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Factors Associated with Blood Flow Velocity in the Upper Limb of Cancer Patients with Peripherally Inserted Central Catheters: A Cross-Sectional Study

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Article

Keywords: Blood Flow Velocity, Peripherally Inserted Central Catheters, Cancer Patients, Nursing Intervention, Hemodynamics, Thrombosis Prevention, Doppler Ultrasound, Cross-sectional Study

Posted Date: November 5th, 2025

DOI: https://doi.org/10.21203/rs.3.rs-6889221/v1

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Additional Declarations: No competing interests reported.

Version of Record: A version of this preprint was published at Scientific Reports on September 8th, 2026. See the published version at https://doi.org/10.1038/s41598-026-64200-9.

Abstract

Background

Peripherally inserted central catheters (PICC) are widely used in cancer care for long-term intravenous access, yet complications such as thrombosis remain a concern. Blood flow velocity is a key hemodynamic parameter closely associated with thrombosis risk. However, limited research has focused on the factors influencing blood flow velocity in cancer patients with PICC placement.

Methods

This cross-sectional study enrolled 405 cancer patients who underwent PICC insertion. Data on demographic, clinical, nutritional, and catheter-related characteristics were collected at admission. Blood flow velocity and vessel diameter were assessed using Doppler ultrasound within 48 hours after catheterization. Univariate and correlation analyses were conducted to identify potential influencing factors. Variables with $P < 0.1$ were entered into a stepwise multiple linear regression model to determine independent predictors of blood flow velocity.

Results

Univariate analysis showed significant associations between blood flow velocity and gender ($P = 0.006$), hypertension ($P = 0.034$), radiotherapy history ($P = 0.018$), and catheterization method ($P = 0.035$). Correlation analysis identified positive correlations between blood flow velocity and NRS2002 score ($P = 0.032$), systolic pressure ($P = 0.034$), and diastolic pressure ($P = 0.017$). Multiple linear regression revealed that gender ($B = -1.349$, $P = 0.009$), education level ($B = -0.626$, $P = 0.026$), NRS2002 score ($B = 0.674$, $P = 0.034$), and diastolic pressure ($B = 0.067$, $P = 0.034$) were independent predictors of blood flow velocity.

Conclusions

Gender, education level, nutritional status, and blood pressure were significant determinants of blood flow velocity in PICC-inserted limbs. These findings support the need for individualized nursing strategies, including nutritional screening and hemodynamic monitoring, to prevent PICC-related complications.

1. Background

Peripherally inserted central catheters (PICC) are widely used in oncology patients to provide long-term venous access for chemotherapy, intravenous medications, and supportive care[1]. PICC involves inserting a catheter through a peripheral vein and positioning its tip in the central vein, offering

advantages such as simplicity, long-term use, and reduced discomfort from repeated venipuncture[2]. Due to these benefits, PICC has gained broad acceptance in clinical nursing practice[3]. However, despite its advantages, PICC placement is associated with certain complications, among which thrombosis is one of the most concerning[4]. Thrombosis not only compromises treatment outcomes but also affects patients' quality of life[5].

Thrombosis development is closely linked to Virchow's triad, which identifies three primary risk factors: slow blood flow, hypercoagulability, and endothelial injury[6]. Among these, slow blood flow is a critical factor in venous thrombosis formation, particularly in patients with PICC catheters[7]. The presence of a catheter can disrupt normal venous flow, resulting in localized blood stasis and an elevated risk of thrombus formation[8]. Additionally, cancer patients are prone to a hypercoagulable state, which, combined with long-term treatments such as chemotherapy and radiotherapy, further exacerbates blood viscosity and enhances thrombosis risk.

Although extensive research has been conducted on the incidence, causes, and prevention strategies for PICC-related thrombosis[9], limited studies have explored the specific factors influencing blood flow velocity in patients with PICC catheters. Since blood flow velocity is a critical indicator of hemodynamic stability and is closely associated with thrombosis risk[10], investigating its influencing factors could provide valuable insights for improving patient care. Notably, no previous studies have comprehensively analyzed the factors impacting blood flow velocity in the catheterized limb among oncology patients. Therefore, this study aimed to fill this research gap by investigating the demographic, clinical, and catheter-related factors influencing blood flow velocity in oncology patients with PICC catheters. The findings are expected to provide evidence for targeted nursing interventions to optimize vascular health and reduce PICC-related complications.

2. Methods

2.1. Study Design and Setting

This cross-sectional study was conducted at the Department of Oncology, The First Affiliated Hospital of Guangxi Medical University from January 2021 to December 2023. The study aimed to investigate the factors influencing blood flow velocity in the upper limbs of cancer patients with PICC.

2.2. Study Participants

A total of 405 cancer patients who underwent PICC insertion were enrolled. Inclusion criteria were as follows: (1) patients diagnosed with malignant tumors requiring PICC placement for chemotherapy, nutritional support, or medication delivery; (2) age ≥ 18 years; (3) ability to cooperate with ultrasound assessments; (4) provision of informed consent. Exclusion criteria included: (1) active infection at the catheterization site; (2) history of deep vein thrombosis in the catheterized limb before PICC insertion; (3) patients with incomplete data.

2.3. Sample Size Calculation

The sample size calculation was conducted using PASS 15.0 software. Based on a squared multiple correlation coefficient (ρ^2) of 0.2 under the null hypothesis, with a significance level of 0.05, a power of 90%, and 29 independent variables, the minimum required sample size was 171 patients. Considering a 20% dropout rate, the adjusted sample size was 214 patients. Ultimately, a total of 405 patients were included to enhance the robustness and reliability of the results

2.4. Measurements

Data were collected in accordance with predefined categories to ensure a structured and comprehensive assessment of potential influencing factors on blood flow velocity. The key variables were categorized as follows:

2.4.1. Demographics and General Information

Demographic characteristics included age, gender, education level, and occupation. BMI (Body Mass Index) was calculated using the formula: BMI = weight(kg)/height(m)^2. BMI ≥ 24 kg/m² was defined as overweight, and BMI ≥ 28 kg/m² was defined as obesity[11].

2.4.2. Clinical Characteristics

Clinical data included tumor diagnosis, tumor stage, tumor metastasis, and history of hypertension, chemotherapy, and radiotherapy. Tumor stage was based on the TNM staging system, and tumor type classification was based on the patient's electronic medical record.

2.4.3. Nutritional Status and Functional Assessment

Nutritional status was assessed by the NRS2002 score (Nutritional Risk Screening 2002), which was proposed by Kondrup et al. and has been widely used in nutritional risk screening for hospitalized patients[12]. The NRS2002 score covers BMI, recent weight loss, reduced food intake, and disease severity. A score of ≥ 3 indicates nutritional risk. In addition, the functional status of patients was assessed by the KPS score (Karnofsky Performance Status)[13]. The KPS score ranges from 0 to 100 points, and the lower the score, the worse the patient's functional status. The KPS score is completed by experienced clinical medical staff through interviews and medical record review when the patient is admitted to the hospital.

2.4.4. Catheter-Related Factors

Catheterization-related factors included the method of catheterization (conventional catheterization or tunneled catheterization), the inserted blood vessel (basilic vein or brachial vein), the puncture site (left upper limb or right upper limb), the length of the catheter, and the catheter-vessel diameter ratio. All PICC catheterization operations were performed by specially trained clinical nurses following aseptic operation specifications.

2.4.5. Vascular ultrasound examination

Vascular ultrasound examination uses Philips EPIQ 7C ultrasound system equipped with 5–12 MHz linear array probe.

Blood flow velocity measurement: The patient is in a supine position, the limb on the examined side is slightly abducted, the probe is placed along the longitudinal axis of the blood vessel, and color Doppler ultrasound imaging is used to clearly display the blood flow signal. The measurement point of blood flow velocity is selected at the distal part about 2 cm away from the tip of the catheter, and the peak systolic blood flow velocity (PSV) at this point is recorded. Each patient is measured three times, and the average value is taken as the final data to improve the accuracy and repeatability of the measurement.

Vascular inner diameter measurement: Using B-mode ultrasound imaging technology, the probe is placed vertically above the blood vessel to measure the inner diameter of the vein near the catheter puncture point. The widest part of the blood vessel is selected as the final inner diameter data during measurement. Each patient is measured three times in a row and the average value is taken.

To reduce the interference of external factors on blood flow velocity, all ultrasound examinations are completed in an examination room with an ambient temperature controlled at 24–26℃. During the examination, the patient should try to stay relaxed and avoid exerting limb force to reduce the impact of blood flow fluctuations on the measurement results.

2.4.6. Coagulation Function Indicators

Coagulation indices included prothrombin time (PT), fibrinogen (FIB), activated partial thromboplastin time (APTT), thrombin time (TT), and D-dimer. These indices were measured by the hospital laboratory using an automatic coagulation analyzer, and the tests strictly followed the standardized procedures. Each measurement was conducted by trained healthcare professionals following standardized protocols to ensure data accuracy and consistency.

2.5. Data Collection

Data collection is divided into two key time points: when the patient is admitted to the hospital and within 48 hours after PICC catheterization.

Data collection at admission: Demographic data (age, gender, education level, occupation), clinical characteristics of the disease (diagnosis, stage, metastasis, hypertension, chemotherapy, radiotherapy), nutrition and functional assessment data (NRS2002 score, KPS score) are completed through structured interviews and electronic medical record review when the patient is admitted to the hospital. All interviews are conducted by trained medical staff to ensure the accuracy and consistency of the data.

Data collection 48 hours after PICC catheterization: Information related to catheterization (catheterization method, inserted blood vessel, puncture site, catheter insertion length) is recorded immediately after the catheterization is completed. Vascular ultrasound examination (blood flow velocity

and vascular inner diameter) is completed by nurses with rich ultrasound experience within 48 hours after the catheterization is completed. All data are independently checked by two researchers to ensure the completeness and accuracy of the data.

2.6. Statistical Analysis

All statistical analyses were conducted using SPSS version 27.0. Descriptive statistics were employed to summarize demographic, clinical, and procedural characteristics. Continuous variables were expressed as mean ± standard deviation (Mean ± SD) if they followed a normal distribution. For skewed data, the median and interquartile range (IQR) were reported. Categorical variables were presented as frequencies(n)and percentages(%). For univariate analysis, independent sample t-tests were used to compare continuous variables between two groups, while one-way analysis of variance (ANOVA) was applied for comparisons involving more than two groups. Correlation analysis was conducted using Pearson correlation coefficients to assess relationships between continuous variables and blood flow velocity. To identify independent predictors of blood flow velocity, variables with $P < 0.1$ in the univariate and correlation analysis were entered into a stepwise multiple linear regression model. The stepwise method was employed to ensure that only the most relevant predictors were retained in the final model. Multicollinearity was assessed using variance inflation factors (VIF), with a VIF value exceeding 10 considered indicative of potential multicollinearity. Statistical significance was set at $P < 0.05$.

2.7. Ethical Considerations

This study has been approved by the Medical Ethics Committee of the First Affiliated Hospital of Guangxi Medical University (NO.2022-KY-(001)). The ethical norms of the Declaration of Helsinki on medical research were strictly followed during the study, and the privacy and data security of patients were fully protected. All patient information was coded to ensure data anonymity and confidentiality.

3. Results

3.1. Baseline Characteristics of the Study Participants

A total of 405 participants were included in the study. The baseline characteristics are presented in Table 1. The mean age of the participants was 52.72 ± 11.88 years, and the majority were female (56.8%). Regarding educational background, 40.5% had completed junior high school, while only 9.4% had attended college or above. The most common occupation was farmer/worker (71.4%). The mean BMI was 21.86 ± 3.25 kg/m².In terms of clinical characteristics, 42.2% of patients had digestive system tumors, 11.6% had hematological tumors, and 46.2% had other types of malignancies. Among the participants, 65.2% were at tumor stage IV, and 80.5% had tumor metastasis. Regarding catheterization, 91.6% of patients had conventional catheterization, while 8.4% underwent tunnelled catheterization. The mean catheter insertion length was 39.22 ± 2.81 cm, with a mean vessel diameter of 6.08 ± 2.77 mm and a catheter-to-vessel diameter ratio of 0.25 ± 0.08. The median catheter dwell time was 30 days (IQR: 15–60 days), and the mean blood flow velocity was 14.60 ± 5.20 cm/s.

Table 1
Baseline Characteristics of the Study Participants (n = 405)

Variable	N (%) / Mean ± SD
Gender	
Male	175 (43.2)
Female	230 (56.8)
Age (years)	52.72 ± 11.88
Education Level	
Primary School or Below	97 (24.0)
Junior High School	164 (40.5)
Senior High School/Technical School	106 (26.2)
College or Above	38 (9.4)
Occupation	
Farmer/Worker	289 (71.4)
Employee/Civil Servant	32 (7.9)
Retired/Other	84 (20.7)
BMI (kg/m²)	21.86 ± 3.25
Diagnosis	
Digestive System Tumor	171 (42.2)
Hematological Tumor	47 (11.6)
Others	187 (46.2)
Tumor Stage	
I	23 (5.7)
II	34 (8.4)
III	84 (20.7)
IV	264 (65.2)
Tumor Metastasis	
Yes	326 (80.5)
No	79 (19.5)
Hypertension	

Variable	N (%) / Mean ± SD
Yes	42 (10.4)
No	363 (89.6)
Chemotherapy History	
Yes	157 (38.8)
No	248 (61.2)
Radiotherapy History	
Yes	353 (87.2)
No	52 (12.8)
Catheterization Method	
Conventional Catheter	371 (91.6)
Tunnelled Catheter	34 (8.4)
Insertion Vein	
Basilic Vein	344 (84.9)
Brachial Vein	61 (15.1)
Puncture Site	
Left Upper Limb	278 (68.6)
Right Upper Limb	127 (31.4)
Catheter Insertion Length (cm)	39.22 ± 2.81
Vessel Diameter (mm)	6.08 ± 2.77
Catheter-Vessel Diameter Ratio	0.25 ± 0.08
Blood Flow Velocity (cm/s)	14.60 ± 5.20

Continuous variables are presented as Mean ± SD; non-normally distributed variables are presented as Median (IQR).

3.2. Univariate Analysis

Univariate analysis identified several factors significantly associated with blood flow velocity. Male patients exhibited a significantly higher mean blood flow velocity (15.40 ± 4.89 cm/s) compared to female patients (14.00 ± 5.36 cm/s) (P = 0.006). Patients with hypertension demonstrated a notably higher blood flow velocity (16.21 ± 5.33 cm/s) than those without hypertension (14.41 ± 5.16 cm/s) (P = 0.034). Radiotherapy history was also significantly associated with blood flow velocity, with patients who

had received radiotherapy showing a lower mean blood flow velocity (13.27 ± 4.06 cm/s) compared to those without radiotherapy (14.80 ± 5.33 cm/s) (P = 0.018). Additionally, the method of catheterization influenced blood flow velocity, as patients with tunnelled catheters had a significantly higher blood flow velocity (16.43 ± 5.10 cm/s) compared to those with conventional catheters (14.43 ± 5.19 cm/s) (P = 0.035). Other variables, including educational background, occupation, tumor stage, tumor metastasis, chemotherapy history, insertion vein, and puncture site, showed no statistically significant differences in blood flow velocity. These results highlight that gender, hypertension, radiotherapy history, and catheterization method are key factors influencing blood flow velocity in patients with PICC catheters (Table 2).

Table 2
Univariate Analysis of Factors Influencing Blood Flow Velocity

Variable	**n (%)**	**Blood Flow Velocity (cm/s)**	***F/t***	***P***
Gender			2.745	0.006
Male	175 (43.2)	15.40 ± 4.89		
Female	230 (56.8)	14.00 ± 5.36		
Education Level			2.195	0.088
Primary School or Below	97 (24.0)	15.54 ± 5.34		
Junior High School	164 (40.5)	14.70 ± 5.82		
Senior High School/Technical School	106 (26.2)	13.69 ± 4.05		
College or Above	38 (9.4)	14.34 ± 4.56		
Occupation			0.051	0.951
Farmer/Worker	289 (71.4)	14.58 ± 5.41		
Employee/Civil Servant	32 (7.9)	14.41 ± 4.43		
Retired/Other	84 (20.7)	14.73 ± 4.77		
Diagnosis			2.631	0.073
Digestive System Tumor	171 (42.2)	14.94 ± 5.20		
Hematological Tumor	47 (11.6)	15.70 ± 5.61		
Others	187 (46.2)	14.01 ± 5.05		
Tumor Stage			0.127	0.944
I	23 (5.7)	13.96 ± 4.95		
II	34 (8.4)	14.72 ± 5.39		
III	84 (20.7)	14.68 ± 4.58		
IV	264 (65.2)	14.62 ± 5.41		
Tumor Metastasis			-1.378	0.169
Yes	326 (80.5)	14.43 ± 5.15		
No	79 (19.5)	15.32 ± 5.39		
Hypertension			2.128	0.034
Yes	42 (10.4)	16.21 ± 5.33		
No	363 (89.6)	14.41 ± 5.16		

Variable	n (%)	Blood Flow Velocity (cm/s)	*F/t*	*P*
Chemotherapy History			-1.813	0.069
Yes	157 (38.8)	14.01 ± 5.09		
No	248 (61.2)	14.01 ± 5.09		
Radiotherapy History			2.425	0.018
Yes	353 (87.2)	13.27 ± 4.06		
No	52 (12.8)	14.80 ± 5.33		
Catheterization Method			-2.18	0.035
Conventional Catheter	371 (91.6)	14.43 ± 5.19		
Tunnelled Catheter	34 (8.4)	16.43 ± 5.10		
Insertion Vein			-0.285	0.776
Basilic Vein	344 (84.9)	14.57 ± 4.91		
Brachial Vein	61 (15.1)	14.78 ± 6.66		
Puncture Site			-0.356	0.722
Left Upper Limb	278 (68.6)	14.54 ± 5.27		
Right Upper Limb	127 (31.4)	14.74 ± 5.07		

3.3. Correlation Analysis

Correlation analysis revealed that several clinical variables were significantly associated with blood flow velocity. Among the examined factors, NRS2002 score showed a positive correlation with blood flow velocity (r = 0.106, *P* = 0.032), suggesting that higher nutritional risk was linked to increased blood flow velocity. Similarly, both systolic blood pressure (r = 0.105, *P* = 0.034) and diastolic blood pressure (r = 0.119, *P* = 0.017) demonstrated significant positive correlations with blood flow velocity, indicating that elevated blood pressure may contribute to faster blood flow in patients with PICC catheters. Other variables, including age, BMI, KPS score, catheter retention time, arm circumference, catheter insertion length, daily exercise duration, and coagulation-related parameters, showed no significant correlation with blood flow velocity. These findings highlight the potential influence of nutritional status and blood pressure on vascular dynamics in patients undergoing PICC catheterization (Table 3).

Table 3
Correlation Analysis Between Blood Flow Velocity and Clinical Variables

Variable	*r*	*P*
Age	0.008	0.876
BMI	-0.021	0.675
KPS	-0.026	0.604
NRS2002 Score	0.106	0.032
Systolic Blood Pressure	0.105	0.034
Diastolic Blood Pressure	0.119	0.017
Catheter Retention Time	0.055	0.267
Arm Circumference	0.005	0.920
Catheter Insertion Length	0.017	0.740
Daily Exercise Duration	0.066	0.182
Catheter-to-Vessel Ratio	-0.04	0.418
PT	0.061	0.218
FIB	0.026	0.609
APTT	-0.025	0.615
TT	-0.056	0.264
D-D	0.031	0.536

3.4. Multiple Linear Regression Analysis

The multiple linear regression analysis identified four variables significantly associated with blood flow velocity in cancer patients with PICC (Table 4). Gender was a significant factor, with female patients exhibiting lower blood flow velocity compared to males (B = -1.349, 95% CI: -2.362 to -0.335, P = 0.009). Education level showed a significant negative association with blood flow velocity (B = -0.626, 95% CI: -1.175 to -0.077, P = 0.026). NRS2002 score was positively associated with blood flow velocity (B = 0.674, 95% CI: 0.052 to 1.296, P = 0.034). Additionally, diastolic blood pressure was positively associated with blood flow velocity (B = 0.067, 95% CI: 0.005 to 0.128, P = 0.034). The variance inflation factors (VIF) for all variables were below 10, indicating no significant multicollinearity concerns.

Table 4
Multiple Linear Regression Analysis of Factors Influencing Blood Flow Velocity

Variable	*B*	*SE*	*β*	*t*	*P*	*95% CI (Lower)*	*95% CI (Upper)*	*VIF*
Constant	12.126	2.804	—	4.324	< 0.001	6.613	17.639	—
Gender	-1.349	0.515	-0.129	-2.617	0.009	-2.362	-0.335	1.019
Education Level	-0.626	0.279	-0.110	-2.241	0.026	-1.175	-0.077	1.015
NRS2002 Score	0.674	0.316	0.104	2.129	0.034	0.052	1.296	1.006
Diastolic Blood Pressure	0.067	0.031	0.104	2.125	0.034	0.005	0.128	1.018

4. Discussion

This study identified multiple factors influencing blood flow velocity in the upper limbs of cancer patients with PICC. The results demonstrated that female patients exhibited significantly lower blood flow velocity compared to males. Additionally, lower education levels were associated with higher blood flow velocity, suggesting potential socioeconomic influences. Nutritional risk, indicated by elevated NRS2002 scores, was positively correlated with increased blood flow velocity. Moreover, higher diastolic blood pressure was significantly linked to greater blood flow velocity. These findings highlight the complex interplay of demographic, clinical, and hemodynamic factors in regulating blood flow dynamics in PICC patients. Understanding these associations may guide targeted interventions to optimize vascular health and reduce PICC-related complications.

The present study offers novel insights into the factors influencing blood flow velocity in cancer patients with PICCs, an area that has been scarcely investigated in previous research. While prior studies have predominantly focused on PICC-related complications such as thrombosis and infection[14], our study is among the first to explore blood flow velocity as an independent outcome. The observed finding that female patients exhibited lower blood flow velocity than males may be attributed to anatomical differences, such as smaller vein diameters, which have been shown to influence venous flow dynamics[15]. Additionally, hormonal differences between males and females may also play a role in vascular regulation, further contributing to observed variations in blood flow velocity.

Interestingly, our study identified an association between lower education levels and higher blood flow velocity. While this relationship has not been previously reported, a plausible explanation may lie in lifestyle differences. Individuals with lower education levels are often more likely to engage in physically demanding occupations, which may promote enhanced peripheral circulation due to increased muscle activity and improved venous return. Previous studies have demonstrated that physical exertion can positively impact venous hemodynamics, potentially contributing to elevated blood flow velocity[16].

Future studies could explore the role of occupational activity levels in PICC-related vascular dynamics to further elucidate this association.

Additionally, our study found that nutritional risk, as indicated by a higher NRS2002 score, was positively correlated with blood flow velocity. This finding may reflect a compensatory mechanism in malnourished patients, where elevated blood flow velocity occurs in response to compromised tissue oxygenation and metabolic demand[17]. This aligns with previous findings suggesting that patients with malnutrition may experience hyperdynamic circulation due to the body's attempt to maintain adequate tissue perfusion[18]. Such compensatory responses should be carefully monitored in clinical practice, as patients with increased blood flow velocity may remain at risk for vascular complications despite the absence of overt thrombotic symptoms.

Furthermore, the positive association between diastolic blood pressure and blood flow velocity aligns with established physiological mechanisms, as elevated blood pressure may enhance venous return and mitigate venous stasis[19]. Patients with higher diastolic blood pressure may experience improved peripheral circulation, which may contribute to higher blood flow velocities and reduced thrombotic risk. This finding suggests that blood pressure monitoring could provide additional insights into identifying patients at risk for PICC-related complications. These findings provide new perspectives on the multifactorial nature of blood flow regulation in PICC-inserted limbs and emphasize the importance of considering demographic, lifestyle, and clinical factors when assessing blood flow dynamics in cancer patients.

From a clinical perspective, these findings provide important guidance for nursing interventions aimed at optimizing PICC management strategies. For patients identified as having lower blood flow velocity, closer monitoring and proactive interventions may be warranted to mitigate thrombotic risks. For example, nursing staff may consider implementing early mobilization strategies, promoting limb exercises, or ensuring adequate hydration to enhance venous return in at-risk individuals. Moreover, recognizing that patients with lower education levels may engage in higher levels of physical activity can inform personalized patient education strategies to further optimize PICC outcomes.

This study employed several methodological approaches that enhance the robustness and reliability of the findings. Notably, blood flow velocity was assessed using Doppler ultrasound within 48 hours after PICC insertion, which ensured consistency in measurement timing and minimized the influence of post-procedural complications or progressive vascular changes. Doppler ultrasound is widely recognized as a non-invasive and highly accurate method for evaluating venous hemodynamics and has been recommended in PICC-related vascular assessment studies[20]. The measurement process involved obtaining three separate readings for each patient and averaging the values to improve data reliability. This approach reduces variability and enhances the precision of recorded blood flow velocity values, a strategy commonly applied in vascular research[7].

Another strength of this study is the comprehensive inclusion of potential influencing factors across multiple domains, including demographic, clinical, nutritional, and hemodynamic variables. The integration of the NRS2002 score to assess nutritional risk adds a valuable dimension to the analysis. While NRS2002 has traditionally been used to identify patients requiring nutritional intervention[21], its role in predicting blood flow velocity has not been previously explored. This study's identification of a positive correlation between nutritional risk and blood flow velocity expands the potential clinical utility of NRS2002 in vascular assessment.

Furthermore, this study's stepwise regression analysis ensured that only the most relevant predictors were retained in the final model, improving model stability and minimizing overfitting[22]. The use of this method effectively identified gender, education level, NRS2002 score, and diastolic blood pressure as independent predictors of blood flow velocity, strengthening the credibility of the findings. These methodological considerations collectively contribute to the novelty and scientific rigor of this study, offering valuable insights for clinical practice and future research.

5. Limitations and Future Directions

Despite its strengths, this study has several limitations that should be acknowledged. First, as a cross-sectional study, this research only captured a snapshot of blood flow velocity at a single time point, limiting the ability to infer causal relationships. Second, this study was conducted in a single-center setting, which may restrict the generalizability of the findings to other populations or healthcare environments. Third, while Doppler ultrasound is considered a reliable tool for assessing venous hemodynamics, operator-dependent variability remains a potential limitation despite efforts to minimize this through standardized protocols and multiple measurements. Additionally, the study did not account for other potential confounders such as medication use, hydration status, or physical activity patterns, which could have influenced blood flow velocity. Lastly, while this study identified key predictors of blood flow velocity, the overall model explained only a limited proportion of the variance in blood flow velocity, suggesting the presence of additional unmeasured factors.

Future research should consider conducting multicenter studies to enhance the generalizability of the findings. Longitudinal designs could provide insights into the dynamic changes in blood flow velocity over time and identify causal relationships. Moreover, incorporating additional variables such as inflammatory markers, lifestyle factors, and vascular anatomical variations may improve the predictive accuracy of blood flow velocity models. Integrating machine learning algorithms into future analyses could also facilitate the identification of complex interactions between multiple risk factors, further refining predictive models.

6. Conclusions

This study provides new insights into the factors influencing blood flow velocity in cancer patients with PICC. The findings suggest that demographic, nutritional, and hemodynamic factors should be carefully

considered in clinical practice to better predict and manage PICC-related complications. Although this study identified key influencing factors, further research is needed to validate these findings in larger, multicenter cohorts. Future studies should adopt prospective designs to explore the dynamic changes in blood flow velocity over time and assess the potential impact of additional variables such as inflammatory markers, lifestyle factors, and vascular anatomy. Moreover, integrating advanced predictive models, such as machine learning algorithms, may enhance the identification of patients at higher risk for PICC-related complications. These findings underscore the need for personalized nursing strategies to improve patient management, reduce adverse outcomes, and ensure the safe and effective use of PICC in clinical practice.

Abbreviations

PICC
Peripherally Inserted Central Catheter
BMI
Body Mass Index
NRS2002
Nutritional Risk Screening 2002
KPS
Karnofsky Performance Status
PT
Prothrombin Time
FIB
Fibrinogen
APTT
Activated Partial Thromboplastin Time
TT
Thrombin Time

Declarations

Author Contributions

Lu Ting contributed to research design, data analysis, and manuscript drafting. Wei Jiejing was responsible for data collection, organization. Xu Yi contributed to statistical analysis, manuscript revision, and served as the corresponding author. All authors read and approved the final version of the manuscript.

Funding

This research was supported by the Guangxi Zhuang Autonomous Region Health and Family Planning Commission (Grant No. Z20201111).

Conflicts of Interest

The authors declare that they have no competing interests.

Acknowledgements

The authors would like to thank the clinical and nursing teams at The First Affiliated Hospital of Guangxi Medical University and Nanxishan Hospital of Guangxi Zhuang Autonomous Region for their support throughout the study.

Clinical Trial Registration

Clinical trial number: Not applicable.

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