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Impact of needle bevel position during venipuncture on functional outcomes in hemodialysis patients. A single-center observational study.

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Received: January 8, 2026.
Accepted: March 27, 2026.
Published: March 30, 2026.
Editor: Dr. Franklin Mora.

How to cite:
Criollo L, Dorta J, Bacallao R, Borges M, De la Cruz V, Sánchez N. Impact of needle bevel position in venipuncture on functional outcomes in hemodialysis patients. A single-center observational study. REV SEN 2026; 14(2):157-171.

DOI: http://doi.org/10.56867/169
Sociedad Ecuatoriana de Nefrología, Diálisis y Trasplantes.
ISSN-L: 2953-6448

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Summary

Introduction: The position of the needle bevel during cannulation of the hemodialysis vascular access appears to influence pain, bleeding, and procedure efficiency, but the evidence is conflicting. The objective of this study was to identify the potential effect of the hemodialysis needle bevel position on hemostasis time, pain intensity, and the occurrence of complications, as well as on the delivered dialysis dose and extracorporeal circuit pressures.

Material and method: Experimental, randomized, controlled, single-center crossover study conducted in June-July 2025 at a private clinic in Ecuador. Patients with autogenous arteriovenous fistulas in use for over three months were included. Each patient served as their own control. The study lasted 4 weeks, with two weeks for each bevel position. Descriptive analyses and inferential statistics were applied.

Results: A total of 136 patients (3264 punctures) participated, 62.5% male. No significant differences were observed in arterial hemostasis times (9.92 vs. 9.85 minutes) or venous hemostasis times (10.38 vs. 10.32 minutes), nor in pain (1.73 vs. 1.87) based on bevel orientation. It also did not influence dialysis dose (1.82 vs. 1.80) or extracorporeal pressures. Bleeding from puncture was lower with the bevel facing downward (12.7% vs. 18.6%; *P*=0.001).

Conclusions: The orientation of the needle bevel does not affect hemostasis time, pain, received dialysis dose, or extracorporeal circuit pressures. The downward bevel orientation is associated with less bleeding during punctures.

Keywords: Hemodialysis; arteriovenous fistula; bevel; pain; bleeding.

Introduction

Despite current advances, the survival and quality of life of patients on hemodialysis (HD) are much lower than those of the general population [1]. A series of factors determine this, among which the deterioration of vascular access stands out. Even in patients with the best vascular access, the autologous arteriovenous fistula (AVF) is associated with early and late complications that reduce its survival, partly due to complications during puncture [2, 3].

A FAVa of a hemodialysis patient receives around 312 punctures per year (156 sessions x 2 punctures), which are accompanied by pain at the puncture site and the potential development of complications [4]. The pain from the puncture depends on the tearing caused by the needle in the skin and the underlying tissues, where sensitive nerve endings are located [5]. When the needle is removed, a small thrombus forms to seal the hole [2, 3]. As a result of repeated punctures, scar tissue with very little elasticity develops in the surrounding area, which can lead to stenosis and aneurysms [2].

To prevent this phenomenon, it is essential that the conical bevel of the needles be highly polished, which adds to the direction of the bevel during the puncture[4, 6]. In theoretical terms, it would seem advisable, for thrombus formation, to puncture with the bevel facing downward, provided the needle is positioned in the direction of the flow (toward the heart), as the flap tends to rise with the blood flow and close the puncture site [7].

The results of studies evaluating the impact of the bevel position of hemodialysis needles on pain, post-hemodialysis hemostasis time, the occurrence of complications, and their effect on hemodialysis technical parameters are heterogeneous [8-10]. In a study of 100 patients, it was observed that the downward bevel reduces bleeding during puncture and in the first hours of HD, but does not affect hemostasis at puncture sites upon needle removal [8]. Another crossover study of 35 patients found shorter hemostasis time and less pain with the downward bevel [9]. Conversely, in a randomized, crossover clinical trial of 42 patients, no differences were observed in post-hemodialysis hemostasis times, puncture pain, or extracorporeal circuit pressures by needle position [10].

The objective of the present study was to identify the possible effect of the bevel position of HD needles on hemostasis time, pain intensity, and the occurrence of short-term complications of AVF, as well as on the dialysis dose received and extracorporeal circuit pressures.

Materials and Methods

Study Design

This study is experimental, randomized, crossover design. The source is prospective.

DOI (Ecuadorian Society of Nephrology): http://doi.org/10.56867/164

Scenario

The present study was conducted at the Hemodiavyr Hemodialysis Center. Cia Ltda of the Complementary Health Network of Pichincha, in Quito, Ecuador. The study period was from June 1, 2025 to July 31, 2025.

Participants

Adult patients over 18 years of age were included, with upper limb autologous arteriovenous fistulas (AVF) (in bipuncture), on thrice-weekly hemodialysis (HD) for more than three months and willing to participate. Patients with known coagulation disorders were excluded; patients with deep AVF, hematomas, stenosis, thrombosis, or pseudoaneurysms were also excluded.

Variables

The sociodemographic variables were: age, sex, weight, height, and nutritional status. The cause of the disease, time in the hemodialysis program, type of AVF (distal or proximal), upper limb of the AVF, position of the arterial needle (with or against the flow), heparin dose, pain with punctures, hemostasis time when removing the needles, complications of the AVF, dialysis dose (KT/V), pre-pump blood pressure, and venous pressure were determined.

Data sources/measurements

The source was direct. Informed consent was obtained from all participants before the start of the study. For two weeks, nursing staff were trained in angioaccess puncture with the needle bevel facing downward and in using the visual analog scale to assess pain. Subsequently, the 4-week study continued as described above: 6 HD sessions in each bevel position. No changes were made to the hemodialysis prescription (including anticoagulation) or technique during the study; all hemodialysis sessions were performed on NIPRO Diamax machines with Elisio H dialyzers, and the needles were TulipTM 15G, manufactured by NIPRO Medical Corporation. In each HD session, one hour after the start of the session, venous and arterial (negative) pressure was collected at a blood flow rate of 300 ml/min (standard). Dialysis dose was also estimated using spectrophotocolorimetry with the HD machine's own equipment. The volume of distribution of urea (V) was estimated from total body water using Watson's (anthropometric) formula [11]. For nutritional assessment, body mass index and the WHO classification into categories were used [12].

Biases

The surveys were applied in a standardized manner by the principal investigator, using a pre-established guide approved in the research protocol. The information was reviewed by two researchers independently and recorded in copy. Only records with total agreement were included.

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Study size

The sample was probabilistic. The rate of stage 5d chronic kidney disease in the province of Pichincha is 102.63 cases per 100 thousand inhabitants (MSP Report, Ecuador, November 2022). With a population of 3,089,473 inhabitants in Pichincha, it is estimated that the province has 3,171 patients, of which 94.5% are in hemodialysis programs, constituting 2,996 patients. 98.7% of the cases have prevalence in adults, which is 2,957 cases. With an expected frequency of 10.5% for a single hemodialysis center, a confidence limit of 5%, and a confidence level of 95%, the sample size was 134 cases. EPI Info Version 7.2 was used (CDC, Atlanta, March 9, 2025, U.S.A.)

Quantitative variables

The results of the ordinal variables are presented in frequencies and percentages. The results of the scale variables are presented as averages. Scale variables were not converted into quantitative variables.

Statistical analysis

Descriptive statistics with frequency distribution were used for qualitative variables; absolute and relative frequencies (percentages) were calculated for each category of the variables. For quantitative variables, the mean and standard deviation were calculated, and in the specific case of patient age, the minimum and maximum were also determined.

Subsequently, to compare the hemostasis time, the intensity of puncture pain, and the technical aspects of hemodialysis between the two treatment groups, the parametric t-test for comparing means in independent samples was used. For comparing the frequency of angioaccess complications occurrence between these groups, the non-parametric homogeneity test (Pearson's Chi-square with continuity correction) was employed. For all hypothesis tests that were conducted, a significance level α=0.05 was set.

Results

Participants

A total of 136 patients were enrolled in the study, reaching 100% of the sample size.

Study population characteristics

The group had a mean age of 61 years, the youngest patient was 25 years old and the oldest was 93 years old. The distribution by age groups is presented in Table 1. There were 85 men (62.5%). The mean weight was 63.1 kg (SD- 11.5) and the average height was 157.7 cm (SD- 8.1). Table 1 presents the nutritional assessment of the patients according to body mass index, showing that patients with normal weight and overweight accounted for 87.5% of the study population.

The most common causes of CKD in patients were diabetes mellitus in 57 (41.9%) and arterial hypertension in 54 (39.7%) (Table 1). Patients had been on HD for an average of 54 months (4.5 years). Of the AVFs, 80 (58.8%) were proximal (from the elbow flexure: brachiocephalic or

DOI (Ecuadorian Society of Nephrology): http://doi.org/10.56867/164

brachiobasilic) and 56 (41.2%) distal (from the forearm, radiocephalic); 91 (66.9%) were located in the left upper limb. The arterial needle was placed in the direction of blood flow (toward the heart) in 108 patients (79.4%) and against the flow (toward the anastomosis) in 28 (20.6%), (Table 1). The average dose of regular heparin used per session was 1381.5 IU (SD - 960.4).

Table 1. Clinical characteristics of the patients.

Variable	Category	No.	%
Age groups (years)	< 30	2	1.5
	30-49	28	20.6
	50-69	65	47.8
	≥70	41	30.1
Gender	Male	85	62.5
	Female	51	37.5
Nutritional assessment	Malnourished	1	0.7
	Normal weight	68	50.0
	Overweight	51	37.5
	Obese	16	11.8
Cause of Chronic Kidney Disease	Diabetes mellitus	57	41.9
	Arterial hypertension	54	39.7
	Unknown	8	5.9
	Obstructive	7	5.1
	Other	5	3.7
	Non-diabetic glomerulopathy	3	2.2
	Polycystic kidney disease	2	1.5
Type of autologous arteriovenous fistula	Proximal (elbow)	80	50.8
	Distal (forearm)	56	41.2
Upper limb of the fistula	Left	91	66.9
	Right	45	33.1
Arterial needle position	With the flow	108	79.4
	Against the flow	28	20.6

Main results

When evaluating the potential effect of the bevel position on post-hemodialysis hemostasis time (Table 2), it was observed that there were no significant differences between post-hemodialysis bleeding times in arterial punctures (9.92 vs. 9.85 min) (P=0.081), nor in venous punctures (10.38 vs. 10.32 min) (P=0.151). The reported pain by bevel direction type showed no significant differences (P=0.06).

The analysis of complications arising from punctures (Table 3) reveals a higher frequency of bleeding at the time of puncture with the bevel facing upward (152) [18.6%] compared to the bevel facing downward (104) [12.7%]. The remaining short-term complications were very rare and showed no significant differences by bevel position.

Table 2. Mean and standard deviation of post-hemodialysis bleeding times and pain with punctures according to bevel position.

Variable	Bevel upward		Bevel downward		*P*
	Mean	S.D	Mean	S.D	
Arterial bleeding time (min)	9.92	1.83	9.85	1.81	0.081
Bleeding time venous (min)	10.38	1.78	10.32	1.84	0.151
Pain (visual analog scale 0-10)	1.73	1.27	1.87	1.36	0.060

Table 3. Complications of vascular access punctures according to the bevel position.

Complication	Bevel upward		Bevel downward		*P*
	No.	%	No.	%	
Bleeding with punctures	152	18.6	104	12.7	0.001
Bleeding within the first hour	0	0	3	0.4	0.083
Hematoma	2	0.2	4	0.5	0.413
Bleeding within the second hour	0	0	0	0	---
Pseudoaneurysm	0	0	0	0	---
Thrombosis	0	0	0	0	---
Stenosis	0	0	0	0	---

Table 4. Dialysis dose and extracorporeal system pressures according to bevel position.

Variable	Bevel upward		Bevel downward		*P*
	Mean	S.D	Mean	S.D	
KT/V (dimensionless)	1.82	0.18	1.80	0.18	0.057
Pre-pump arterial pressure (mmHg)	-209.1	85.14	-213.0	85.85	0.431
Venous pressure (mmHg)	140.1	34.8	139.8	32.5	0.401

When examining the dialysis dose received (KT/V) per HD session (Table 4), it can be observed that the values were very similar across bevel positions, differing by only 0.02. Similarly, the pre-pump arterial and venous pressures did not differ by bevel position, with respective mean values of -209.1 and -213.0 mmHg for the bevel facing upwards and downwards, and 140.1 and 139.8 mmHg.

Discussion

Main study findings

The present study evaluated the effect of bevel position (upward versus downward) during arteriovenous fistula puncture in a cohort of 136 chronic hemodialysis patients, predominantly elderly male adults with chronic kidney disease secondary to diabetes mellitus and arterial hypertension. The most relevant finding of this research demonstrates that bevel orientation does not significantly influence post-hemodialysis hemostasis times, patient-perceived pain, treatment efficacy (measured through Kt/V), or extracorporeal system line pressures. However, it was observed that the puncture technique with the bevel upward is associated with a significantly higher frequency

of bleeding at the exact moment of puncture compared to the bevel downward (18.6% vs. 12.7%, *P*=0.001), whereas the remaining short-term complications were infrequent and independent of the technique used.

Interpretations

From a clinical perspective, equivalence in hemostasis times, system pressures, and clearance (Kt/V) suggests that both cannulation techniques are safe and ensure the efficacy of dialysis treatment, without compromising the long-term integrity of vascular access or extracorporeal circuit hemodynamics. However, the significant disparity in immediate bleeding during puncture has important practical implications. This phenomenon could be explained by the mechanics of the incision: introducing the needle with the bevel facing upward tends to lift a small "flap" of epidermal and vascular tissue, facilitating temporary blood extravasation before the needle is fully settled. In contrast, insertion with the bevel facing downward acts like a scalpel, creating a more linear and clean cut that allows tissues to adjust tightly around the needle body. Consequently, adopting the bevel-down puncture technique could represent a valuable strategy in hemodialysis units not only to optimize procedural neatness but also to reduce patient anxiety associated with blood visualization and lower the occupational risk of biological fluid exposure for nursing staff.

Practical applications

Translating these results into daily clinical practice, the main application lies in the opportunity to standardize and optimize cannulation protocols in hemodialysis units. Since insertion with the bevel facing downward has been shown to significantly reduce initial blood extravasation without compromising treatment efficacy or increasing pain perception, its systematic adoption offers clear operational advantages. On the one hand, it makes nursing processes more efficient by reducing the need for additional interventions and supplies to control spot bleeding, while simultaneously decreasing the biological and occupational risks associated with fluid handling. On the other hand, it directly impacts the quality of care: by minimizing visual exposure to blood, the psychological stress and apprehension patients experience during circuit connection are mitigated. Consequently, these findings provide strong evidence for updating procedure manuals and service quality management, suggesting the incorporation of the downward bevel technique into continuing education programs as a practice of excellence in vascular access care.

Related studies

The effect of the bevel position of HD needles on technical elements such as dialysis dose and extracorporeal circuit pressures, as well as on puncture pain and the occurrence of angioaccess complications, is an important and controversial topic, as not all evidence points in the same direction [10]. Consequently, this is a subject that requires international-scale research efforts; however, there are no Latin American studies providing robust evidence in this regard [10, 13, 14].

Among the characteristics of the participating patients, it is noteworthy that more than half will use a proximal AVF, when the vascular access management guidelines recommend starting with the most distal locations [2, 4]. This may have been influenced by the fact that the most frequent cause of CKD is diabetes mellitus, and in these patients, the creation of AVFs, in general and especially in thin vessels (more distal), is difficult [15]. Additionally, in other similar series, a predominance of proximal accesses is observed [10].

The predominance of FAVa on the left side was expected, considering that it is recommended to perform it on the non-dominant limb and that the majority of the population is right-handed [16].

The absence of differences in hemostasis times at the end of HD, in both arterial and venous access, contrasts with the results of Gaspar et al., who, in 17 patients (374 punctures per bevel position), found shorter hemostasis times with the bevel facing downward [17]. Similarly, Özen et al., also found in a study similar to ours (two weeks in each bevel position), but with only 35 patients, a reduction in post-hemodialysis hemostasis time [9]. In the evaluation of this particular aspect, the work of Crespo et al. is very interesting, who in a study of 48 patients compared the size of the skin incision with the puncture (expression of tearing, and potential origin of bleeding and pain) in both bevel positions, and found that the size of the skin incision was smaller with the bevel facing downward [18]. However, Fernández Castillo et al., as in this study, could not demonstrate a shortening of hemostasis times with the bevel facing downward [8]. Likewise, in their trial, Loizeau et al. found no differences in hemostasis times based on the orientation of the HD needle bevel [10].

The pain from HD punctures is a problem to be solved, as it is a common complaint among patients, with a deleterious impact on the quality of life of individuals, who may even prefer a central catheter as vascular access, with all the risks that this entails, due to fear of puncture pain [19-21].

The intensity of pain in our series is quite mild, with a mean below 2 on the visual analog scale (0-10), and is very similar to that reported by Loizeau et al. [10]. On the other hand, Airken et al. have indicated that the reported magnitude of puncture pain is influenced by the tool used, as although 25% of patients report severe pain in the questionnaire, the average value on the numerical scale is only 3 [22].

Regarding the position of the bevel, in the previously mentioned studies by Özen et al. and Crespo et al., less pain was observed with the bevel oriented downward [9, 18]. However, Crespo et al. could not document a correlation between pain intensity and the size of the skin incision 18. Nevertheless, Loizeau et al. found no relationship between bevel orientation and pain [10]. Similarly, Mahmoud et al. found no differences in reported pain during arterial needle punctures of the AVF in 50 patients [23].

The lesser bleeding with the puncture, identified in this study by the bevel facing downward, is consistent with multiple studies and appears to be the most consistent finding in this type of research [4, 8, 17, 18]. This is a very important element to consider, especially in patients with a tendency to bleed [4].

Although the technical elements of HD, such as KT/V and extracorporeal circuit pressures, have been less studied according to the bevel position, as in this study, no consistent evidence of a relationship between these elements has been found, unlike changes in HD needle gauge, which do seem to influence the efficiency of the dialysis procedure [10, 25].

It should be kept in mind that, regardless of the findings of this study, a personalized approach to angioaccess puncture is advocated, in which the nurse's experience and the resources available in the unit carry significant weight, as new technical elements such as ultrasound-guided cannulation and plastic cannulas are gaining more space every day, along with continuous training programs for nephrology nursing [26]. This study's strengths include the large number of patients included and the fact that they served as their own controls (crucial when investigating

subjective variables such as pain), but it is a single-center study and the observation period was relatively short.

Study Limitations

Despite the clinical utility of our findings, it is crucial to acknowledge certain methodological limitations in the present study. First, the research design focused exclusively on the evaluation of hemodynamic variables and short-term complications (such as immediate bleeding, post-session hemostasis, and intradialytic efficacy). Therefore, the current data do not allow us to determine whether the bevel position has a long-term impact on arteriovenous fistula survival, vascular endothelial preservation, or the development of chronic structural complications such as stenosis or pseudoaneurysms. Second, since cannulation is an inherently operator-dependent procedure, it is impossible to establish a strict double-blind design; nursing staff inevitably know the technique used, which could introduce unintentional bias in puncture site compression or bleeding reporting. Finally, although the sample size was fully achieved, multicenter studies with prospective longitudinal follow-up are necessary to validate the generalization of these results to more heterogeneous populations and to evaluate the biomechanical behavior of the vascular access over time. Therefore, future studies should address these research avenues.

Conclusion

The orientation of the bevel of hemodialysis needles during puncture does not affect the hemostasis time of the AVF at the end of hemodialysis, the pain perceived by the patient during puncture, the received dialysis dose, or the extracorporeal circuit pressures. The downward bevel orientation is associated with a lower frequency of bleeding during punctures.

Abbreviations

AVF: Autologous arteriovenous fistula.
HD: Hemodialysis.
SD: Standard deviation.

Supplementary Information

Supplementary materials have not been declared.

Acknowledgments

We thank the medical, nursing, administrative staff, and patients of the Vyr HEMODIAVYR unit where the study was conducted.

Author Contributions

Luisa Fernanda Criollo Pullupax: Conceptualization, data curation, investigation, visualization, original draft writing.
José Antonio Dorta Díaz: Conceptualization, formal analysis, methodology, project administration, resources, software, supervision, validation, writing – review and editing.
Raymed Antonio Bacallao Méndez: Conceptualization, data curation, investigation, visualization, and original draft writing.

Mariant Borges Colina: Conceptualization, data curation, investigation, visualization, and original draft writing.
Katty Victoria de la Cruz Angulo: Conceptualization, data curation, investigation, visualization, and original draft writing.
Narcisa Verónica Sánchez Ruiz: Conceptualization, data curation, investigation, visualization, and original draft writing.
All authors read and approved the final version of the manuscript.

Funding
The study was self-funded by the authors.

Data or materials availability
There is availability to share the data or materials of the present study upon request to the corresponding author, with a justified academic request.

Declarations

Ethics Committee Approval and Consent to Participate
The protocol was approved by the ethics committee of the institution "Centro de Hemodiálisis Vyr HEMODIAVYR", Quito, Ecuador.

Consent for Publication
Not applicable when specific patient images, X-rays, or photographs are not published.

Conflicts of Interest
The authors declare no conflicts of interest.

Use of Generative AI
The authors declare that they have used generative AI responsibly, without replacing the authors' critical thinking, expertise, and judgment. The AI was used under supervision and control to develop the discussion section. The use of the AI tool maintains the privacy and confidentiality of data and contributions, including published and unpublished manuscripts, as well as any personally identifiable information. The journal's policies, which allow the use of generative AI only in the introduction and discussion sections, have been complied with.
Only limited rights are granted to AI to provide a service.
The accuracy, completeness, and impartiality of all AI-generated results were carefully reviewed and verified to ensure that the manuscript reflects an authentic and original contribution.

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DOI (Sociedad Ecuatoriana de Nefrología): http://doi.org/10.56867/169