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Utility of a scheduled puncture map of prosthetic vascular acess for hemodialysis in daily practice

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ABSTRACT

Introduction: Polytetrafluoroethylene prosthetic fistulas are an alternative when native vascular accesses are not viable. Their use is associated with more complications and lower survival related to repetitive punctures.

Objectives: To describe the technique and puncture characteristics of prosthetic fistulas, and analyze the practical utility after the implementation of a scheduled puncture map.

Material and Method: We conducted a 6-week prospective, single-center study, with patients with prosthetic fistulas. We analyzed clinical and sociodemographic characteristics, puncture technique, ultrasound parameters, degree of clinical and ultrasound destructuring, dialysis characteristics, and vascular access-related complications, after the implementation of a scheduled puncture map.

Results: A total of 6 hemodialysis patients with prosthetic fistulas were studied (50% women, 80% humeroaxillary). The mean prosthesis usage time was: 47.1±46.1 months and they had a mean of 2.6±3.4 previous vascular accesses. All patients were punctured in an antegrade direction and with 16G gauge needles. At the end of the 3 study, we increased the percentage of patients with ladder puncture (60 vs 100%) as well as the distance between needles (9.3±1.3 vs 12.3±1.4 cm; p < 0.05), withoutchanges to the analyzed parameters. Throughout the study, 2 patients presented hematomas and extravasations, without other complications.

Conclusions: The implementation of a scheduled puncture map allowed us to improve the technique and optimize the puncture of prosthetic fistulas without any associated complications. We consider the implementation of our scheduled puncture map important in our routine clinical practice.

Keywords: vascular access; hemodialysis; polytetrafluoroethylene prosthesis and scheduled puncture map.

RESUMEN

Utilidad de un mapa de punción programada del acceso vascular protésico para hemodiálisis en la práctica diaria

Introducción: Las fístulas protésicas de politetrafluoroetileno constituyen una alternativa cuando los accesos vasculares nativos no son viables. Su uso se asocia a más complicaciones y menor supervivencia relacionada con su punción repetitiva.

Objetivos: Describir la técnica y características de punción de las fístulas protésicas, y analizar la utilidad práctica tras implementar un mapa de punción programada.

Material y Método: Estudio unicéntrico prospectivo de 6 semanas, con pacientes con fístulas protésicas. Analizamos características clínicas y sociodemográficas, técnica de punción, parámetros ecográficos, grado de desestructuración clínica y ecográfica, características de diálisis, y complicaciones relacionadas con el acceso vascular, tras la implementación de un mapa de punción programada.

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Resultados: Se estudiaron 6 pacientes en hemodiálisis, con fístula protésicas (50% mujeres, 80% húmero axilar). El tiempo medio uso de la prótesis fue: 47,1±46,1 meses y tenían una media de 2,6±3,4 accesos vasculares previos. Todos los pacientes eran puncionados en dirección anterógrada y con agujas de calibre 16G. Al final del estudio incrementamos el porcentaje de pacientes con punción en escalera (60 vs 100%) y un aumento de la distancia entre agujas (9,3±1,3 vs 12,3±1,4 cm, p<0,05), sin alteraciones en los parámetros analizados. A lo largo del estudio, 2 pacientes presentaron hematomas y extravasaciones, sin otras complicaciones.

Conclusiones: la implementación de un mapa de punción programada permitió mejorar la técnica y optimizar la punción de las fístulas protésicas sin complicaciones asociadas. Consideraremos importante la implementación de nuestro mapa de punción programada en la práctica clínica diaria.

Palabras clave: acceso vascular; hemodiálisis; prótesis de politetrafluoroetileno y mapa de punción programada.

INTRODUCTION

Patients with Chronic Kidney Disease (CKD) who require renal replacement therapy through hemodialysis (HD) need an adequate and well-functioning vascular access (VA) that provides appropriate blood flow for optimal treatment efficacy[1,2].

It is well known that the native arteriovenous fistula (nAVF) has a higher survival rate and fewer complications than other accesses, and should be considered the first choice for vascular access[1-3]. The nAVF is the VA of choice for patients receiving renal replacement therapy via HD, due to its high survival rate and lower rate of complications[1,2,6,7]. Polytetrafluoroethylene prosthetic arteriovenous fistulas (pAVFs) are an effective alternative when native VAs are not viable. Often, cannulation is difficult due to these patients' poor vascular condition and history of failed native VAs, leading to repeated punctures in the same location[2,3]. As a result, their use is associated with more complications such as aneurysmal dilations and prosthetic wall damage, ultimately reducing VA survival[1-3,6]. Therefore, it is crucial to develop strategies that improve cannulation techniques and minimize complications related to vascular access in patients with pAVFs.

A proper cannulation technique is vital for the long-term survival of fistulas. Nurses are primarily responsible for VA cannulation in HD and must learn and develop this skill as best as possible while also being capable of detecting potential complications[6,7].

Various clinical VA guidelines highlight that the most appropriate cannulation technique for both native and prosthetic fistulas is the stepwise or rotational puncture method, as it better preserves VA integrity and longevity[1,6,7]. This technique involves punctures along the entire venous pathway or prosthesis, helping to maintain the structural integrity of the VA wall and preventing dilations or aneurysms.

Typically, patients with a pAVF for HD have significant associated comorbidities, poor vascular conditions, and a history of failed native VAs. These factors often complicate the correct cannulation of the PTFE and contribute to structural complications or even thrombosis[2-8,10].

Given the need to maximize the efficacy and durability of vascular access in these patients, the implementation of a scheduled puncture map (SPM) could represent a significant advancement in clinical practice, offering a structured and systematic guide for cannulation that could improve the long-term survival and performance of pAVFs in HD.

The aim of our study was to describe the cannulation technique and characteristics of pAVFs in our unit and to assess the practical utility of implementing a SPM.

MATERIAL AND METHOD

We conducted a single-center, 6-week prospective study. Patients from the Consorci Sanitari de Terrassa (CST) on regular HD and with a normally functioning pAVF for more than 3 months, who gave informed consent, were included. Patients with nAVFs or using catheters as VA for HD were excluded.

We analyzed the main clinical characteristics, sociodemographic data, and history of previous VAs of the included patients. Data were collected regarding the VA cannulation technique: type of puncture, direction, needle gauge and distance between needles, as well as hemostasis time. Additionally, humeral blood flow (Qa) and the arterial and venous diameters at the puncture site of the prosthesis were evaluated using Doppler ultrasound, along with standard dialysis parameters (pump flow, dynamic pressures, recirculation percentage, KT, liters cleared), and various clinical complications related to VA (pain score via VAS, hematomas, extravasations, or thrombosis).

Furthermore, the degree of clinical and ultrasound-based prosthesis deterioration was assessed using custom-designed evaluation scales. Clinical deterioration was evaluated by experienced staff based on visual or palpable signs of structural damage due to repeated use or procedural complications.

Three weekly evaluations were averaged. Clinical scores ranged from 0 to 2 (0=no visible or palpable deterioration, 1=occasional damaged area, signs of hematoma, hardening, prosthesis enlargement, or small aneurysm, 2=visibly or palpably deteriorated prosthesis).

Ultrasound-based deterioration was assessed using a proprietary scale evaluating prosthesis condition. It included

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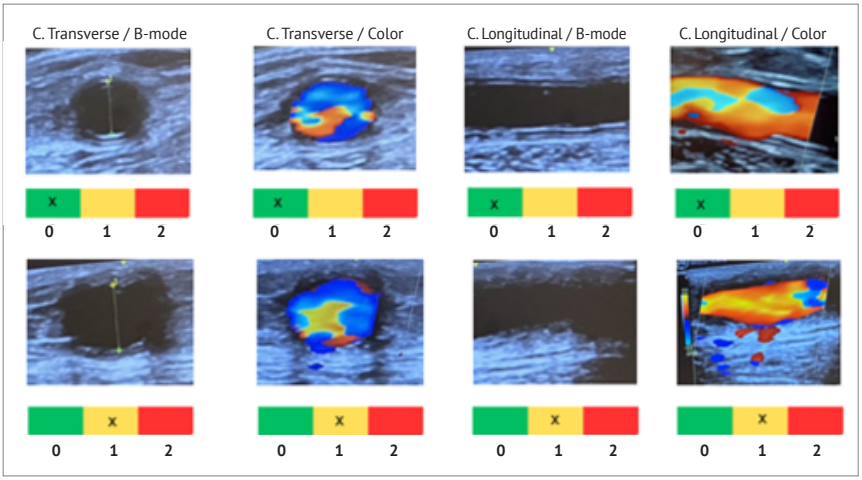

Figure 1. Degree of ultrasound disorganization. Degree of disorganization assessed using a qualitative scale with scores ranging from 0 to 2 (0= absence of disorganization, 1= occasionally disorganized area, 2= disorganized prosthesis), evaluated in both B-mode and color Doppler, in transverse and longitudinal planes.

ultrasound assessment of structural (surface or texture irregularities) and hemodynamic (blood flow abnormalities) changes, as well as the integrity of surrounding tissue.

Four ultrasound zones were defined: distal zone (outside usual arterial puncture sites), habitual arterial puncture zone, habitual venous puncture zone, and proximal zone (outside usual venous puncture sites). Each zone was scored from 0 to 2 (0=no deterioration, 1=occasional deterioration, 2=deteriorated prosthesis) in B-mode and color Doppler, in transverse and longitudinal planes. The total score ranged from 0 to 16 (absent 1–4, mild 5–8, moderate 9–12, severe 13–16) **(figure 1)**.

At the start, prosthesis appearance and function were analyzed through physical examination and standardized ultrasound, establishing usual puncture zones. All assessments were conducted by the same medical and nursing team throughout the study. Ultrasound evaluations were performed by a single physician. Each patient was assigned to the same nurse for the entire study.

Following this, the SPM was implemented. It consisted of a clockwise rotation cannulation scheme based on the initial ultrasound evaluation. Stepwise cannulation was indicated for all pAVFs. Each session followed the SPM to determine puncture location. If the indicated site could not be used, it was marked and an alternative zone selected. A single nurse ensured correct adherence to the SPM throughout, without changes in cannulation technique **(figure 2)**.

All variables mentioned earlier were analyzed at the beginning and end of the study.

Descriptive statistical analysis was performed using SPSS version 27. Quantitative variables were expressed as mean and standard deviation. Qualitative variables were expressed as percentages or frequency distribution. The Mann-Whitney U test or Wilcoxon test was used to compare variables. Statistical significance was set at $p<0.05$.

The entire study was conducted in accordance with Good Clinical Practice and the Declaration of Helsinki, with prior approval and institutional guidelines.

RESULTS

Our HD unit includes a total of 64 prevalent hospital-based patients, divided into daily shifts of 16 patients in the morning and afternoon from Monday through Saturday.

During the study period, a total of 6 patients with pAVFs were included. Table 1 shows the main clinical and demographic characteristics. The main cause of CKD in 3 patients (50%) was diabetic nephropathy. Half were women (3 patients, 50%) and half men. Their mean age was 66.1±15.1 years, with a mean of 78.1±73.4 months on HD. The mean Charlson Index was 10.1±2.6 points. Hypertension was the main cardiovascular risk factor in 5 patients (83%). Two patients (33%) were on antiplatelets and 1 (17%) on anticoagulants.

In 4 patients (80%), the prosthesis was located in the humero-axillary region. The mean use duration of the prosthesis was 47.1±46.1 months, with a mean of 2.6±3.4 previous VAs. All patients underwent anterograde needle punctures using 16G needles.

At the end of the study, stepwise puncture use increased from 4 to 6 patients (60% to 100%), with a significant increase in the distance between needles (9.3±1.3 cm vs. 12.3±1.4 cm,

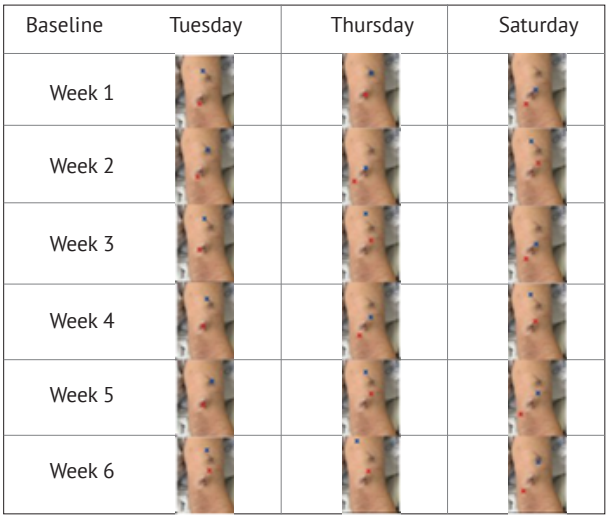

Figure 2. Scheduled puncture map.

Table 1. Main clinical and demographic characteristics of the patients.

PACIENTE	EDAD	FACTORES DE RIESGO	SEXO	TIEMPO EN HD	ETIOLOGÍA ERC	LOCALIZACIÓN PTFE	AV PREVIOS	MESES USO PTFE
1	56	DM, HTN	M	31	DM	HUMERAL	1	55
2	49		M	360	CKD-TIN	FEMORAL	9	171
3	72	DM, HTN	M	6	UNDEFINED	HUMERAL	0	10
4	55	DM, HTN, ASA	M	24	DM	HUMERAL	2	34
5	88	HTN, IHD, ASA	M	88	HTN	FEMORAL	4	72
6	64	DM, HTN, IHD, OAC	M	13	DM	HUMERAL	0	28

Main clinical and demographic characteristics of the patients: age (years); DM: diabetes mellitus; HTN: hypertension; ASA: acetylsalicylic acid; IHD: ischemic heart disease; OAC: oral anticoagulants; M: male; F: female; HD time in months; CKD-TIN: chronic tubulointerstitial nephropathy.

p<0.05), without changes in clinical (0.81±0.9 vs. 0.83±0.9) or ultrasound deterioration (6.2±5.7 vs. 6.3±5.6), hemostasis time (15.1±2.5 vs. 17.4±3.4 minutes), pain level (VAS 1.2±1.4 vs. 1.1±1.2), or humeral flow (Qa 1671.3±496.2 vs. 1605.8±579.1 mL/min).

No significant changes were observed in dialysis parameters (start vs. end): blood flow (Qb 390±20.3 vs. 391±20.4 ml/min), dynamic arterial pressure (DAP 218±13.4 vs. 221±12.9 mmHg), venous pressure (VP 247±10.6 vs. 250±25.5 mmHg), dialysis dose (Kt 48.5±2.9 vs. 49.7±3.7), recirculation percentage (Rc 13.2±1.2 vs. 13.1±2.7%), and liters of blood cleared (88.8±3.2 vs. 90.9±3.1).

Two patients developed hematomas and extravasations. No episodes of prosthesis thrombosis were reported

DISCUSSION

Our results show that implementing an SPM can improve cannulation technique in pAVFs without compromising vascular access durability or HD therapy effectiveness. Furthermore, it offers safety, as no major VA-related complications occurred during the study period.

After a comprehensive literature review, we found no published studies on the use of SPMs in routine clinical practice, making it difficult to compare our results. Unfortunately, the potential advantages of buttonhole cannulation in terms of hematomas, extravasations, or aneurysm formation have not been evaluated in prosthetic VAs, as current guidelines recommend stepwise cannulation and suggest puncture diagrams to preserve functionality and avoid complications[1,11,12]. Other strategies, such as digital VA monitoring, ultrasound-guided puncture, or AI-based puncture programs, may help detect thrombosis-risk events earlier[13,15].

Based on our findings, this cannulation strategy for prosthetic VAs can be a useful daily tool for optimizing management and improving efficacy and survival of vascular accesses. Therefore, we plan to implement the SPM in our unit's routine clinical practice.

Additionally, our results provide valuable information about the cannulation technique and characteristics of pAVFs in our unit.

We succeeded in improving the technique, ensuring that by study end, all prostheses were cannulated using the stepwise technique. We also significantly increased puncture length without associated complications. These results should, in theory, help preserve VA integrity and reduce complications. However, we cannot provide long-term patency and survival data due to the short follow-up period.

Puncturing pAVFs in "native" segments, as guided by ultrasound per our SPM, was safe and effective. This is supported by the lack of significant changes in prosthesis clinical or ultrasound deterioration, hemostasis time, pain level, humeral flow, or standard dialysis parameters. No thromboses occurred, though some patients did experience minor complications like hematomas and extravasations – common in daily practice[1]–linked to initiating puncture in newly evaluated native segments.

Of note, importance of accurate ultrasound evaluation in difficult VA cannulations, allowing alternative sites beyond habitual zones in pAVFs. Nursing staff should be proficient in routine VA ultrasound and further their knowledge of ultrasound-guided cannulation[16], especially in complex cases.

The main strength of our study lies in its innovative nature and ease of implementation in daily clinical practice using rigorous methodology. In our view, the SPM could be integrated into any HD unit with minimal requirements.

Regarding the study's limitations, it is worth mentioning its single-center nature and the small sample size, which was limited by the current number of AV grafts in our unit. However, this single-center approach allowed for greater rigor in the methodology used. Similarly, the short study period did not allow for the analysis of data related to survival or other complications over a longer timeframe. Finally, the lack of validated scales for assessing prosthesis deterioration may influence our results, although we did not find any standardized scales in the literature focused on the

deterioration of prosthetic AV accesses. Therefore, our results should be interpreted with caution, as they are based solely on our experience and exclusively on this type of vascular access. Studies with better designs are needed to establish more robust conclusions. Nevertheless, this work can serve as an initial point for the development of future studies to assess the long-term utility of a SPM in prosthetic AV accesses.

In conclusion, the results of this study suggest that the implementation of an SPM can improve the puncture technique in grafts, without compromising the durability of the vascular access or the effectiveness of HD therapy. This strategy can be considered a useful tool in daily clinical practice to maximize the effectiveness and survival of vascular accesses.

These findings are promising and support the consideration of implementing SPM in daily clinical practice. However, further research is needed to confirm these results and evaluate the long-term utility of SPM.

Conflicts of interest

The authors declare no conflicts of interest related to the research, authorship, and/or publication of this manuscript.

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