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ORIGINAL RESEARCH

The Effectiveness of Electronic Cannulation Atlas in Patients with Arteriovenous Fistula

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Objective: This study aimed to assess the effectiveness of an electronic cannulation atlas in preventing and treating complications of arteriovenous fistula.

Methods: The observation group, consisting of 92 dialysis patients from July to December 2021, was managed with an electronic cannulation atlas. After 6 months, the incidence of complications such as stenosis, hematoma, thrombus, aneurysm, and cannulation failure was compared between the groups. Nurse satisfaction with the electronic cannulation atlas system was also assessed through a questionnaire.

Results: The observation group had lower incidence rates of arteriovenous fistula stenosis, thrombus, aneurysm, and failure rate of cannulation compared to the control group, with statistically significant differences ($p<0.05$). The incidence rates of hematoa were similar in both groups, showing no significant difference ($p>0.05$). After 3 months of management, the incidence of arteriovenous fistula complications in the observation group was significantly lower than in the control group ($p<0.05$). Additionally, utilizing the electronic cannulation atlas system was found to increase nurses' job satisfaction.

Conclusion: The use of electronic cannulation atlas for the treatment of patients' arteriovenous fistula could effectively reduce the incidence of complications of patients' arteriovenous fistula, reduce the failure rate of cannulation, reduce the workload of nurses, and improve the job satisfaction of nurses.

Keywords: arteriovenous fistula, informatization, cannulation atlas, management of hemodialysis patients, complications

Introduction

Chronic kidney disease (CKD) has emerged as a significant health concern globally, following diseases such as diabetes, cardiovascular disease, and tumors. The incidence of CKD has been steadily increasing, with a global prevalence of 13.4%.[1] Research indicates that approximately 11% of the Chinese population suffer from CKD, equating to around 120 million individuals, and this number continues to rise annually.[2] Treatment options for end-stage kidney disease (ESKD) include hemodialysis, peritoneal dialysis, and kidney transplantation. Hemodialysis is the preferred choice for a majority of ESKD patients globally, ranging from 61.4% to 91.9%. This preference is influenced by factors such as the scarcity of kidney donors, the high expenses of surgery, and the risks of infection linked to peritoneal dialysis.[3–5] Arteriovenous fistula (AVF) is recommended as the primary dialysis access by experts and guidelines,[6,7] often referred to as the "lifeline" for hemodialysis patients. However, studies have shown that vascular access issues, particularly AVF patency, contribute significantly to the high hospitalization rate among dialysis patients. The two-year patency rate of AVF is only 75%, highlighting the importance of addressing vascular access maintenance in hemodialysis patients.[8] The management of arteriovenous fistulas in hemodialysis patients is crucial, with a focus on planning cannulation patterns, selecting cannulation angles, and improving cannulation methods.[9–12] However, as the number of patients using AVF for dialysis increases, the current management methods have limitations. Traditional paper Atlas increases nurses' workload

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and poses challenges in updating and storing information. Leveraging information technology and artificial intelligence in nursing can greatly reduce workload and enhance medical practices.[13,14] To address these issues, we developed an information management system for AVF cannulation management in hemodialysis patients. This system not only saves nursing resources but also ensures timely and accurate patient cannulation information, reducing complications. The study's positive outcomes were detailed below.

Study Design

Convenience sampling was utilized to select AVF patients attending our blood purification center from January 2021 to June 2021 as the control group, and those attending from July 2021 to December 2021 as the observation group. Patients entering the control group would not be included in the observation group (Figure 1).

Inclusion criteria included patients with arteriovenous fistula in dialysis mode, informed consent, absence of cognitive or communication disorders, a survival cycle of over 12 months, and with fistulas by radial artery-cephalic vein surgery. Exclusion criteria encompassed severe organic diseases, tumors, poor compliance, had undergone endovascular interventions. All patients were followed up for 6 months. A total of 92 patients were identified in the observation group and 85 in the control group, with no statistically significant differences in general patient data between the two groups (Table 1).

This study was approved by the Ethics Committee of The Central Hospital of Wuhan, Number: WHZXKYL2022-181, and performed following the guidelines outlined in the Declaration of Helsinki. Written informed consent was obtained from all the study participants.

1.1.2 The study included a total of 55 nurses working at the blood purification center between July and December 2021. The group consisted of 43 women and 12 men, with educational backgrounds including 1 master's degree, 45 bachelor's degrees, and 9 junior college degrees.

Methods

The Vascular Atlas Process

This study involved vascular atlas of the arteriovenous fistula in two groups of patients. The vascular access physician drew the vascular course on the patient's arm under ultrasound guidance. Subsequently, the vascular access nurse took

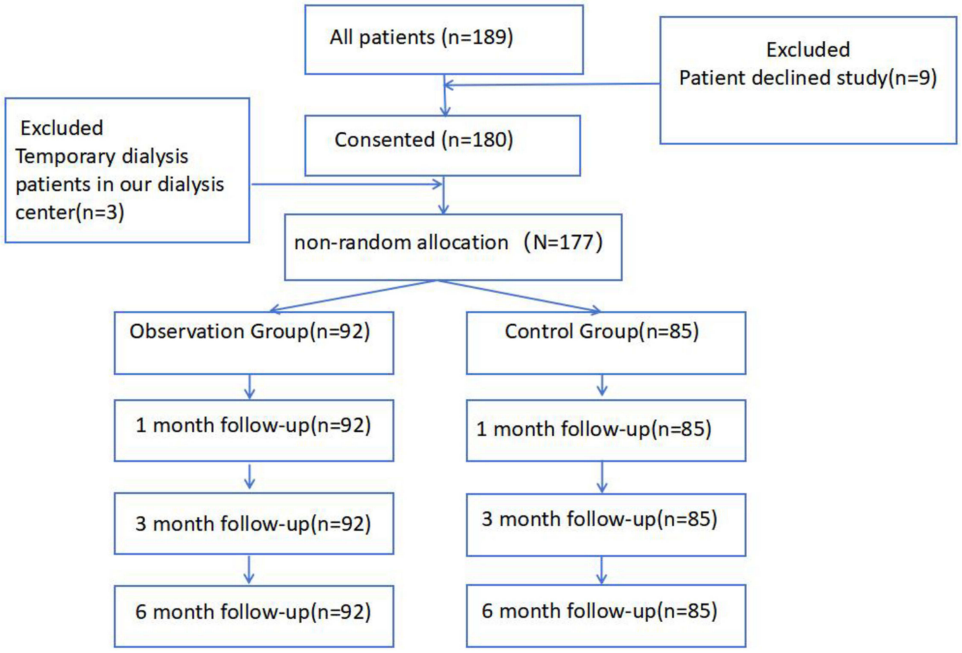

Figure 1 Flowchart of the study.n.

Table 1 Comparison of General Information of the Two Groups of Patients

Characteristic	Observation Group (n=92)	Control Group (n=85)	$t/\chi^2/z$	p
Gender			χ^2= 0.277	0.599
Male	61	55		
Female	31	30		
Age ($\bar{x} \pm s$) (years)	62.46±12.80	62.14±11.24	t=0.71	0.273
Educational attainment			z=−0.753	0.48
Below elementary school	59	54		
Secondary and post-secondary	32	27		
Undergraduate and above	1	4		
Length of dialysis(months)	50.90±36.34	56.82±22.47	t=1.29	0.198

a photograph of the atlas and marked the cannulation point. A paper atlas was created with the patient's vascular course printed on A4 paper, labeled with information such as the patient's name, gender, and ID number, and a file of cannulation information was generated. Electronic cannulation atlas entailed importing photos of the patient's vascular course into the electronic cannulation atlas management system and labeling the information related to the patient's arteriovenous fistula.

Interventions for Patients in the Control Group

In the control group, the nurse evaluated the patients' arteriovenous fistulas and used paper cannulation charts for management. These charts were kept by the vascular access team and placed bedside before dialysis sessions. The nurse recorded the cannulation points during dialysis, including site, angle, method, time, and any AVF-related complications.

The Design Process of Electron Cannulation Atlas

The design process of the electron cannulation atlas involves several key steps. Firstly, the vascular access physician created a diagram of the patient's AVF course with ultrasound guidance. Next, the vascular access nurse photographed the vascular access atlas and carefully edited the image to highlight the cannulation points (Figure 2). Subsequently, the nurse imported the edited photographs into the cannulation atlas module within the Xuetoutong system. The nurse then established the sequence of cannulation points in the electronic cannulation atlas system, which automatically suggested cannulation sites for each dialysis session. Additionally, the system allowed for the documentation of unforeseen events, such as multiple cannulation failures or hematomas during a dialysis session, with a red warning sign alerting the nurse.

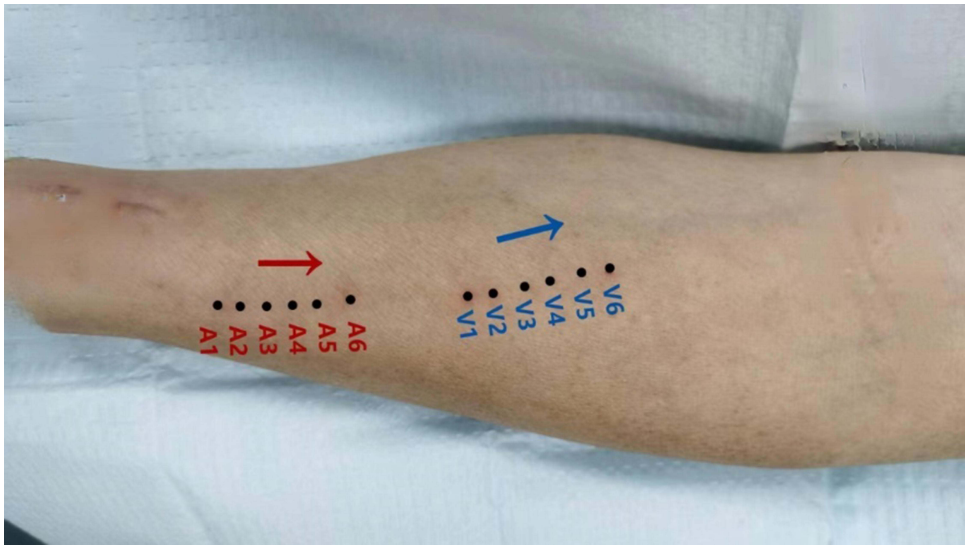

Figure 2 Photo for the some cannulation sites.

Notably, the electronic cannulation atlas had been granted a patent for invention with the patent number ZL201921939342.4.

Interventions for Patients in the Observation Group

Involved the use of an electronic cannulation atlas system. Nurses verified the patient's identity and cannulation information before the procedure. Following cannulation, nurses documented details such as the cannulation site, angle, method, time, and any AVF-related complications during dialysis.

1.3 Evaluation indexes: Statistics on the incidence of arteriovenous fistula-related complications such as: arteriovenous fistula stenosis, hematoma, thrombus, Aneurysms, cannulation failure rate, and nurses' satisfaction with the electronic cannulation atlas system in the two groups after 6 months.

Aneurysms was defined as a fistula with a diameter greater than three times the diameter of the surrounding normal internal fistula vessels or an absolute diameter greater than 1.8 cm.

Endovascular stenosis was the local stenosis greater than 50% of the diameter of nearby normal vessels with following conditions: natural blood flow of the AVF <500 mL/min; inability to meet the dialysis prescription; elevated dialysis venous pressure; difficulty in cannulation, decreased dialysis adequacy; and abnormal signs of the fistula.

Thrombosis was the presence of a blood clot in an arteriovenous fistula vessel as seen by the sonographer on ultrasound.

The satisfaction questionnaire comprised five sections: information utility, data accuracy, functional applicability, operational convenience, and overall satisfaction. Nurses rated each section on a 5-point Likert scale, ranging from "Strongly Disapprove" to "Strongly Approve", with a total possible score of 5 to 25. A higher score indicated a more positive evaluation of the system by nurses. The Cronbach's alpha coefficient for the questionnaire was calculated as 0.957, and all 55 distributed questionnaires were effectively collected.

Statistical Analysis

Excel was used for data entry, followed by double-checking and import into SPSS software version 27 (IBM Corp., Armonk, NY, USA). Normality tests were conducted, with count data presented as frequencies and percentages, and measurement data as mean ± standard deviation ($\bar{x} \pm s$). The chi-square test was applied for count data, while the *t*-test was used for normally distributed measurement data. Nonparametric tests, such as the rank sum test, were employed for data not conforming to normal distribution. The level of statistical significance was set at 5%.

Results

Comparison of Complications Associated with Arteriovenous Fistula After Applying Different Treatment Modalities in Two Groups (Table 2)

The control group had a total of 6120 cannulations at 6 months, resulting in 39 cannulation failures, while the observation group had 6623 cannulations with 11 failures.

This study demonstrated that the implementation of information management by nurses for patients with AVF resulted in lower incidence rates of complications such as hematoma (1.08% vs 3.53%), endovascular stenosis (5.43% vs 22.35%), thrombus (7.61% vs 21.18%), arteriovenous aneurysm (9.78% vs 20.00%), and cannulation failure rate

Table 2 Comparison of Complications Associated with Arteriovenous Fistula After Applying Different Treatment Modalities in Two Groups

Characteristic	Observation Group (n=92)	Control Group (n=85)	χ^2	p
Hematoma (%)	1 (1.08)	3 (3.53)	1.020	0.341
Endovascular stenosis (%)	5 (5.43)	19 (22.35)	6.921	0.009
Thrombosis (%)	7 (7.61)	18 (21.18)	6.705	0.010
Cannulation failure rate (%)	11 (0.17)	39 (0.63)	4.132	0.047
Aneurysms (%)	9 (9.78)	17 (20.00)	4.022	0.045

(0.17% vs 0.63%) in the observation group compared to the control group. Specifically, the rates of endovascular stenosis, thrombus, and arteriovenous aneurysm, and the cannulation failure rate were significantly lower in the observation group than in the control group ($p<0.05$). However, there was no significant difference in the incidence of hematoma between the two groups ($p>0.05$).

The Comparison of Complication Incidence of Arteriovenous Fistulae in Paper Cannulation Charts and Electronic Cannulation Atlas Groups at Different Time Periods (Table 3)

After 3 months of using different methods of cannulation management (paper cannulation charts and electronic cannulation atlas groups) in the 2 groups, the complication rate of arteriovenous fistula in the observation group was significantly lower than that in the control group, with a statistically significant difference ($p<0,05$).

Comparative Analysis of the Complications Time of Arteriovenous Fistula Due to Different Intubation Methods (Figure 3)

By Kaplan-Meier analysis, the occurrence of intra-arteriovenous fistulae in patients dialyzed with AVF within the first 2 months was not influenced by the method of cannulations. Additionally, the incidence of complications associated with intra-arteriovenous fistulae after three months was lower in patients in the observation group compared to those in the control group.

The Nurses' Satisfaction Survey on the Electronic Cannulation Atlas System (Table 4)

Satisfaction with the nurses' electronic cannulation atlas system was greater than 90% in all cases. Nurses' satisfaction was at a high level.

Discussion

Comparison of Complications Associated with Arteriovenous Fistula After Applying Different Treatment Modalities in Two Groups

The study suggested that the lower incidence of complications in the observation group may be attributed to factors such as nurses' cannulation technique proficiency, compression time, and pressure at the cannulation point post-dialysis. The research team proposed updating the system in the future to include information on optimal cannulation angles, subcutaneous depth, vessel diameter, and pressure of AVF to enhance nurses' success rates in cannulation AVF, reduce hematoma occurrence, and minimize cannulation-related damage in patient with AVF. Research had indicated that creating cannulation charts for nurses working with patients having arteriovenous fistulas can enhance the success rate of cannulation procedures, alleviate patient anxiety, and decrease the likelihood of complications.[15–18]

The most commonly used modalities for AVF cannulation in China are the buttonhole cannulation and the rope ladder cannulation method. In the buttonhole cannulation method, nurses used a sharp needle to repeatedly cannulated in the same position and angle until a tunnel was formed, then switched to a blunt needle. The rope ladder method involved alternating bottom-up cannulations along the vessel. However, increased AVF cannulations had been associated with

Table 3 Comparison of the Rate of AVF in Paper Cannulation Charts and Electronic Cannulation Atlas of Patients at Different Time Intervals

Groups	1 Month of Intervention (%)	2 Months of Intervention (%)	3 Months of Intervention (%)	6 Months of Intervention (%)
Observation Group (n=92)	0	8 (8.69)	15 (16.30)	22 (23.91)
Control Group (n=85)	0	12 (14.12)	27 (31.76)	57 (67.06)
c2	–	1.296	5.835	31.391
p	–	0.255	0.016	0.000

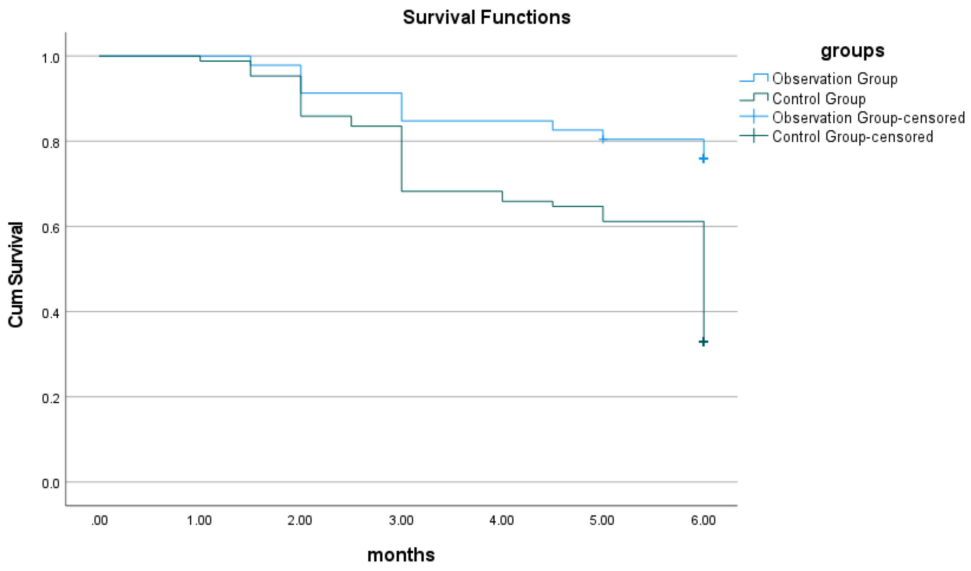

Figure 3 Surviva analysis for the primary patency.

thickening of the arteriovenous fistula vessel wall, raising the risk of Aneurysms and vessel stenosis.[19,20] The risk of vascular stenosis was also increased. The Chinese expert consensus on vascular access for hemodialysis recommended the rope ladder cannulation method. In contrast, The National Kidney Foundation 2019 KDOQI Clinical Practice Guideline for Vascular Access recommends rope ladder cannulation and limiting buttonhole cannulation to special circumstances. The 2018 Clinical Practice Guidelines of the European Society for Vascular Surgery recommend the buttonhole, They also recognize additional benefits of buttonhole cannulation, such as lower infiltration rates, less pain, and easier for self-cannulating patients.[6,7,21]

The buttonhole cannulation method was considered the most effective approach for preventing complications of aneurysms.[8] However, its implementation in clinical practice poses challenges. This method required a nurse to consistently cannulate at the same angle to create a complete subcutaneous tunnel. On the other hand, the rope ladder cannulation method imposes more stringent criteria on the patient's blood vessels, requiring them to be distensible and at least 6 cm in length. Hemodialysis patients, who were often elderly and might have underlying conditions like diabetes mellitus and hypertension, tend to have blood vessels in poor condition, making cannulation more difficult for nurses.[11,22,23] Patients' fear of pain often hindered nurses from changing the cannulation point, thereby making it challenging to implement the rope ladder cannulation method in clinical settings.[24] Our research team utilized information technology to strategically plan and establish fixed cannulation points for patients. By avoiding repeated cannulation

Table 4 Nurse Satisfaction Survey on Electronic Cannulation Atlas

Dimension (Math)	Satisfaction (Persons)					S
	CAM	F	I	D	SD	
Information Utility	32	19	4	0	0	92.72
Data Accuracy	34	21	0	0	0	100.00
Functional applicability	35	17	2	1	0	94.55
Operational Convenience	31	19	3	2	0	90.91
Overall satisfaction	32	21	2	0	0	96.36

Notes: Satisfaction = (number of people agreeing + number of people strongly agreeing)/total number of people x 100%.
Abbreviations: CAM, Could not agree more; F, favor; I, inconclusive; D, disapprove; SD, Strongly disagree; S, Satisfaction.

at new sites and instead focusing on forming fixed cannulation points, we were able to reduce patient pain and minimize damage to smooth muscle. The use of an electronic cannulation atlas resulted in fewer cannulation points for each patient, ultimately lowering the risk of Aneurysms formation caused by the impact of blood flow on the vein at the cannulation points.[25]

Utilizing information technology helped prevent subcutaneous tunnels and multiple cannulations at the same point, promoting vessel recovery and reducing infection risk of arteriovenous fistulas. Our electronic cannulation atlas combined buttonhole and rope ladder cannulation techniques, easing nurse requirements and implementation challenges. The atlas system provided access to previous dialysis data and used red markers to alert nurses of recent hemodialysis incidents, enhancing patient safety.

Comparative Analysis of the Rate of Complication of AVF in Two Groups of Patients Over Different Time Periods

The patency rate of AVF in patients was influenced by factors such as the patient's age and the nurse's cannulation technique. Improper choice of cannulation point and incorrect direction of cannulation by the nurse can lead to stenosis and thrombosis in patients.[11,26–28] The patient's age, the nurse's experience with cannulation technology, and their supervision of patients' self-monitoring of AVF were all factors that could impact the likelihood of complications in patients with AVF.[29,30] In this study, patients in the observation group were managed using an electronic cannulation atlas for AVF patients, while the control group received traditional cannulation atlas management. The results indicated that one-month post-intervention, neither group experienced AVF-related complications. However, three months post-intervention, the observation group had a 16.30% AVF-related complication rate, whereas the control group had a higher rate of 31.76% ($p<0.05$). Patients in the intervention group had a higher rate of first-time patency of the arteriovenous fistula than those in the control group at 6 months of the follow-up cycle ($p<0.05$). This significant difference ($p<0.05$) suggested that the implementation of an informatized electronic cannulation atlas was effective in reducing AVF-related complications in patients undergoing maintenance hemodialysis, especially with increasing dialysis duration. The implementation of electronic information atlas management for patients with AVF could effectively reduce the occurrence of AVF related complications as patients age and undergo dialysis. Updating paper cannulation atlases became challenging with increased dialysis time, leading to inconsistencies between actual cannulation points and the paper atlas information due to vessel dilatation. Electronic cannulation atlases allowed for real-time updates, accurate understanding of patient complications at different time periods, targeted health education, and recording of improvement measures. This electronic system not only ensured timely information on AVF, reduced nurse workload, but also increased nurse and patient enthusiasm for managing AVF.

Analysis of Nurses' Satisfaction with the Electronic Cannulation Atlas System

With the rise of big data and advancements in information technology, the field of nursing is expected to become more integrated with various information systems and technologies. This integration is anticipated to enhance the efficiency and job satisfaction of nurses.[31,32] The system utilizes efficient functions and large storage capacity to integrate and consolidate fragmented information on the patient's previous dialysis. This allows nurses to conduct a more comprehensive assessment of the patient based on their previous dialysis data, enabling a better understanding of the patient's condition and helping to prevent risks associated with the dialysis process. The satisfaction rate among nurses in this department regarding the electronic cannulation Atlas was 96.36%, indicating a general belief that the system provides convenience. However, satisfaction with the ease of operation was slightly lower at 90.91%. The quality control team has raised concerns about the system planning procedure, which could potentially lead to a 2-minute waiting time for nurses following the system planning steps for patients with AVF. The dialysis time for each patient is 4 hours, and each charge nurse is responsible for caring for 6 arteriovenous fistula (AVF) patients. This can create time constraints for the charge nurse. However, the system can guide the responsible nurses through the steps needed to carry out medical instructions. This is particularly helpful for younger nurses with less experience in cannulation. The electronic cannulation system not only aids nurses in performing the procedure, but also allows for a bidirectional check between humans and machines to

prevent the occurrence of avoidable adverse events. The electronic cannulation atlas system enhanced the scope and depth of the nursing information system, facilitating information integration and sharing while also assisting nurses in the improved assessment and management of patients.

Summary

Autologous AVF was a crucial vascular pathway for patients, and maintaining its patency and longevity was essential for patient survival. Implementing an electronic information technology system for AVF dialysis management streamlines processes, reduced errors, and minimized AVF-related complications, promoting self-repair of autologous AVF blood vessels. Healthcare provider should focus on establishing evidence-based management strategies, educating patients on health maintenance, and guiding them in implementing proper nursing care to safeguard this lifeline.

Limitations: As this study was non-randomized and limited to the blood purification center of our hospital, there were inherent limitations. The small sample size and inclusion of non-new fistula patients might impact the study results. Moving forward, it is recommended that scholars conduct regional randomized controlled studies, increase sample size, and explore scientific management methods to reduce AVF-related complications, prolong AVF service life, enhance patient quality of life, and extend patient survival.

Data Sharing Statement

The datasets analyzed during the current study are available from the corresponding author on reasonable request.

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Disclosure

Xu Fang reports a licensed patent for an electronic cannulation mapping device. All authors declare that there is no other conflict of interest in this work.

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