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The impact of anatomical variables on haemodialysis tunnelled catheter replacement without fluoroscopy

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Abstract

Aim: Tunnelled haemodialysis (HD) catheters can be used instantly, but there are several anatomical variables that could impact it survival. This study aimed to examine the impact of different novel anatomic variables, with catheter replacement.

Methods: In a single-centre a prospective cohort in chronic kidney disease G5 patients were conducted. The primary outcome was to determine the factors associated with catheter replacement during the first 6-month of follow-up. All procedures were performed without fluoroscopy. Three anatomic regions for catheter tip position were established: considered as superior vena cava (SVC), cavo-atrial junction (CAJ) and mid-to deep atrium (MDA). Many other anatomical variables were measured. Catheter-related bloodstream infection was also included.

Results: Between January 2019 and January 2020 a total of 75 patients with tunnelled catheter insertion were analysed. Catheter replacement at 6-month occur in 10 (13.3%) patients. By multivariate analysis, the incorrect catheter tip position (SVC) (OR 1.23, 95% CI 1.07–1.42, p <.004), the presence of extrasystoles during the procedure (OR 0.88, 95% CI 0.78–0.98, $p = .03$), incorrect catheter tug (OR 1.31, 95% CI 1.10–1.55, $p = .003$), incorrect catheter top position (kinking; OR 1.40, 95% CI 1.04–1.88, $p = .02$) and catheter-related bloodstream infection (OR 2.60, 95% CI 2.09–3.25, p <.001) were the only variables associated with catheter replacement at 6-month follow-up.

Conclusion: The risk of catheter replacement at 6-month follow-up could be attenuated by avoiding incorrect catheter tug and top position, and by placing the vascular catheter tip in the CAJ and MDA.

KEYWORDS
catheter dysfunction, catheter replacement, catheter tip position, haemodialysis, tunnelled catheter

SUMMARY AT A GLANCE

The success of tunnelled haemodialysis catheters depends on delivery of good blood flow, absence of infection and longevity of function. This study examines a variety of anatomical variables that would seem intuitively valid but have not been studied and their impact on the chances of catheter replacement over 6 months.

1 | BACKGROUND

Tunnelled haemodialysis (HD) catheters can be used instantly and is generally easily inserted by a well-trained interventional nephrologist. Optimal positioning of the functional catheter tip is crucial for efficient HD.[1] The latest Kidney Foundation Kidney Disease Outcomes Quality Initiative (KDOQI) guidelines recommend placing the functional catheter tip in the right atrium (mid-level) or cavo-atrial junction (CAJ) with its arterial lumen facing the mediastinum[2] to prevent blood recirculation and to avoid catheter-induced superior vena cava (SVC) complications[3] and catheter dysfunction, defined as blood flow rates <300 ml/min at a pre-pump arterial pressure more negative than −250 mmHg.[4] Other definitions of catheter dysfunction include frequent arterial and venous pressure alarms, poor conductance and poor dialysis efficiency based on the urea reduction ratio or Kt/V calculations.[5,6] Although the proper placement of the catheter tip has been demonstrated, we believe that other anatomical characteristics could complicate the catheter's functionality. This study aimed to examine the impact of different novel anatomic variables, including catheter tip position on catheter dysfunction and replacement. We hypothesize that these variables are associated with catheter dysfunction that leads to catheter replacement.

2 | MATERIALS AND METHODS

2.1 | Data sources and study design

This is a single-centre, prospective cohort study at the Hospital Civil de Guadalajara Fray Antonio Alcalde, Mexico, conducted at the nephrology department between January 2019 and 1 January 2020. All grade 5 chronic kidney disease (CKD) patients defined according to the KDIGO guidelines[7] were considered. All catheters were inserted by nephrology fellows under ultrasound guidance. A Palindrome™ symmetric tip dialysis catheter was used in all tunnelled catheters. The catheter length was calculated before placement using the formula proposed by Czepizak et al.[8] using the patient's height (cm)/10 for the right internal jugular vein and the patient's height (cm)/10 + 4 cm for the left internal jugular vein. See Table 1 Appendix for the range of patient's heights for a given size of the Palindrome catheter. Patients were followed over 6 months after HD catheter insertion with pre-specified variables. We excluded patients who died before their first HD session, patients with lack of data, those who could not undergo a chest X-ray, patients with successful arteriovenous fistula creation, patients with non-tunnelled catheters and with acute kidney injury.

Since the main objective of the study was to follow up the catheters for 6 months, all non-tunnelled catheters (normally placed in AKI) were excluded in the analysis since their use for long periods of time goes against what is dictated by KDOQI guideline.[2]Age, gender, height, indication of catheter placement, history of previous vascular catheters, blood haemoglobin, platelet count, prothrombin time, partial thromboplastin time, serum creatinine, serum urea and serum potassium; blood pressure during the procedure, anatomic position, the presence of extrasystoles, number of puncture attempts, jugular vein collapsibility index, catheter tug (TUG) (defined as free aspiration of blood through a 10-cc syringe), catheter top (TOP) (catheter curvature in the neck, shown in Figure 1(C)) and heparin (1000 IU/mL or 5000 IU/mL); skin-to-internal jugular vein distance, neck circumference, clavicle-to-catheter insertion site distance, internal jugular vein and carotid artery diameter and distance between the internal jugular vein and carotid artery (shown in Figure 1(B)); three anatomic regions for catheter tip position were considered[9,10] (shown in Figure 1(A)): (a) above the mediastinal–right heart border angle (SVC); (b) within one vertebral body below this point (CAJ) and (c) greater than one vertebral body below this point (mid- to deep right atrium [MDA]). Correct tip position was defined as the one in the mid-to deep right atrium (MDA) or CAJ. Complications were recorded during catheter insertion. Catheter replacement was considered when the catheter needed to be removed due to the occurrence of dysfunction or bloodstream infection during the follow-up. Catheter dysfunction was defined as a blood flow rate <300 ml/min during two consecutive HD sessions and the need for further interventions to improve the HD sessions. Patients were considered to have a catheter-related bloodstream infection if they fulfilled three criteria: (1) a clinical suspicion of infection; (2) concordant-positive blood cultures obtained from the catheter lumen and the dialysis bloodline and (3) absence of an alternate source of bacteremia.[11] The protocol followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.[12]

2.2 | Vascular catheter insertion technique

All patients had previously signed informed consent forms. First, the anterior area of the neck was palpated in search of the carotid artery zone; the right internal jugular vein was visualized by ultrasound (Site Rite 5 device) and, if appropriate, was chosen as the preferred access site. The selected area was scrubbed with povidone-iodine or chlorhexidine followed by local anaesthesia with 2% lidocaine. The vein was punctured under ultrasound guidance, and the guidewire was driven into the central vein. Two small sections were made approximately 0.5–1 cm in size, one at the point of guidewire entry into the

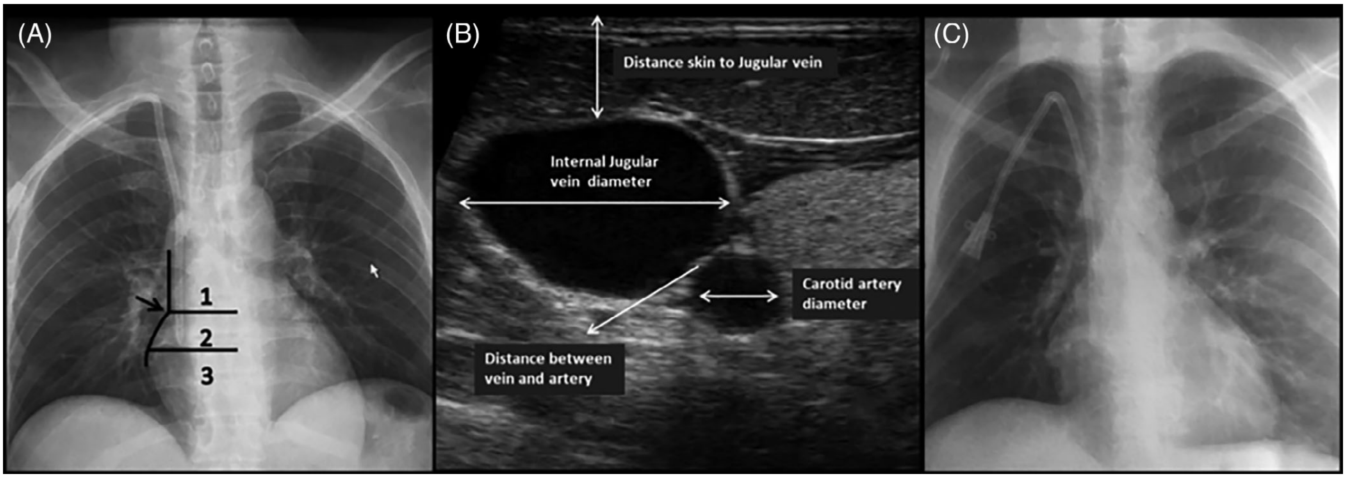

FIGURE 1 (A) x-ray image of the chest in the supine position demonstrates zones used to categorize catheter tip location into (1) superior vena cava, (2) cavo-atrial junction or (3) mid- to deep right atrium. The concave angulation formed by the border of the right atrium convexity and the right mediastinal border defined the border between zones 1 and 2 (arrow). (B) Ultrasound short-axis technique of the internal Jugular vein, carotid artery, distance between vein and artery and distance between skin and internal Jugular vein. (C) incorrect catheter TOP position (kinking)

neck and the second 3–5 cm below the clavicle, depending on catheter size and the patient's chest anatomy. The subcutaneous tract was created using a tunnelling trocar, and the catheter was inserted through the sheath that had been peeled away. A chest X-ray was performed immediately after the procedure to detect any complications as well as the catheter tip position. The three T's of the catheter were confirmed in each procedure: (1) position of the catheter tip; (2) TOP, catheter curvature at the neck and (3) TUG (free aspiration of blood through a 10-cc syringe). Incisions were sutured with 2-0 nylon. If any sluggish problem during the procedure was observed, the catheter was pulled out a few centimetres until adequate flow was achieved in both lumens (this without leaving the cuff outside the tunnel). After that, a HD session was given to the patient and if catheter dysfunction was presented, a fluoroscopy was scheduled to correct the problem or to change the catheter, considering a case of catheter dysfunction. Our previously described catheter insertion technique follows the recommendations of the KDOQI clinical practice guideline for vascular access: 2019.[2]

2.3 | Study outcomes

The primary outcome was to determine the factors associated with catheter replacement during the first 6-month of follow-up. As secondary outcomes, we considered whether there was an association between anatomic variables and complications during the procedure.

2.4 | Statistical analysis

Categorical descriptive data are presented as frequencies and continuous variables as the means ± SDs and percentages (%). The Shapiro–Wilk test was used to determine the distribution of the variables that presented an abnormal distribution, so it was decided to use the Wilcoxon signed-rank test to determine the differences between the variables. Catheter survival was measured using Kaplan–Meier survival curves. A univariate and multivariate logistic regression model was used to determine the variables associated with catheter replacement during the 6-month follow-up, adjusted for age, gender, height, the presence of previous catheters, serum potassium, systolic BP, anatomic position, the presence of extrasystoles, jugular vein collapsibility index, TUG, catheter length, heparin, neck circumference, breastbone–chin distance, clavicle-to-catheter insertion site distance, catheter tip position, TOP position, skin-to-internal jugular vein distance, internal jugular and carotid diameter, the distance between vein and artery and catheter-related bloodstream infection. Only the independent variables found to have $p < .05$ based on univariate analysis were included in the multivariate analysis. The R Studio program was used for data analysis. $p < .05$ was considered significant.

3 | RESULTS

Between January 2019 and January 2020, 211 consecutive CKD grade 5 patients underwent vascular catheter insertion. We excluded 7 (3.3%) patients due to a lack of data, 5 (2.3%) did not have a chest X-ray, 5 (2.3%) died before their first HD session, 27 (12.7%) had acute kidney injury, 32 (15.1%) with a successful AV fistula creation, and 60 (28.4%) with non-tunnelled catheters, resulting in 75 patients included in the final analysis (shown in Figure 2). Forty-five (60%) were males, with a mean age of 42.1 ± 15.3 years. Diabetes was recorder in 21 (28%) cases. The mean blood haemoglobin level was 8.9 ± 1.6 g/dl, mean serum urea level 204 ± 102 mg/dl, mean platelet count was 242 ± 97 10^3/μl, and the mean eGFR was 9.3 ± 4.5 ml/min/1.73 m^2. A total of 36 (48%) patients had previous catheters, 29 (80.5%) of which were placed in the right internal jugular vein. Catheter insertion was in the right internal jugular vein in 56 (74.6%) patients and left internal jugular vein in 19 (25.4%) patients, and a correct catheter tip position was observed in 61 (81.3%) patients. Extrasystoles during guidewire insertion were present in 39 (52%) patients; Catheter replacement at the 6-month follow-up occurred in 10 (13.3%) patients.

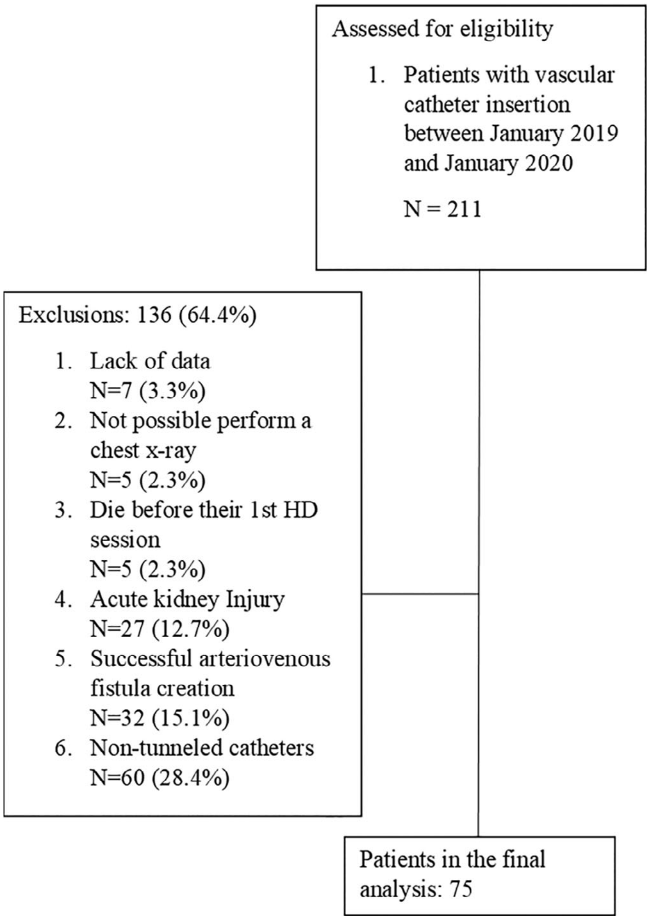

FIGURE 2 Flow chart of patients assessed

Catheter survival at the 6-month follow-up was 86.3% (95% CI 0.78–0.94; shown in Figure 3). The cause of catheter replacement was catheter-related bloodstream infection in 5 (6.6%) patients and dysfunction in 5 (6.6%) patients. Patients with catheter replacement at the 6-month follow-up had lower JV collapsibility index, fewer episodes of extrasystoles during the procedure, less correct catheter TUG and TOP and less often had a correct tip position than the non-catheter replacement group (Table 1).

In an attempt to identify variables associated with catheter replacement at the 6-month follow-up a univariate logistic regression was performed, and those with an increase risk were: incorrect catheter tip position (OR 1.20, 95% CI 1.17–1.46, $p = .04$), incorrect TOP position (kinking; OR 1.37, 95% CI 1.11–1.82, $p = .02$), catheter-related bloodstream infection (OR 2.53, 95% CI 2.01–3.18, $p < .001$), and incorrect TUG (OR 1.28, 95% CI 1.17–1.49, $p = .03$). Only one decreased the risk, which was the presence of extrasystoles (OR 0.84, 95% CI 0.72–0.98, $p = .02$). A similar effect was observed according to multivariate analysis: incorrect catheter tip position (OR 1.23, 95% CI 1.07–1.42, $p < .004$), incorrect TUG (OR 1.31, 95% CI 1.10–1.55, $p = .003$), incorrect TOP position [kinking] (OR 1.40, 95% CI 1.04–1.88, $p = .02$), and catheter-related bloodstream infection (OR 2.60, 95% CI 2.09–3.25, $p < .001$) and again, the presence of extrasystoles during the procedure decreased the risk (OR 0.88, 95% CI 0.78–0.98, $p = .03$; Table 2).

Catheter-related bloodstream infection rate that required catheter replacement was 1.80 per 100 patient-months.

A carotid diameter >0.85 cm (OR 1.09, 95% CI 1.00–1.17, $p = .02$) and a number of punctures >1 (OR 1.17, 95% CI 1.07–1.28 $p = .001$) were variables associated with complications during catheter insertion in the multivariable analysis (Table 2 Appendix).

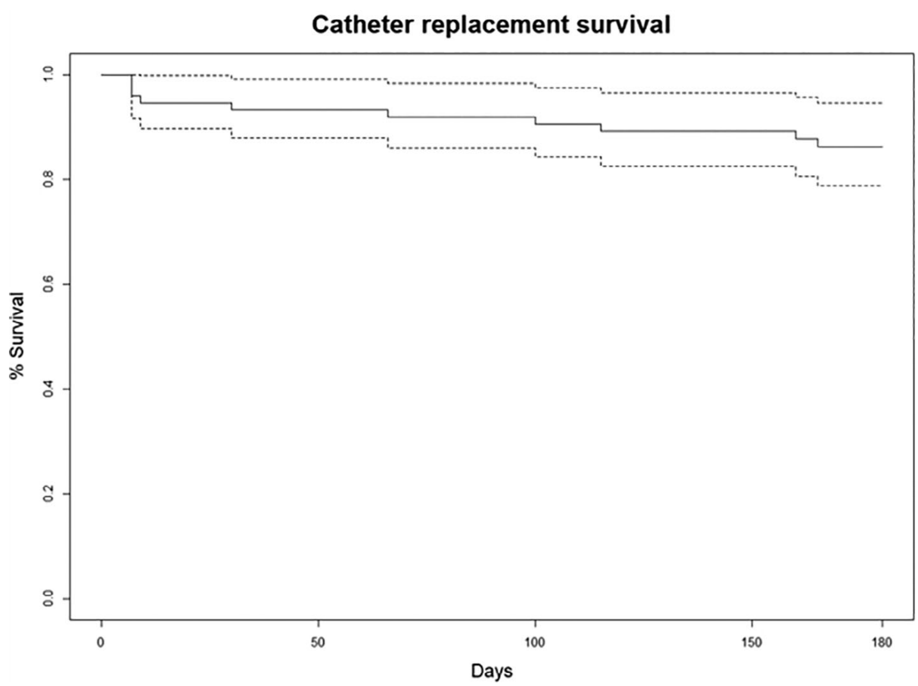

FIGURE 3 Catheter replacement survival at 6-month follow-up

TABLE 1 Patient characteristics

Variable	Total	Catheter replacement at 6-month follow-up	Non-catheter replacement at 6-month follow-up	p
(N) (%)	75	10 (13.3)	65 (86.7)	
Age (years), mean (SD)	42.1(15.3)	35.3 (12.8)	43.2 (15.5)	.16
Gender (N [%])				.49
Female	30 (40)	5 (50)	25 (38.4)	
Male	45 (60)	5 (50)	40 (61.6)	
Height (m), mean (SD)	1.61 (8.2)	1.62 (9.1)	1.60 (7.2)	.72
eGFR (ml/min), mean (SD)	9.3 (4.5)	10.3 (6.0)	9.2 (4.3)	.83
Cause of catheter placement in CKD (N [%])				
Diabetic nephropathy	21 (28)	3 (30)	18 (27.8)	
Hypertension	19 (25.3)	3 (30)	16 (24.6)	
Urologic disease	5 (6.7)	1 (10)	4 (6.1)	
Glomerulonephritis	5 (6.7)	1 (10)	4 (6.1)	
Unknown	25 (33.3)	2 (20)	23 (35.4)	
Previous catheters (N [%])	36 (48)	6 (60)	30 (46.1)	.42
Haemoglobin (g/dl), mean (SD)	8.9 (1.6)	8.9 (1.7)	8.9 (1.6)	.76
Prothrombin time (sec), mean (SD)	13.6 (5.4)	12.0 (2.3)	13.9 (5.7)	.08
Partial thromboplastin time (sec), mean (SD)	34.9 (14.6)	35.9 (9.4)	34.7 (15.3)	.85
Creatinine (mg/dl), mean (SD)	11.6 (5.2)	12.7 (7.7)	11.4 (4.8)	.77
Urea (mg/dl), mean (SD)	204 (102)	198 (109)	205 (101)	.74
Potassium (mg/dl), mean (SD)	4.5 (0.8)	4.2 (0.9)	4.5 (0.8)	.15
Platelets ($10^3/\mu l$), mean (SD)	242 (97)	223 (69)	245 (100)	.55
Systolic BP (mmHg), mean (SD)	134 (21)	129 (22)	135 (21)	.32
Diastolic BP (mmHg), mean (SD)	79 (11)	80 (11)	79 (11)	.81
Anatomic position (N [%])				.25
Right jugular vein	56 (74.6)	6 (60)	50 (76.9)	
Left jugular vein	19 (25.4)	4 (40)	15 (23.1)	
Extrasystoles present (N [%])	39 (52)	2 (20)	37 (56.9)	.03
Number of punctures (N [%])				.82
1 puncture	62 (82.6)	8 (80)	54 (83)	
>1 puncture	13 (17.3)	2 (20)	11 (17)	
JV collapsibility index, mean (SD)	25.1(20.7)	18.1 (23.1)	26.1 (20.2)	.02
Correct TUG (N [%])	67 (89.3)	6 (60)	61 (93.8)	.03
Heparin (N [%])				.81
1000 UI	50 (66.6)	7 (70)	43 (66.1)	
5000 UI	25 (33.3)	3 (30)	22 (33.8)	
Complications (N [%])				
Bradycardia	1 (1.3)	0 (0.0)	1 (1.5)	
Artery puncture	1 (1.3)	0 (0.0)	1 (1.5)	
Neck circumference (cm), mean (SD)	39.2 (6.2)	37.1 (3.5)	39.5 (6.5)	.49
Breastbone–chin distance (cm), mean (SD)	10.0 (2.4)	10.0 (2.3)	10.1 (2.4)	.99
Clavicle-to-catheter insertion site distance (cm), mean (SD)	3.7 (1.7)	3.2 (1.3)	3.8 (1.7)	.56
Correct catheter tip position (N [%])	61 (81.3)	6 (60)	55 (84.6)	.04
Correct TOP (N [%])	70 (93.3)	7 (70)	63 (96.9)	.001
Skin-to-internal jugular vein distance (cm), mean (SD)	1.5 (0.7)	1.3 (0.7)	1.5 (0.7)	.31
Jugular diameter (cm), mean (SD)	1.3 (0.5)	1.2 (0.4)	1.3 (0.6)	.87
Carotid diameter (cm), mean (SD)	0.9 (0.4)	0.7 (0.2)	0.9 (0.4)	.24

(Continues)

TABLE 1 (Continued)

Variable	Total	Catheter replacement at 6-month follow-up	Non-catheter replacement at 6-month follow-up	*p*
Distance between vein and artery (cm), mean (SD)	0.4 (0.3)	0.5 (0.6)	0.4 (0.2)	.64
Cause of Catheter Replacement at 6-month follow-up (N [%])				
Catheter-related bloodstream infection	5 (6.6)	5 (50)	0 (0.0)	
Catheter dysfunction	5 (6.6)	5 (50)	0 (0.0)	

Note: BP means blood pressure; CKD, Chronic kidney disease; TUG, normal blood aspiration with a 10 cc syringe in each catheter lumen; Correct tip, catheter tip in the cavo-atrial junction or mid right atrium; Normal TOP, no kinking.

4 | DISCUSSION

Vascular access in patients with CKD grade 5 is a cornerstone for HD therapy; it should be adequate to assure efficient HD.[3] In this single-centre prospective cohort study, we found different anatomical variables that significantly increase the risk of catheter replacement at 6-month follow-up, including the incorrect catheter TOP (kinking), TUG and tip position. None of the other anatomical variables were associated with catheter replacement.

The insertion technique of the long-term catheter is sometimes a challenge for the physician. An important part of this procedure is tunnelling, which involves the catheter being conducted through subcutaneous tissues from the exit site usually in the infraclavicular area to the point on the neck where the guidewire was introduced into the jugular vein. Hamid et al., reported catheter kinking in 10 out of 193 (4.9%) procedures and was the cause of catheter malfunction.[13] In our study, we were able to observe similar results, catheter kinking occurred in 5 (6.6%) of the procedures, and conferred 1.4-fold times the probability of catheter replacement, the highest risk. Most of the authors who describe results of cuffed catheter insertion or replacement do not report tunnelling related problems in detail and only concentrate on non-infection complications in the early period of dialysis, including catheter malfunction due to thrombosis or malposition of the tip.[13–17] Our study sought to focus on each of these complications together. To reduce the risk of such complications, Song et al. recommend another technique of puncturing the internal jugular vein at lateral access (posterior to sternocleidomastoid muscle), instead of puncturing at the Sedillot's triangle (the space between sternal and clavicular heads of sternocleidomastoid muscle).[18] This approach may lessen the number of angulations, leading to better flow rates and catheter function. There are no recommendations regarding the correction of the pinched/kinked catheter. In most instances, the catheter had to be replaced. Some authors, however, try to correctly set the kinked catheter by open surgical mode with the help of vascular surgeons.[19]

The catheter TUG test involves rapidly withdrawing blood with a syringe to ensure adequate blood flow without hesitation. The presence of incorrect TUG it's a cause of early catheter dysfunction,[20] but to our knowledge, there are no data on how much its presence increases this risk or, even more severe, the risk of catheter replacement. If an incorrect TUG problem is identified, it should be corrected before the patient leaves the procedure room, but sometimes this problem is not always possible to correct, leaving one of the two catheter lumens dysfunctional. We were able to observe that their presence during the catheter insertions increases the risk of catheter replacement by 1.3-fold times. This increased risk can be explained: first, that the catheter could be in direct contact with the vessel wall obstructing the lumen blood flow out of the catheter; and second, that could be in relation with incorrect TOP position or the presence of an early clot in the catheter.

Previous studies have reported similar results in which the distal tip position of the long-term HD catheter is the mainstay for adequate functioning and subsequent efficient dialysis.[2] Although, indeed, the insertion of catheters guided by fluoroscopy to leave the catheter tip in the CAJ and the right atrium is used in several specialized centres, other centres, including ours, do not have the resources for this routine use, so it is imperative to properly calculate the portion of the catheter that is inserted into the patient, such as the proposed premeasured C-length technique by Lee and Lee,[21] and to always perform an X-ray to ensure the correct position of the catheter tip and, if necessary, use fluoroscopy for correct position placement. Guideline of the K/DOQI recommends that tunnelled catheter be inserted under ultrasound (based on evidence) and fluoroscopic guidance (based on opinion) to limit insertion complications and maximize blood flow. The K/DOQI recommendation makes it difficult for nephrologists to perform this procedure without access to fluoroscopy, mainly in developing countries. The technique of tunnelled catheter placement without fluoroscopy was tested previously, concluding that there was no difference in major or minor complications between the blind and the fluoro-guided group.[22] Regarding this previous point, KDOQI considers it reasonable that if fluoroscopy is not used to insert a tunnelled catheter, alternative imaging is used to ensure that the catheter tip has been correctly placed.[2]

We used the radiographic concave angulation formed by the intersection of the right mediastinal border and the convex right heart border as a reference point (Figure 1(A), arrow) to determine the catheter tip position.[9] An additional auxiliary method to determining the position of the catheter tip on the chest X-ray is the use of the vertebral body unit, which was defined as the distance between two adjacent vertebral bodies, including the intervertebral disk space to determine the CAJ, using the carina as a landmark. Song et al.[23] reported that the position of the catheter tip on the CAJ in adults was

TABLE 2 Univariable and multivariable logistic regression model to determine the variables associated with catheter replacement during 6-month follow-up

	Univariate (95% CI)	*p*	Multivariate (95% CI)	*p*
Age	0.99 (0.99–1.00)	.13		
Gender female	1.05 (0.90–1.23)	.49		
Height (cm)	0.99 (0.99–1.00)	.67		
Previous catheters	1.06 (0.91–1.24)	.42		
Serum Potassium (mg/dl)	0.95 (0.87–1.03)	.25		
Systolic BP (mmHg)	0.99 (0.99–1.00)	.41		
Left Internal Jugular Vein	1.10 (0.92–1.32)	.25		
Extrasystoles present	0.84 (0.72–0.98)	.02	0.88 (0.78–0.98)	.03*
Jugular vein collapsibility index	0.99 (0.99–1.00)	.25		
Incorrect TUG	1.28 (1.17–1.49)	.03	1.31 (1.10–1.55)	.003*
Catheter length	0.98 (0.96–1.01)	.33		
Heparin (5000 IU/ml)	0.98 (0.83–1.15)	.81		
Neck circumference (cm)	0.99 (0.98–1.00)	.24		
Breastbone–chin distance (cm)	0.99 (0.96–1.03)	.99		
Clavicle-to-catheter insertion site distance (cm)	0.97 (0.93–1.02)	.32		
Incorrect catheter tip position	1.20 (1.17–1.46)	.04	1.23 (1.07–1.42)	.004*
Incorrect TOP position (kinking)	1.37 (1.11–1.82)	.02	1.40 (1.04–1.88)	.02*
Skin-to-internal jugular vein distance (cm)	0.95 (0.86–1.05)	.34		
Jugular diameter (cm)	0.97 (0.85–1.10)	.65		
Distance between vein and artery (cm)	1.16 (0.93–1.44)	.17		
Catheter-related bloodstream infection	2.53 (2.01–3.18)	<.001	2.60 (2.09–3.25)	<.001*

Note: RJV, right jugular vein; Incorrect tip, catheter tip not in the cavo-atrial junction or mid right atrium; Normal TUG, defined as free aspiration of blood through a 10-cc syringe.
*p = <0.05

reliably estimated to be 2.4 vertebral body units below the carina. Significantly more accurate methods for determining the position of the catheter tip include transesophageal echocardiography, CT and ECG-based methods, but unfortunately, these methods are often not routinely available.

Some studies have reported that pneumothorax and catheter misplacement after ultrasound-guided catheter insertion are rare, and the costs of a postprocedural X-ray are exceedingly high, concluding that routine postprocedural X-ray is unnecessary.[24] Based on the evidence shown, we believe that postprocedural X-ray or ultrasonographic techniques for catheter tip detection are needed to ensure a correct catheter tip position, even in patients with acute kidney injury who are at risk of early catheter dysfunction.

It is reasonable to assume that an incorrect catheter tip position generates dysfunction and then catheter replacement for the following explanations: first, it promotes turbulence by being too close to the vessel wall; second, the turbulence promotes a procoagulant state that can generate thrombosis in the catheter lumen; third, the proximity of the vessel wall to the catheter lumen favours limited blood flow, triggering pressure alarms on the HD machine and limiting flow to <300 ml; and finally, low blood flow can decrease the dialysis efficiency.

We also found a reduction in the risk of catheter replacement at 6-month follow-up when extrasystoles were present during the procedure. (OR 0.88, 95% CI 0.78–0.98, $p = .03$). This could be explained by the fact that the catheter was inserted in the CAJ and the right atrium, which would generate the stimulus in the Sinoatrial node.

We did not find significant differences in catheter replacement when catheters were inserted in the left internal jugular vein compared to the right internal jugular vein (OR 1.10, 95% CI 0.92–1.32, $p = .25$; Table 2), in contrast with other studies that reported higher dysfunction rates.[9]

When analysed these novel anatomical variables in relation to complications during the procedure, we found that a carotid diameter >0.85 cm and attempts of more than 1 puncture were the only significant variables in the multivariate analysis.

Catheter-related bloodstream infection was the strongest non-anatomic factor associated with a 2.6-fold increase in catheter replacement (OR 2.60, 95% CI 2.09–3.25, p <.001), similar to other studies[25] that reported a rate of 2.16 per 100 patient-months, while our population presented a rate of 1.80 per 100 patient-months.

As previously mentioned, the other anatomical variables did not present a significant difference in catheter replacement. The logical plausibility of their measurement is mentioned below. The rationale for measuring the JV collapsibility index was that with the greater collapse of the vessel there would be greater difficulty in cannulating the jugular vessel. We believed that a greater neck circumference and a shorter breastbone–chin distance could make insertion of the catheter more difficult since these parameters help to diagnose a short neck, which has been recognized as a cause that complicates cannulation.[26] With a shorter clavicle-to-catheter insertion site distance, it could be assumed that the clavicle could generate pressure and kink the catheter, but this fact was not found. Skin-to-internal jugular vein distance and the jugular and carotid diameters could be a risk of complications and dysfunction in cases where ultrasound is not available for catheter placement since the risk is almost non-existent if ultrasound is available.

Finally, we want to clarify that HD patients receiving treatment through the use of a central venous catheter, are at a substantially higher risk for hospitalization, life-threatening infections and all-cause mortality, in comparison to patients with an arterial–venous fistula or arterial–venous graft, and these types of venous access should be placed as soon as possible.

The strengths of our study are the measurement of different anatomical and clinical variables before and during catheter insertion. To our knowledge, the results presented in this study have never been published and could represent a new strategy to prolong the life of HD catheters. The prospective design included patients with uremic syndrome with urgent indications for initiating HD, which makes our cohort unique. Another strength was that we only used one type for tunnelled catheters (Palindrome™ symmetric tip for tunnelled catheters) which reduced the bias of the catheter tip type (shotgun-tip, split-tip and others) and the influence of thrombotic events, as reported in previous studies.[27]

Our trial has some limitations. First, we did not establish the different causes of catheter dysfunction, such as lumen thrombosis or fibrin shell, since we could not evaluate catheter dysfunction by CT venography/ fluoroscopy; however, these complications have been associated with incorrect catheter tip position.[28] Second, the sample size was relatively small. Third, the follow-up was only 6 months. Fourth, the study was carried out in a single centre.

5 | CONCLUSIONS

The risk of catheter replacement at 6-month follow-up could be attenuated by avoiding incorrect catheter TOP and TUG position, and by placing the vascular catheter tip in the right atrium or CAJ. Further studies are required to validate our results in studies with a larger number of patients.

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CONFLICT OF INTEREST

The authors declare that they have no competing interests.

AUTHOR CONTRIBUTIONS

PAM participated in the research design, performance of research, data analysis and writing of the paper. JGNG participated in the performance of research. GNB participated in the research design. AMFL participated in the data analysis. TPR participated in the performance of research. EAAD participated in the data analysis. VEGM participated in the data analysis. EYO participated in the data analysis. JR participated in the data analysis. GGG participated in writing the paper. JSCI participated in the conception, design and interpretation of data.

ETHICS STATEMENT

The study was approved by Hospital Civil de Guadalajara Fray Antonio Alcalde Institutional Review Board and was conducted in adherence with the Declaration of Helsinki. All informed consent has been obtained from the subjects.

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REFERENCES

1. Danese MD, Liu Z, Griffiths RI, et al. Catheter use is high even among hemodialysis patients with a fistula or graft. *Kidney Int*. 2006;70(8):1482-1485. https://doi.org/10.1038/sj.ki.5001786
2. KDOQI Vascular Access Guideline Work Group. KDOQI clinical practice guideline for vascular access: 2019 update. *Am J Kidney Dis*. 2020;75(4 (suppl 2)):S1-S164.
3. Santoro D, Benedetto F, Mondello P, et al. Vascular access for hemodialysis: current perspectives. *Int J Nephrol Renovasc Dis*. 2014;7:281-294.
4. Moist LM, Hemmelgarn BR, Lok CE. Relationship between blood flow in central venous catheters and hemodialysis adequacy. *Clin J Am Soc Nephrol*. 2006;1(5):965-971.
5. Chan MR. Hemodialysis central venous catheter dysfunction. *Semin Dial*. 2008;21(6):516-521.
6. Ponikvar R, Buturović-Ponikvar J. Temporary hemodialysis catheters as a long-term vascular access in chronic hemodialysis patients. *Ther Apher Dial*. 2005;9(3):250-253.
7. KDIGO. 2012 clinical practice guideline for the evaluation and management of chronic kidney disease. *Kidney Int Suppl*. 2013;3:1-150.
8. Czepizak CA, O'Callaghan JM, Venus B. Evaluation of formulas for optimal positioning of central venous catheters. *Chest*. 1995;107(6):1662-1664. https://doi.org/10.1378/chest.107.6.1662
9. Engstrom BI, Horvath JJ, Stewart JK, et al. Tunneled internal jugular hemodialysis catheters: impact of laterality and tip position on catheter dysfunction and infection rates. *J Vasc Interv Radiol*. 2013;24(9):1295-1302.
10. Aslamy Z, Dewald CL, Heffner JE. MRI of central venous anatomy. Implications for central venous catheter insertion. *Chest*. 1998;114:820-826.
11. Farrington CA, Allon M. Complications of hemodialysis catheter bloodstream infections: impact of infecting organism. *Am J Nephrol*. 2019;50:126-132. https://doi.org/10.1159/000501357
12. Von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. *Rev Esp Salud Publica*. 2008;82(3):251-259.

13. Wang K, Wang P, Liang XH, Yuan FF, Liu ZS. Cufed-tunneled hemodialysis catheter survival and complications in pediatric patients: a single-center data analysis in China. *Int J ClinExp Med*. 2015;15:9765-9771.
14. Wang L, Wei F, Chen H, Sun G, Yu H, Jiang A. A modifed de novo insertion technique for catheter replacement in elderly hemodialysis patients: a single clinic retrospective analysis. *J Vasc Access*. 2016;2: 506-511.
15. Mandolfo S, Acconcia P, Bucci R, et al. Hemodialysis tunneled central venous catheters: fve-year outcome analysis. *J Vasc Access*. 2014;15: 461-465.
16. Donati G, Cianciolo G, Mauro R, et al. PTFE grafs versus tunneled cufed catheters for hemodialysis: which is the second choice when arteriovenous fstula is not feasible? *Artif Organs*. 2015;39:134-141.
17. Xu D, Liu T, Dong J. Urgent-start peritoneal dialysis and hemodialysis in ESRD patients: complications and outcomes. *PLoS One*. 2016;8: e0166181.
18. Song D, Yun S, Cho S. Posterior triangle approach for lateral in-plane technique during hemodialysis catheter insertion via the internal jugular vein. *Ann Surg Treat Res*. 2015;88:114-117.
19. Sampathkumar K, Ramakrishnan M, Sah AK, Sooraj Y, Mahaldhar A, Ajeshkumar R. Tunneled central venous catheters: experience from a single center. *Indian J Nephrol*. 2011;21:107-111.
20. Niyyar VD, Chan MR. Interventional nephrology: catheter dysfunction—prevention and troubleshooting. *CJASN*. 2013;8(7): 1234-1243. https://doi.org/10.2215/CJN.00960113
21. Lee JB, Lee YM. Pre-measured length using landmarks on posteroanterior chest radiographs for placement of the tip of a central venous catheter in the superior vena cava. *J Int Med Res*. 2010;38:134-141.
22. Yevzlin AS, Song GU, Sanchez RJ, Becker YT. Fluoroscopically guided vs modified traditional placement of tunneled hemodialysis catheters: clinical outcomes and cost analysis. *J Vasc Access*. 2007;8:245-251.
23. Song YG, Byun JH, Hwang SY, Kim CW, Shim SG. Use of vertebral body units to locate the cavoatrial junction for optimum central venous catheter tip positioning. *Br J Anaesth*. 2015;115:252-257.
24. Chui J, Saeed R, Jakobowski L, et al. Is routine chest X-ray after ultrasound-guided central venous catheter insertion choosing wisely? *Chest*. 2018;154(1):148-156.
25. Brown RS, Brickel K, Davis RB. Two-year observational study of bloodstream infection rates in hemodialysis facility patients with and without catheters. *Clin J Am Soc Nephrol*. 2018;13(9):1381-1388.
26. Luckraz H. Venous pseudo-aneurysm as a late complication of short-term central venous catheterisation. *Cardiovasc Ultrasound*. 2003;1:6. https://doi.org/10.1186/1476-7120-1-6
27. Wang K, Wang P, Liang X, Lu X, Liu Z. Epidemiology of haemodialysis catheter complications: a survey of 865 dialysis patients from 14 haemodialysis centres in Henan province in China. *BMJ Open*. 2015;5:e007136.
28. Smiljanic R, Brunetta Gavranic B, Jelakovic B. The different impacts on the long-term survival of tunneled internal jugular hemodialysis catheters based on tip position and laterality. *Blood Purif*. 2017;43(4): 315-320.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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