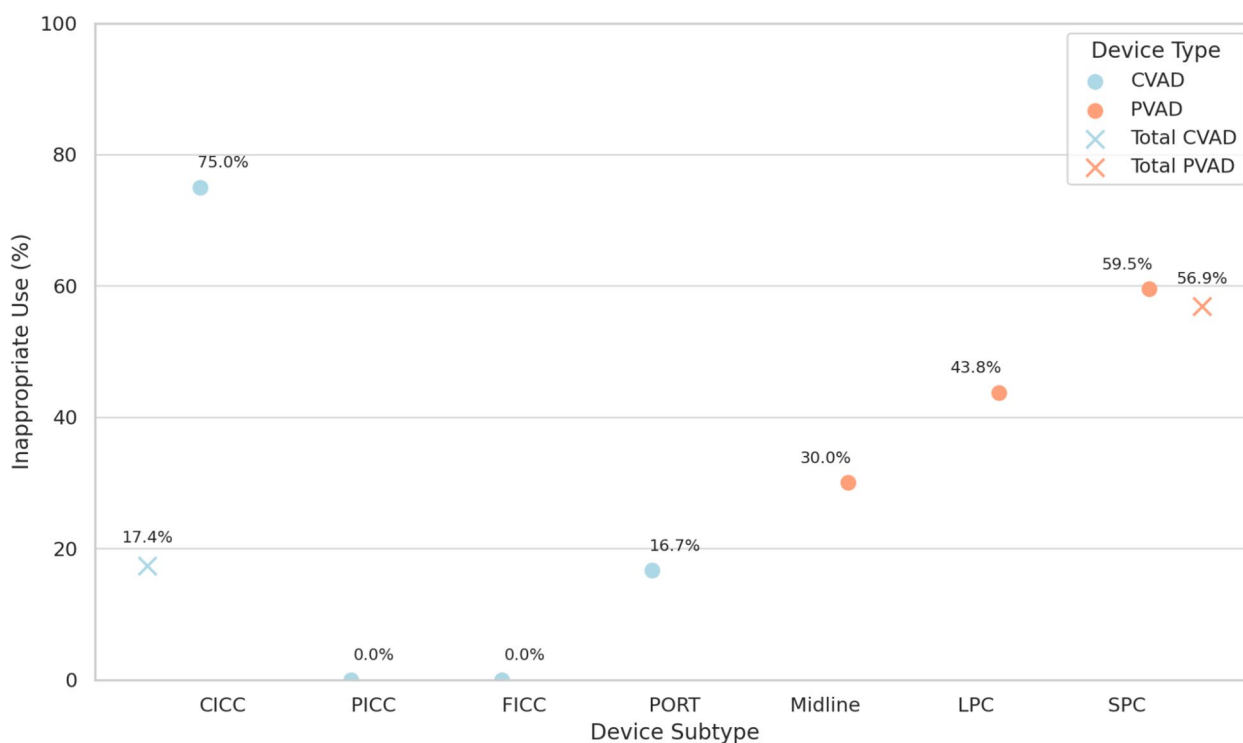
MC showed the highest appropriateness rate (70%), followed by LPC (56.2%). SPC had the lowest appropriateness rate (40.5%), with a total of 170 PVADs (56.85%) deemed as inappropriate (Table 2 and Fig. 3).

The majority of PVADs were used for antibiotic therapy (191 cases, 63.9%) and pain management (193 cases, 64.5%). Another indication was fluid therapy, accounting for 169 cases (56.5%), representing more than half of the inserted PVADs. Other indications included the administration of blood products ($n=28$; 9.4%) and contrast medium infusion ($n=19$; 6.4%).

Median dwell time of PVADs was 4 days for SPC, 6 days for LPC and 5 days for MC.

Table 2 Appropriateness and inappropriateness of CVADs and PVADs

CVAD	N of CVAD (%)	N of appropriate CVAD (%)	N of inappropriate CVAD (%)
Total	23	19 (82.6)	4 (17.4)
CICC	4 (17.4)	1 (25)	3 (75)
PICC	10 (43.5)	10 (100)	0 (0)
FICC	3 (13)	3 (100)	0 (0)
PORT	6 (26.2)	5 (83.3)	1 (16.7)
PVAD	N of PVAD (%)	N of appropriate PVAD (%)	N of inappropriate PVAD (%)
Total	299	129 (43.1)	170 (56.9)
Midline	10 (3.3)	7 (70)	3 (30)
LPC	32 (10.7)	18 (56.2)	14 (43.8)
SPC	257 (85.9)	104 (40.5)	153 (59.5)

**Fig. 3** Rate of inappropriateness among all VADs (CVADs and PVADs)**CVADs and PVADs complications**

Overall, 47 VAD failures were observed: 6 (26.1%) CVADs and 41 (13.7%) PVADs.

Among CVADs, CICC showed no complications. Regarding PICCs, a single complication ($n=1$, 10.0%) was observed, represented by a malfunction. All three FICCs inserted showed malfunctions ($n=3$, 100%), while PORTs presented one episode of local infection and two cases of bleeding (33.3%), one of which led to removal.

Regarding PVADs, midlines reported no complications. LPCs presented 4 malfunctions and 1 episode of phlebitis

($n=5$, 15.6%). All the complicated LPCs were removed. SPCs suffered 15 malpositions, 11 phlebitis, 5 extravasations, and 5 multiple punctures ($n=36$, 14.0%). All the complicated SPCs required removal.

Discussion

This study explored the appropriateness of vascular access selection in two wards of a tertiary care University Hospital. At present, no validated scale or severity grading for VAD inappropriateness exists. From a patient-safety perspective, authors' conceptual framework

considers 100% appropriateness as the target, analogous to infection prevention strategies (i.e.: “targeting zero”) [13]. Any deviation from this ideal is therefore considered clinically relevant.

In this study, despite the policies for appropriate device choice having been implemented for many years, a high rate of inappropriate VAD selection was found, occurring in 17.4% and 57.8% of CVADs and PVADs, respectively. The lower rate of inappropriateness among CVADs may reflect a greater awareness of the increased risks of complications associated with CVADs compared to PVADs, including arterial or lung puncture, thrombosis, and infection [10, 14]. Therefore, greater caution in their indication and management may have been adopted. Moreover, the administration of solutions not fully compatible with the peripheral route via a PVAD is a major factor contributing to inappropriateness and may have influenced the results.

Interestingly, among CVADs, a notable difference in terms of appropriateness was found. PICC and FICC showed a 100% appropriateness rate, whereas CICC showed only 25%. This finding cannot be easily explained. It may be that CICC is more frequently placed in emergencies and then left in place for more than 48 h and used for drugs compatible with the peripheral route. Additionally, not all the CICCs in the authors’ hospital are suitable for contrast media infusion, and they may have been misused. Moreover, in the authors’ hospital, PICC and FICC are implanted by a Vascular Access Team (VAT). VAT is a multidisciplinary group of vascular access specialists [15] whose duties include not only inserting a VAD but also verifying their indication and selecting the most appropriate one for that specific patient: this may have contributed to a greater appropriateness. On the contrary, CICCs are often implanted by “occasional inserters” (i.e., non-vascular access specialists), who may also have been responsible for the greater rate of intraprocedural complications (i.e., multiple venipunctures) found among the CICC group compared to PICC and FICC ones. One port out of 6 was considered inappropriate, likely due to its use while other PVADs were available for the infusion of peripherally compatible solutions for more than 48 h. Unlike INS Standards [9] the authors’ hospital policies do not support port use in hospitalized patients, aligning with recent international recommendations [16]. In fact, Frequent device manipulation may increase risks of colonization, occlusion, and skin complications. Notably, PICC was the most represented CVAD (43.5%), well beyond CICC (17.4%) and FICC (13%). According to local hospital policies and consensus documents [17, 18], PICC is indeed the CVAD of choice in the hospitalised patient. This is

easily explained by several reasons, including: the lack of major risks at the insertion even in fragile patients, such as those with coagulation disorders or cardiorespiratory problems [19], low risk of late complications [18, 20, 21], and the possibility of discharging the patient at long-term facilities or at home with the PICC.

Among PVADs, SPC and LPC showed the greatest inappropriateness rate, being 59.5% and 43.8% respectively. Possible causes of inappropriate SPC and LPC selection include insufficient knowledge of drug characteristics and/or underestimation of potential risks. On the other hand, midline catheters exhibited the lower (30%) inappropriateness rate. Again, the presence of a VAT may play a role in explaining those differences. In fact, in the authors’ hospital, SPC and LPC are placed by ward doctors and nurses, whereas midlines are placed by a VAT. As for CVADs, a VAT may be beneficial in guaranteeing a more correct VAD selection. Nevertheless, additional research is necessary to substantiate these findings. The main causes of PVAD inappropriateness may be related to prolonged dwell time beyond clinical needs, during which the device was either unused or no longer indicated; for instance, fourteen PVADs (4.7%) were used for chemotherapy, and six (2.0%) for total parenteral nutrition.

VAD failures varied by type. In fact, CVADs showed a higher failure rate than PVADs (26.1% vs 13.7%). This result should be interpreted cautiously, given the small number of CVADs and, possibly, some missing information on the time, date and reasons for removal of PVADs, especially SPC; further larger studies are needed to substantiate these findings.

Regarding PVADs, SPCs drove the PVAD failures mainly due to several episodes of malposition and phlebitis, which led to removal. Midlines registered no failures, supporting their role as a safe peripheral alternative when therapy exceeds short durations, even though this may also reflect selection bias and limited sample size. LPC also presented failures, even if only in 5 cases. SPCs and LPCs showed higher failure rates than midlines (14.0% and 15.6% vs none respectively), aligning with their greater inappropriateness.

Zero failures in the CICC group is a reassuring result, but again, it is likely biased by the small number. The same for 100% failure among FICCs (3/3), which likely reflects poor insertion technique and management, but also may be biased by the very small sample.

Observing the distribution of VAD placement per DIVA and non-DIVA patients (Fig. 2), the trend suggests an increased number of VAD placements in the DIVA group, even if a statistical significance ($p=0.216$) was not reached. Given the smaller sample size in this latter group ($n=25$), these results should be considered with caution.

Nonetheless, the relation between DIVA and the greater number of VAD implanted highlights a clinically relevant issue for its impact on patient's safety, well-being, and the efficiency of the entire process [6, 22].

As a matter of fact, inappropriate VAD selection is associated with higher complication rates, greater costs, and poorer patient experience [23, 24]. Therefore, a proactive vascular planning leading to an optimal VAD selection should always be encouraged. As “antimicrobial stewardship” refers to a set of coordinated strategies aimed at improving the appropriate use of antibiotics [25], similarly, a “vascular access stewardship” should be implemented to select the right VAD for the right patient, at the right moment. Adequate training of healthcare providers and the implementation of standardized protocols for appropriate vascular access device selection represent crucial steps toward ensuring optimal clinical outcomes. Nevertheless, these measures alone may be insufficient to fully address issues of appropriateness and reduce complications in clinical practice. Investigating whether systematic VAT involvement can enhance decision-making processes, optimize device selection, and ultimately improve patient outcomes may represent an area for further research.

This study has several limitations. Firstly, it was conducted in a single centre, which may limit the generalizability of the findings. Secondly, the observational nature of the results does not allow for direct causality assessment regarding inappropriate VAD selection and complication rates, which may have been likely underestimated. Thirdly, the small number of CVADs does not allow a reliable comparison between the CVADs and PVADs' appropriateness and to draw definite conclusions. Fourthly, this study analysed only few possible VAD inappropriateness scenarios, but other different ones may be chosen. And lastly, available data did not allow a reliable breakdown of specific causes of inappropriateness.

Conclusion

This study revealed a high prevalence of inappropriate vascular access device (VAD) selection among hospitalized patients, with PVADs being most frequently misused. Such inappropriate selection is likely to contribute to a higher incidence of complications, reduced clinical efficiency, and increased patient discomfort. These findings underscore the need for targeted interventions and institutional strategies to promote appropriate VAD selection based on clinical indication, therapy duration, and patient-specific factors. Further research is warranted to develop, implement, and evaluate evidence-based interventions that can optimize vascular access practices and improve patient outcomes.

Acknowledgements

We thank all the doctors and nurses in charge of the patients during the study for their support.

Disclosures

FP reported personal fees as an invited speaker and for advisory board membership from Becton & Dickinson. The other authors reported no conflict of interest.

Authors' contributions

FP and GV led the trial. All the investigators mentioned as coauthors collected and/reviewed the data. FF did the statistical analysis. FP, FF, and GV wrote the Article.

Funding

The Azienda Ospedaliera Universitaria Careggi, Florence, Italy, sponsored the study. Becton & Dickinson provided an unrestricted grant.

Data availability

Individual participant data will not be available directly to external users but will be available after de-identification to researchers who provide a methodologically sound proposal, 3 months following article publication and up to 5 years later. Proposals should be sent to fulvio.pinelli@unifi.it.

Declarations

Competing interests

F.P. reported personal fees as an invited speaker and for advisory board membership from Becton & Dickinson. The other authors reported no competing interests. The Azienda Ospedaliero-Universitaria Careggi, Florence, Italy, sponsored the study. Becton & Dickinson provided an unrestricted grant.

Received: 6 October 2025 Accepted: 17 February 2026

Published online: 24 February 2026

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