A change in direction for haemodialysis access? – antegrade vs. retrograde tunnelled haemodialysis catheter insertion and catheter survival

Abstract (270 words excluding subtitles)

Aim

To assess the relationship between antegrade versus retrograde catheter type and catheter survival.

Background

Tunnelled haemodialysis catheters (THDCs) are required when arteriovenous fistula (AVF) use is unfeasible. Catheter survival is a key outcome, as repeated THDCs are associated with reduced vascular access options. THDCs are inserted via antegrade or retrograde technique, depending on catheter type. No published studies have compared outcomes between the two.

Methods

A single-centre retrospective audit was conducted at Taranaki Base Hospital, New Zealand, of THDCs inserted from May 2010-November 2025. Catheter type was determined from imaging. Catheter survival was defined as time from catheter insertion to removal in days, with censorship of removal for reasons other than dysfunction. Kaplan-Meier survival analysis and multivariable Cox proportional hazards model were used to calculate hazard ratios (HR) for dysfunctional catheter removal (DCR). Infection rate and 30-day mortality were compared.

Results

199 THDCs were included (antegrade n=51; retrograde n=148). Baseline demographics were similar, except ethnicity and duration on dialysis. Unadjusted median catheter survival was shorter for antegrade catheters (147.0 vs 248.5 days, p=0.01), confirmed on Kaplan-Meier (log-rank p<0.01). After multivariable adjustment, the DCR HR for antegrade vs retrograde was 2.74 (95%CI 0.70-10.70, p=0.15). Comparing antegrade vs retrograde, catheter removal due to infection (7.8% vs 8.1%, p=1.00) and 30-day mortality (2.0% vs 4.7%, p=0.68)) were non-significant

Conclusions

Antegrade catheters were associated with shorter catheter survival, which was non-significant after multivariable adjustment. Infection rate and 30-day mortality were comparable. This has implications on catheter choice and interventional training. Low event numbers and small sample size are likely to explain the non-significance. Larger,

multi-centre prospective studies are warranted to clarify the relationship between catheter type and outcomes.

Introduction

Haemodialysis (HD) requires reliable and safe vascular access with adequate flow rates. An arteriovenous fistula (AVF) is the optimal vascular access; however, in New Zealand – like many parts of the world – multiple systemic barriers often make this difficult to achieve in a timely manner. These barriers include late patient presentation or referral to nephrology services, lack of formalized policies for vascular access formation and long wait times for fistula maturation, resulting in many patients commencing HD without an AVF. In 2024, 83% of incident patients starting HD in New Zealand used a vascular catheter (1), while only 17% used an AVF. For these patients, tunnelled HD catheters (THDCs) mostly serve as temporary or 'bridging' vascular access, until AVF formation or kidney transplantation (2) and for the remainder THDCs are used for long-term access. Key advantages of THDCs include relatively easy insertion, instant usability and for some patients, the preferred vascular access option due to needle phobia. However, compared to AVF, THDCs achieve lower blood flow rates which can negatively influence solute clearance and HD adequacy (3). THDCs also carry increased risks of dysfunction – most commonly related to thrombosis, fibrin sheath formation, malposition and infection, with associated morbidity and mortality (4).

Given the high incidence and prevalence of TDHC use, optimising catheter longevity – or catheter survival – is of considerable clinical importance. Insertion via the right internal jugular vein is preferred, with lower risk of dysfunction and malposition compared to left internal jugular vein insertion (5,6). Numerous studies have demonstrated that positioning the catheter tip in the right atrium (RA) or cavo-atrial junction (CAJ) is crucial for catheter survival, as this is associated with reduced risk of dysfunction compared to catheter tip position in the superior vena cava (SVC) (5,7–10). Catheter survival is therefore a key outcome measure in HD, as multiple THDCs are associated with decreased future vascular access options, due to complications such as central vein stenosis (11,12). Strategies to enhance THDC patency and reduce the need for multiple catheters are therefore greatly desirable.

THDCs can be inserted using the antegrade or retrograde technique. Antegrade catheters can only be inserted using the antegrade technique and vice-versa. For antegrade catheters, the catheter and external hub/ports are joined together as a single unit. The tip and cuff are pulled through the exit-site and subcutaneous tunnel towards the neck, then the tip of the catheter is inserted into the vein over a guidewire or split-sheath. In contrast, retrograde catheters come in two pieces – the external hub/ports are detached from the catheter. The catheter is inserted over a guidewire or split-sheath

into the vein to position the tip first, then pulled subcutaneously away from the neck, through the tunnel to the exit site, hence the term ‘retrograde’. The outer catheter end is then trimmed, and the external hub/ports are attached (13).

Theoretically, the retrograde technique has multiple advantages over the antegrade technique. Catheter tip position is established first, ensuring consistency rather than relying on estimation. Secondly, the cuff is not passed through the exit site, requiring only a small exit-site incision which prevents traumatic bleeding and excessive widening of the tunnel and exit site, avoiding future migration of the catheter tip proximally (i.e. towards the SVC). Lastly, the external hub/ports are detachable, enabling replacement due to damage or dysfunction, without removing the entire catheter (14–17). Anecdotally, antegrade insertion is preferred by proceduralists as it is less time-consuming and less technical, however minor variation in tunnel or catheter length/path with antegrade catheters can considerably change tip position – which cannot usually be corrected post-insertion without catheter replacement (13).

Despite the above theoretical differences between the two catheter types, there is little to no evidence comparing THDC survival between antegrade and retrograde catheters. A single centre, single operator, 6-month retrospective study (18) studied the efficacy and safety of the retrograde Cannon Catheter™ II Chronic Haemodialysis Catheter. 38 insertions were studies, with high flow rates (mean 369.0-404.8mL/min) observed and the mean session Kt/V was 1.55-1.60, exceeding the recommended KDOQI adequacy target of 1.2 (19). Mean catheter survival time was 126.5 ± 53.4 days, with no device-related hospitalizations or deaths. This is the only published study of retrograde THDCs, with no comparison of outcomes with antegrade catheters and partial funding by the catheter manufacturer.

In 2024, a retrospective audit was undertaken at our institution comparing THDC catheter survival between 17 retrograde and 26 antegrade THDCs. The reason for undertaking the audit arose from a change in catheter type, following an ordering error in mid-2022, where antegrade catheters were supplied instead of retrograde catheters (which was the catheter type used at our institution, until that point). Given the proceduralist’s familiarity with antegrade catheters, this catheter type was supplied from that point onwards. The unadjusted median catheter survival (unpublished data) was observed to be longer for retrograde catheters. However, this result was not statistically significant due to the small sample size, highlighting the need for a larger study with adjustment for confounding variables.

The purpose of the present study was to undertake a larger, multi-operator retrospective audit with multi-variable adjustment, to clarify the association between THDC type

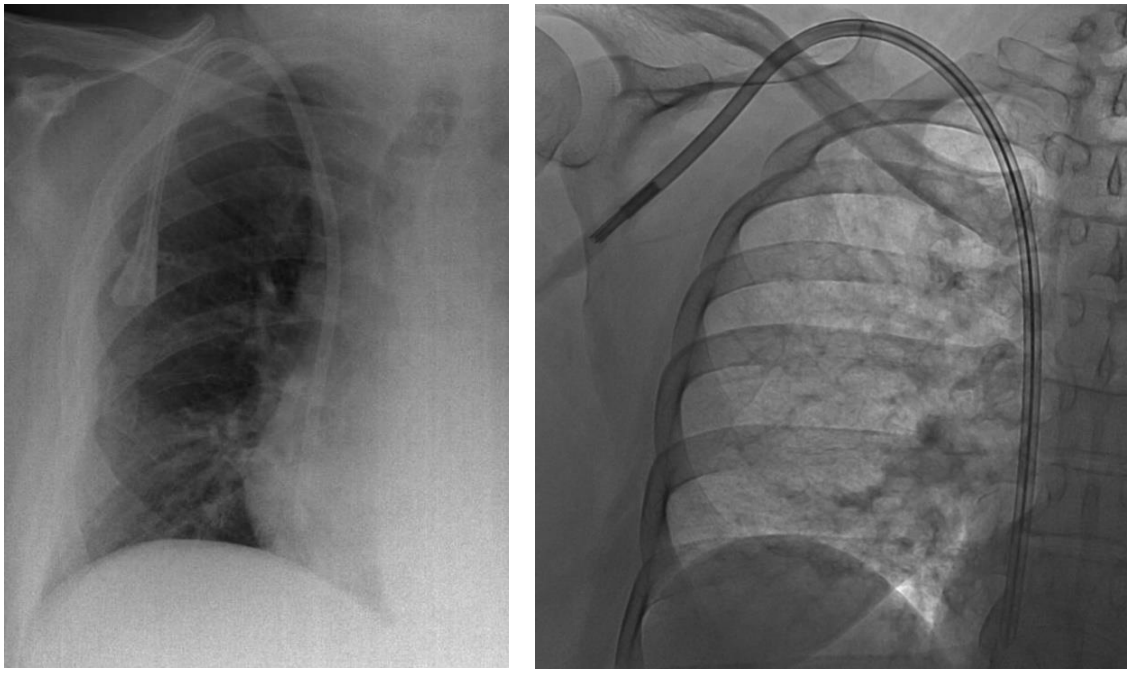
(antegrade vs retrograde) and catheter survival. We hypothesised that catheter survival would be longer for retrograde catheters compared to antegrade catheters.

Methods

Participants

This study was a single-centre retrospective audit conducted at Taranaki Base Hospital, New Plymouth, New Zealand. Patient data for this study was retrieved from electronic health records. From 1 May 2010 onwards, vascular access details were consistently recorded in an electronic renal database, *Renal Reality (20)*. Inclusion criteria were age ≥ 18 years, THDC insertion performed at our institution and availability of radiology imaging showing the external portion of the catheter, to allow retrospective determination of catheter type (antegrade or retrograde) (Figure 1). This study was exempt from ethics approval as it is classified as an "audit or related activity" and therefore falls outside the scope of New Zealand Health and Disability Ethics Committee (HDEC) review.

Figure 1: Radiology images of an antegrade (left) and retrograde (right) catheter with radio-opaque stainless steel connector visible.



Procedural technique

Insertion technique (antegrade or retrograde) depended on catheter type. Catheters used at our institution are typically 15Fr antegrade or 15Fr retrograde THDCs. A subset of retrograde catheters had split tips, which was included as a catheter-specific

variable to minimise confounding. Catheter lengths used at our institution are typically 23cm, 27cm or 31cm, however catheter length was not included in data collection due to inconsistent documentation in electronic health records. Additionally, catheter tip position – irrespective of catheter length – is of greater clinical relevance to the primary outcome measure. All insertions were performed using sterile technique, ultrasound guidance and local anaesthesia, with or without intravenous conscious sedation (midazolam and/or fentanyl) depending on patient preference.

Data collection

Demographic variables included age, sex, ethnicity, body mass index (BMI) and duration on dialysis.

BMI was not consistently recorded at time of insertion due to missing height data. For these patients, BMI was calculated retrospectively using height and/or weight recorded in anaesthetic, echocardiogram or spirometry records within 5 years of catheter insertion.

Duration of dialysis (HD or PD) was determined by subtracting date of the THDC insertion event from the date of first dialysis for the patient and dividing the result by 30 to calculate the duration in months. For patients new to dialysis, the duration was set as '0 months'. For patients with a history of failed kidney transplant, duration on dialysis was calculated from the date of first dialysis after transplant failure.

Catheter-specific variables included catheter type (antegrade vs retrograde), history of vascular access procedures, indication for THDC insertion, insertion site (right or left internal jugular vein (RIJV/LIJV), right external jugular vein (REJV), right or left femoral vein, right or left subclavian vein), new puncture vs exchange-over-guidewire ('railroad'), fluoroscopy use, catheter tip type (split vs non-split), catheter tip position (RA, CAJ, SVC and inferior vena cava IVC) (21), proceduralist specialty (nephrologist vs radiologist), date of catheter insertion, date of catheter removal, reason for removal, patient status at time of removal and mean urea reduction ratio (URR).

Catheter type (antegrade vs retrograde) was retrospectively identified, based on the external catheter hub appearance on fluoroscopy imaging or chest radiography, as discussed earlier, (catheter type was not consistently recorded in electronic health records at time of insertion). Previous vascular access procedures included temporary non-tunnelled dialysis catheters (vascaths), THDCs and AVFs. Indication for THDC insertion was recorded as 'AVF declined by patient', 'dysfunctional AVF' or 'temporary HD access'. Insertion site was recorded and confirmed radiologically. Exchange type was recorded as new puncture or 'railroad'. Radiology images were used to determine use of fluoroscopy, catheter tip type (split or non-split) and tip position, defined

according to established anatomical criteria. In cases of uncertainty, tip position was adjudicated by a consultant nephrologist (MA). If the tip was unable to be visualised, tip position was recorded as missing (N/A). Proceduralists were de-identified, and assigned numeric identifiers (1-9), then categorized by specialty (nephrologist vs radiologist). Date of insertion and date of removal were confirmed using both clinical and radiological records. Catheter survival time was calculated as the interval between insertion and removal, in days.

Reason for catheter removal was categorised as 'dysfunction' (due to any of poor flow rates, catheter dislodgment, thrombus, fibrin sheath formation or malposition), 'infection' (any of refractory exit site infection or line sepsis/bacteraemia), 'change of modality or access' (transition to PD, fistula formation, kidney transplantation, palliation), 'recovery of renal function', 'patient death', 'patient relocation' or 'current' (i.e. catheter still in-situ). Status at time of catheter removal was categorized as haemodialysis (HD), peritoneal dialysis (PD), transplant, palliation, recovery of renal function or death. URR was calculated using the formula: ((pre-dialysis urea – post-dialysis urea)/pre dialysis urea x 100). All URRs recorded during catheter use were averaged to derive a mean URR.

30 day-mortality was calculated by subtracting the date of THDC insertion from the date of death to determine patient survival post-insertion in days. Patients who died within 30 days of insertion were included in this analysis.

Statistical analysis

Statistical analyses were performed using *Microsoft Excel* (version 2502) and *SPSS* (version 31). Continuous variables were summarized using mean, median, standard deviation, 95% confidence intervals and interquartile range. Categorical variables were summarized using frequencies and proportions. Comparisons between antegrade and retrograde groups were conducted using the Chi-square test or Fisher's exact test for categorical variables and independent t-tests or Mann-Whitney U tests for continuous variables, as appropriate. Missing values for BMI, URR and tip position were excluded from univariable comparative analyses. Catheter survival time was calculated in days from date of insertion to date of removal. For catheters not removed, survival time was censored at the study end date (24 November 2025). Using *SPSS*, Kaplan Meier curves were generated for antegrade and retrograde catheters, and groups were compared using the log-rank test. Catheters removed for reasons other than dysfunction (infection, death, change in modality or access, recovery of renal function, patient relocation) and catheters currently in-situ were censored. A Cox proportional hazards regression model was used to assess the association between catheter type (antegrade vs retrograde) and catheter survival while adjusting for relevant covariates. Duration on dialysis was not included in this analysis, as this variable was not specified *a priori* and

did not account for pre-transplant dialysis duration. Multiple imputation was performed for missing BMI and tip position data, generating 50 datasets that were pooled for analysis. Hazard ratios with 95% confidence intervals and p values were reported. Reference categories reflected best-practice clinical standards such as right atrial tip position and fluoroscopy use. A p value ≤0.05 was considered statistically significant.

Results

199 tunnelled catheters were included (antegrade n = 51; retrograde n = 148). 48 additional THDCs identified in the database were excluded because the catheter was inserted at a different institution, or the catheter type could not be confirmed radiologically, due to inability to visualise the external part of the catheter on imaging. Baseline demographic and clinical variables were non-significantly different between the two study groups, except for age at insertion and ethnicity (Table 1). Comparing antegrade vs. retrograde catheters, mean age at insertion was 64.7 years (61.3-68.2) vs 58.0 years (55.7-60.3) p<0.01. The antegrade group had a lower proportion of NZ Māori patients (23.5% vs 43.2%), and a higher proportion of 'Other' ethnicities 15.7% vs 4.1% p = 0.003. Mean BMI was 32.3kg/m^2 (30.3-34.3) vs 30.0kg/m^2 (28.8-31.2) p = 0.55. There were a total of 23 missing BMI values, more frequent in the retrograde group due to a higher proportion of older data (pre-2015) compared to the antegrade group (14.9% vs 2.0%). Median duration on dialysis at time of THDC insertion was 9.8 months (IQR 34.8) for the entire study population. The antegrade group had a median duration of 27.2 months (IQR 35.3) and the retrograde group 4.1 months (IQR 32.2) p = 0.04.

Table 1: Demographics

	Overall (n=199)	**Antegrade (n=51)**	**Retrograde (n=148)**	**p-value**
Mean age at insertion (years) (95%CI)	59.8 (57.8-61.7)	64.7 (61.3-68.2)	58.0 (55.7-60.3)	<0.01
Sex				
Male	122 (61.3%)	36 (70.6%)	86 (58.1%)	0.12
Female	77 (38.7%)	15 (29.4%)	62 (41.9%)	
Ethnicity				
NZ European	109 (54.8%)	31 (60.8%)	78 (52.7%)	<0.01
NZ Māori	76 (38.2%)	12 (23.5%)	64 (43.2%)	
Other*	14 (7%)	8 (15.7%)	6 (4.1%)	
BMI (kg/m^2)**				
Mean BMI (95%CI)	30.6 (29.6-31.7)	32.3 (30.3-34.3)	30 (28.8-31.2)	0.55

<18.5-24.9	41 (20.6%)	7 (13.7%)	34 (23.0%)	0.05
25-34.9	82 (41.2%)	22 (43.1%)	60 (40.5%)	
>35	53 (26.6%)	21 (41.2%)	32 (21.6%)	
N/A* **	23 (11.6%)	1 (2.0%)	22 (14.9%)	
Median duration on dialysis (months) (IQR)	9.8 (34.8)	27.2 (35.3)	4.1 (32.2)	0.04

*Other = Pacific, Indian, African, Other European

**BMI calculated using height/weight documented closest to time of catheter insertion

***Missing data not included in statistical analysis

Catheter-specific variables

A lower proportion of antegrade catheters were inserted into the RIJV (66.7%), compared to the retrograde group (87.8%) p<0.01 (Table 2). There was no significant difference in the proportion of new punctures vs railroad exchanges between groups (19.6% vs 13.5%) p = 0.30.

Indication for insertion differed significantly between groups - temporary access was the most common indication for both groups (80.4% antegrade vs 84.5% retrograde), however more antegrade catheters were inserted for patients who declined AVF creation (19.6% vs 5.4%) and more retrograde catheters were inserted following an AVF (e.g., non-maturation or AVF failure) (10.1% vs 0%) p < 0.01.

Number of prior vascular access procedures differed significantly between groups for vascaths (median = 1 [IQR 0-2] (antegrade) vs 0 [IQR 0-1] (retrograde), p = <0.01 and THDCs (median = 1 [IQR 0-3] (antegrade) vs 0 [IQR 0-1] (retrograde),p < 0.01, both had higher counts in the antegrade group respectively. Number of prior AVF procedures did not differ significantly between groups (median 0 [IQR 0] (antegrade) vs 0 [IQR 0] (retrograde), p = 0.14.

Antegrade catheters had a lower mean URR (56.8% [54.3-59.4]) than retrograde catheters (65.4% [64.2-66.5]) p<0.01.

Fluoroscopy use for antegrade catheters was 86.3% vs retrograde catheters 98.6% p<0.01.

Most antegrade catheters were inserted by nephrologists (98.0%), while radiologists inserted more retrograde catheters (40.5%) p<0.01.

More antegrade catheters were removed for dysfunction (31.4% vs 11.5%), while more retrograde catheters were removed due to patient death (33.1% vs 5.9%) p<0.01 (consistent with a 'cohort effect' due to our unit's shift to antegrade-only catheters in 2022, as patients in the antegrade group were therefore less likely to have died during

the study period). Rates of catheter removal due to infection (exit site or bloodstream) were similar between groups (7.8% antegrade vs 8.1% retrograde) p<0.01.

Antegrade catheter patients remained on dialysis more frequently (92.1% vs 50.8%), whereas palliation or death was more common in the retrograde group (35.1% vs 5.9%) p<0.01 (again consistent with the 'cohort-effect' noted above).

Most catheters in both groups were positioned within the RA or CAJ at time of insertion - 82.3% in antegrade group vs 95.9% in retrograde group p = 0.41.

No patients in the antegrade group had split-tip catheters (0% vs 38.5% p<0.01)

30 day mortality was in the antegrade group was (1/51 (2.0%)) compared to (7/148 (4.7%)) in the retrograde group p=0.68.

Table 2: Catheter-specific Variables

	Overall (n=199)	**Antegrade (n=51)**	**Retrograde (n=148)**	**p-value**
Site				
RIJV	164 (82.4%)	34 (66.7%)	130 (87.8%)	<0.01
LIJV	26 (13.1%)	11 (21.5%)	15 (10.1%)	
Femoral	6 (3.0%)	5 (9.8%)	1 (0.7%)	
Subclavian	*2 (1.0%)*	*1 (2.0%)*	*1 (0.7%)*	
REJV	*1 (0.5%)*	*0 (0%)*	*1 (0.7%)*	
Exchange type				
New Puncture	169 (84.9%)	41 (80.4%)	128 (86.5%)	0.29
'Railroad' Exchange	30 (15.1%)	10 (19.6%)	20 (13.5%)	
Indication				
Temporary access	166 (83.4%)	41 (80.4%)	125 (84.5%)	<0.01
Declined AVF	18 (9.0%)	10 (19.6%)	8 (5.4%)	
Failed AVF	15 (7.6%)	0 (0%)	15 (10.1%)	
Previous access procedures (median, IQR)				
Vascath	0 (0-1)	1 (0-2)	0 (0-1)	<0.01
THDC	0 (0-1)	1 (0-3)	0 (0-1)	<0.01
AVF	0 (0)	0 (0)	0 (0)	0.14
Mean URR (mean, 95% CI)	63.3 (62.1-64.4)	56.8 (54.3-59.4)	65.4 (64.2-66.5)	<0.01
Fluoroscopy				
Yes	190 (95.5%)	44 (86.3%)	146 (98.6%)	<0.01

No	9 (4.5%)	7 (13.7%)	2 (1.4%)	
Proceduralist				
Nephrologist	138 (69.3%)	50 (98.0%)	88 (59.5%)	<0.01
Radiologist	61 (30.7%)	1 (2.0%)	60 (40.5%)	
Indication for removal				
Dysfunction	33 (16.6%)	16 (31.4%)	17 (11.5%)	<0.01
Other (sub-categories shown below)	166 (83.4%)	35 (68.6%)	131 (88.5%)	
Indication for removal (all subcategories				
Dysfunction	33 (16.6%)	16 (31.4%)	17 (11.5%)	<0.01
Infection (exit-site or bloodstream)	16 (8.0%)	4 (7.8%)	12 (8.1%)	1.00
Change of modality or access	76 (38.2%)	15 (29.4%)	61 (41.2%)	
Recovery of renal function	4 (2.0%)	0 (0%)	4 (2.7%)	
Death	52 (26.2%)	3 (5.9%)	49 (33.1%)	
Current	13 (6.5%)	11 (21.6%)	2 (1.4%)	
Patient relocation	5 (2.5%)	2 (3.9%)	3 (2.0%)	
Status at time of removal				
Dialysis	134 (67.4%)	47 (92.1%)	87 (58.8%)	<0.01
Transplant	6 (3.0%)	1 (2.0%)	5 (3.4%)	
Palliation or Death	55 (27.6%)	3 (5.9%)	52 (35.1%)	
Status at time of removal (all subcategories)				
HD	94 (47.3%)	36 (70.6%)	58 (39.2%)	<0.01
PD	40 (20.1%)	11 (21.5%)	29 (19.6%)	
Transplant	6 (3.0%)	1 (2.0%)	5 (3.4%)	
Palliation	3 (1.5%)	0 (0%)	3 (2.0%)	
Recovered	4 (2.0%)	0 (0%)	4 (2.7%)	
Death	52 (26.1%)	3 (5.9%)	49 (33.1%)	
Tip position				
RA	133 (66.8%)	32 (62.7%)	101 (68.2%)	0.41
CAJ	51 (25.7%)	10 (19.6%)	41 (27.7%)	
SVC	6 (3.0%)	3 (5.9%)	3 (2.0%)	
IVC	3 (1.5%)	1 (2.0%)	2 (1.4%)	
N/A	6 (3.0%)	5 (9.8%)	1 (0.7%)	
Split tip				
Yes	57 (28.6%)	0 (0%)	57 (38.5%)	<0.01

No	142 (71.4%)	51 (100%)	91 (61.5%)	
30 day mortality				
Yes	8 (4.0%)	1 (2.0%)	7 (4.7%)	0.68
No	191 (96.0%	50 (98.0%)	141 (95.3%)	

Abbreviations: RIJV = right internal jugular vein, LIJV = left internal jugular vein, REJV = right external jugular vein, AVF = arteriovenous fistula, THDC = tunnelled haemodialysis catheter, HD = haemodialysis, PD = peritoneal dialysis, RA = right atrium, CAJ = cavo-atrial junction, SVC = superior vena cava, IVC = inferior vena cava.

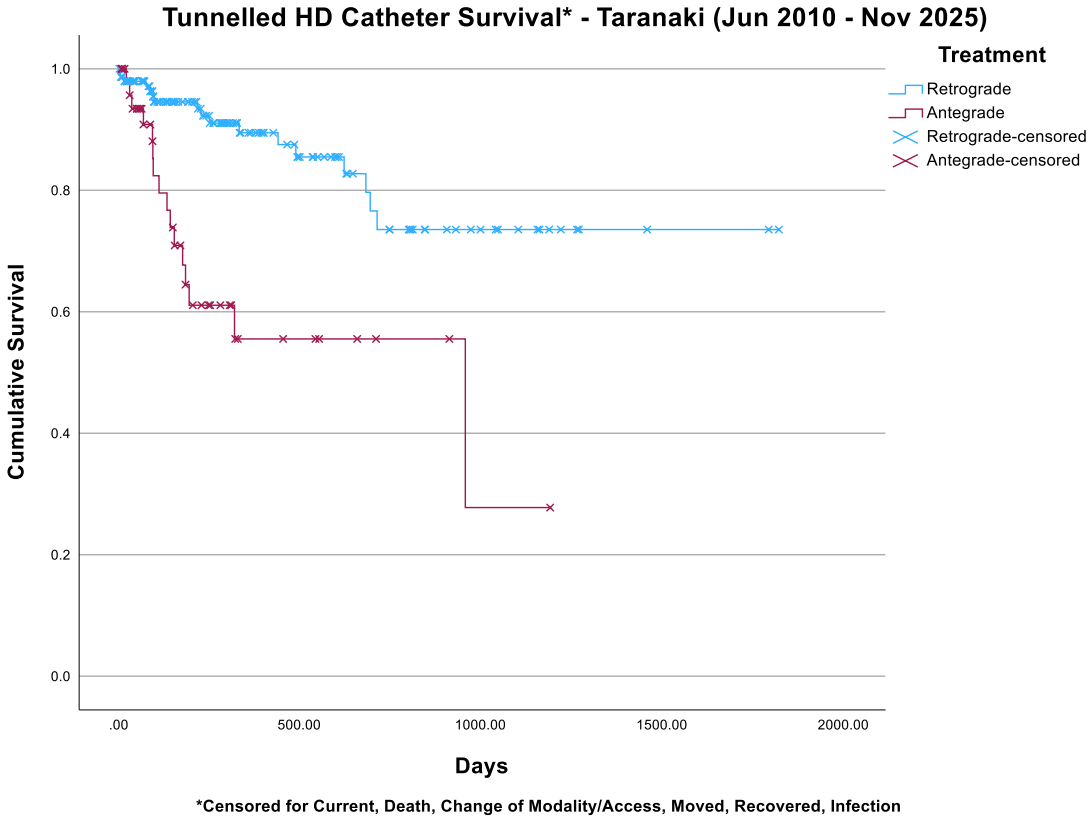
Catheter survival analysis

Before censorship, mean survival [95%CI]: antegrade 238.6 days [161.3-315.9] vs retrograde 371.5 days [310.8-432.2], p=0.02; median survival: antegrade 147 days [56-306] vs retrograde 248.5 days [93-537], p=0.01) (Table 3). A Kaplan-Meier survival analysis (Figure 2) was performed to compare catheter survival between the two study groups (antegrade vs retrograde), with censorship for catheter removal due to reasons other than dysfunction (infection, change of modality or access, recovery of renal function, patient death or patient relocation). Catheters still in-situ at the end of the study period were also censored. The log-rank (Mantel-Cox) test demonstrated a significant difference between the antegrade and retrograde survival curves $p<0.01$. The log-rank test does not adjust for demographic or catheter-specific variables, so this represents an unadjusted comparison of censored survival between the two insertion techniques.

Table 3: Overall survival (uncensored)

	Antegrade (n=51)	**Retrograde (n=148)**	**p value**
Mean survival (95%CI)	238.6 (161.3-315.9)	371.5 (310.8-432.2)	0.02
Median survival (IQR)	147 (56-306)	248.5 (93-537)	0.01

Figure 2: Kaplan-Meier survival curve (catheter survival)



A multivariable Cox proportional hazards regression model was constructed to evaluate the variables associated with catheter survival (Table 4). Hazard ratios shown are for antegrade catheters, with retrograde catheters as the reference. After adjusting for demographic and catheter-specific variables, catheter type was not significantly associated with catheter survival.

Antegrade insertion showed a higher, but statistically non-significant hazard of dysfunctional catheter removal (DCR) compared with retrograde insertion (HR [95%CI] = 2.74 [0.70-10.70], p=0.15).

Demographic variables were not significantly associated with catheter survival. Age at insertion (HR = 0.98 per year [0.95-1.02], p = 0.37), sex (male vs female HR = 1.03 [0.37-2.85], p = 0.95), ethnicity (NZ European vs NZ Māori HR = 0.91 [0.298-2.788], p = 0.87; NZ European vs Other HR = 2.57 [0.441-14.915], p = 0.294) and BMI (HR = 1.04 per kg/m^2 [0.97-1.11], p = 0.24).

For catheter-specific variables, prior vascular access (vascath, THDC or fistula) was not significantly associated with catheter dysfunction regardless of access type or number (Vascath 0 vs 1 HR = 1.644 [0.537-5.034], p = 0.38; Vascath 0 vs 2 HR = 1.497 [0.340-6.582], p = 0.59; Vascath 0 vs 3+ HR = 1.090 [0.185-6.408], p =0.92; THDC 0 vs 1 HR = 2.453 [0.739-8.138], p = 0.14; THDC 0 vs 2 HR = 1.569 [0.288-8.544], p = 0.60; THDC 0 vs

3+ HR = 4.723 [0.912-27.478], p = 0.08; AVF 0 vs 1 HR = 1.117 [0.301-4.139], p = 0.87; AVF 0 vs 2 HR = 7.219 [0.105-494.362], p = 0.36; AVF 0 vs 3+ Insufficient data).

Indication for access was not significantly associated with catheter survival - temporary access vs patient declined AVF HR = 0.93 [0.23-3.74], p = 0.92; temporary access vs failed AVF HR = 0.26 [0.02-3.26], p = 0.30).

Insertion site was not significantly associated with dysfunction - RIJV vs LIJV HR = 0.351 [0.073-1.681], p = 0.19; RIJV vs Femoral HR = 1.213 [0.097-15.162], p = 0.88; RIJV vs Other HR = 0.172 [0.004-8.056], p = 0.36).

Catheters inserted via 'railroad' technique were associated with significantly increased hazard of dysfunction compared with newly inserted catheters HR = 3.079 [1.139-8.318], p = 0.03.

No fluoroscopy use was not significantly associated with dysfunction compared to fluoroscopy use HR = 0.151 [0.012-1.835], p = 0.14.

Split tip catheters were not significantly associated with dysfunction compared to non-split tip catheters HR = 1.119 [0.318-3.938], p = 0.86.

Compared to RA tip position, CAJ tip position was not significantly associated with dysfunction HR = 0.971 [0.282-3.350], p = 0.96. However, SVC tip position was significantly associated with dysfunction compared to RA tip position HR = 14.755 [1.886-115.437], p = 0.01.

There was insufficient data to calculate a hazard ratio for dysfunction comparing RA with IVC tip position.

There was no significant difference in catheter survival between nephrologists and radiologists as proceduralists HR = 1.066 [0.272-4.182], p = 0.93.

Table 4: Cox regression model (catheter survival)

Variable	Hazard Ratio (95% CI)	p-value
Catheter type *(ref. = Retrograde)*		
Antegrade	2.744 (0.704-10.699)	0.15
Age at insertion *(per year)*	0.982 (0.945-1.021)	0.37
Sex *(ref. = Male)*		
Female	1.028 (0.371-2.845)	0.95
Ethnicity *(ref. = NZ European)*		
NZ Māori	0.911 (0.298-2.788)	0.87
Other	2.565 (0.441-14.915)	0.29
BMI *(per kg/m^2)*	1.040 (0.974-1.111)	0.24
Vascath *(ref. = 0)*		

1	1.644 (0.537-5.034)	0.38
2	1.497 (0.340-6.582)	0.59
3+	1.090 (0.185-6.408)	0.92
THDCs *(ref. = 0)*		
1	2.453 (0.739-8.138)	0.14
2	1.569 (0.288-8.544)	0.60
3+	4.723 (0.912-27.478)	0.08
Fistula *(ref. = 0)*		
1	1.117 (0.301-4.139)	0.87
2	7.219 (0.105-494.362)	0.36
3+	N/A	N/A
Indication *(ref. = Temporary access)*		
Declined AVF	0.932 (0.231-3.758)	0.92
Failed AVF	0.262 (0.021-3.264)	0.30
Site *(ref. = RIJV)*		
LIJV	0.351 (0.073-1.681)	0.19
Femoral	1.213 (0.097-15.162)	0.88
Other	0.172 (0.004-8.056)	0.37
Exchange type *(ref. New)*		
'Railroad' exchange	3.079 (1.139-8.318)	0.03
Fluoroscopy *(ref. Yes)*		
No	0.151 (0.012-1.835)	0.13
Split tip *(ref. No)*		
Yes	1.119 (0.318-3.938)	0.86
Tip position *(ref. RA)*		
CAJ	0.971 (0.282-3.350)	0.96
SVC	14.755 (1.886-115.437)	0.01
IVC	N/A	N/A
Proceduralist *(ref. Nephrologist)*		
Radiologist	1.066 (0.272-4.182)	0.93

Discussion

Our study aimed to determine whether THDC type (antegrade vs retrograde) is associated with catheter survival. We are unaware of any previous studies that have compared outcomes between antegrade and retrograde catheters. In the unadjusted analysis, we observed shorter catheter survival with antegrade catheters compared to retrograde catheters. This association did not reach statistical significance after adjustment for demographic and catheter-specific variables. Although the Cox regression model demonstrated a higher hazard of dysfunction with antegrade insertion (HR = 2.74), the wide 95% confidence interval [95% CI 0.70-10.70] indicates imprecision, likely due to low dysfunction counts/high variance in catheter survival and imbalance between the two study groups, leading to a non-significant p value.

As this was a retrospective observational study, residual confounding cannot be excluded. Although we controlled for a broad range of relevant demographic and clinical variables, unmeasured variables such as operator experience and temporal changes in practice over the study period may have influenced susceptibility to catheter dysfunction over time. Additionally, we could not account for minor variations in insertion technique or expertise between different proceduralists over time. Likewise, due to lack of documentation in electronic health records until 2023, we could not account for temporal changes in practice related to catheter anticoagulation locks or disposable catheter access hubs. We did not record fibrin sheath disruption procedures for 'railroad' insertions, as this data was inconsistently recorded and prior to 2023, rarely performed at our institution to our knowledge. Additionally, our institution's predominant use of a specific THDC product could in theory limit external validity to other THDC manufacturers, however there is no evidence to our knowledge that catheter product/brand is associated with catheter survival or other outcomes.

As 'sub-group' findings, this study identified SVC tip position and railroad exchange as independent predictors of tunnelled HD catheter dysfunction. Catheters with tips positioned in the SVC at insertion demonstrated a significantly higher hazard of dysfunction compared with RA tip position (HR = 14.76, p=0.01). This is consistent with existing literature of SVC tip position as a risk factor for catheter dysfunction (5,7–10,16). Similarly, 'railroad' exchange had a significantly higher hazard of dysfunction relative to new punctures (HR = 3.079 p=0.03). Catheter exchange at the same anatomical position is known to be independently associated with a higher risk of complications, including dysfunction due to thrombosis or fibrin sheath (22). At time of dysfunctional THDC exchange, the incidence of a persisting fibrin sheath is 47-82% (23–25). After exchange, Shanaah et al. (23) found no statistically significant difference in the occurrence of subsequent infection or dysfunction however, whether fibrin sheath was present (and treated) or not. Interestingly, a recent Australasian study found that unplanned removal due to mechanical catheter dysfunction, occurred at similar rates for catheters exchanged over guidewire compared with new punctures. Guidewire exchange was not associated with worse complication-free catheter survival compared to new punctures at 1, 6 or 12 months (26). Within-unit differences in catheter survival were not reported however, unlike our study.

It is important to mention that the distribution of tip position and exchange type (new puncture vs 'railroad') was similar between antegrade and retrograde groups in our study, so these variables were unlikely to account for the observed differences in catheter dysfunction and are likely to be independent predictors of catheter survival. Although these associations were statistically significant, the 95% confidence intervals observed (RA vs SVC [95% CI 1.886-115.437], new puncture vs railroad [95% CI 1.139-

8.318] reflect limited precision in estimation of effect size, likely due to the small sub-group size and low dysfunction counts. Therefore, the magnitude of these effects should be interpreted with caution, although the associations are clinically plausible.

We observed that mean URR was significantly higher in the retrograde catheter group compared to antegrade catheters. The 2015 NKF-KDOQI Clinical Practice Guidelines for Haemodialysis Adequacy (19) state that the recommended session Kt/V should be at least 1.2 (equivalent to URR ≥65%) and recommends corrective action when Kt/V falls below this value. Mean URR for antegrade catheters was below this value in our study, unlike retrograde catheters. Davanzo (18) observed that retrograde catheters demonstrated high flow rates, with a mean Kt/V of 1.55-1.60. This observation was hypothesised to reflect better tip positioning with retrograde-inserted catheters – however no comparison was made with antegrade catheters in that study.

Catheter tip position is known to be the most important factor influencing blood flow rates in tunnelled HD catheters (27). High dialysis flow rates in adults are associated with improved dialysis adequacy due to higher Kt/V and URR (28). We did not record flow rates in our study due to lack of consistent documentation in our renal database prior to 2023. However, we observed that the distribution of tip location did not differ significantly between the antegrade and retrograde groups, suggesting that the observed difference in URR is unlikely to be solely attributable to tip position. Although we did not collect data on dialysis treatment times, the standard dialysis treatment time (4 hours) did not change over the study period at our renal unit and any variation to dialysis treatment time is typically guided by clinical factors, including the 3 monthly URR value. It is therefore safe to assume that the observed difference in URR in our study was not due to temporal differences in dialysis treatment time between the two groups. Differences in catheter length can also influence URR but this data was not collected in our study due to lack of consistent documentation. To our knowledge, our study is the first to report a difference in dialysis adequacy between antegrade and retrograde THDCs, highlighting an area for further investigation in future studies.

The median duration on dialysis was observed to have large variance in both study groups, consistent with the inclusion of patients starting dialysis acutely with a THDC. The longer duration observed in the antegrade group reached statistical significance and likely reflects the ‘cohort effect’ in our study population as ‘crash-starts’ on haemodialysis with a THDC have anecdotally decreased in frequency over time at our institution. We did not include this variable in the adjusted analysis as it was not included *a priori*. Additionally, our method for calculating duration on dialysis for patients with previous failed kidney transplant may have underestimated the effect of pre-transplant kidney failure and dialysis on outcomes. Determining the ‘sum total’ duration on dialysis was not possible for these patients due to a lack of historical data on electronic health records.

Although 30 day mortality was lower in the antegrade group (1/51 (2.0%)) compared to the retrograde group (7/148 (4.7%)), this difference was non-significant (p=0.68). There was no significant difference in catheter infection as a reason for catheter removal between the two groups (7.8% vs 8.1%, p=1.00). We can therefore conclude that the two catheter types have similar safety profiles with regard to short-term mortality and clinically significant infection. However these results are likely to be influenced by low event numbers so a larger study would help to confirm this.

Our study has several key strengths. Firstly, we collected data and adjusted for multiple known causes of dysfunction to control for confounding (7,29,30). The temporal transition from retrograde to antegrade insertion technique at an institutional level eliminated the risk of confounding by proceduralist choice as a determinant of catheter type used. As a result, catheter type was largely determined by 'era of procedure' rather than proceduralist decision-making, mitigating confounding by 'indication for catheter insertion'. The retrospective design of this study meant that we included multiple operators undertaking routine, 'real-world' clinical procedures, which enhances external validity and generalisability.

A limitation of our study's retrospective, single-centre design was variation in demographic and catheter-specific variables between the antegrade and retrograde groups. Our study may have been underpowered to detect a statistically significant association between insertion technique and catheter survival. This is reflected in some subgroups with very low event numbers and wide 95% confidence intervals. This made it difficult to accurately determine effect size, even when results were statistically significant. We observed that earlier clinical data (2010-2015) often contained less detail than data documented in more recent years. This resulted in missing data for BMI and catheter tip position (particularly for femoral THDCs, where tip position is not usually confirmed radiologically), that had to be accounted for by multiple imputation in the Cox regression analysis.

We did not include other baseline demographics such as comorbidities or smoking, due to lack of consistent documentation in electronic health records. This data would be easier to collect in a prospective study.

While our study observed a statistically non-significant association after adjustment, the statistical limitations mentioned earlier and lack of previous research into antegrade vs retrograde THDCs, leads us to conclude that the evidence remains equivocal as to any difference in catheter survival between the two groups. Many limitations in our study could be alleviated by a larger sample size with higher dysfunction events. Future research into antegrade vs retrograde catheter survival could arise from a THDC registry or a randomised controlled trial, though the latter would be challenging in some aspects (e.g. blinding proceduralists and patients is not possible) and potentially costly. In contrast, a registry-based approach would capture 'real-world'

practice across multiple centres and jurisdictions, with sufficient statistical power to detect a difference in catheter survival after adjustment for multiple variables. Currently, the ANZDATA (Australia and New Zealand Dialysis and Transplant) Registry collects data on tunnelled HD catheter infection rates for every renal unit in New Zealand and Australia. Future data collection of catheter type (antegrade vs retrograde) and catheter survival is therefore a realistic aim, in our opinion.

We believe that our findings may have practical relevance in selected clinical contexts, despite being statistically non-significant after multi-variable adjustment. Due to the similar cost and risk profile between the two catheter types, retrograde catheters insertion could be justified in our opinion, for patients anticipated to require prolonged THDC use, e.g. due to limited vascular access options, those with a poor prognosis (e.g. less than 6 months estimated survival) or those anticipating kidney transplantation within 6 months. Even modest differences in THDC performance translates to fewer dysfunction episodes and additional vascular procedures over time. Although the two catheter types used in this study cost the same, formal cost-benefit analysis would require consideration of procedure time differences between retrograde and antegrade insertion, as anecdotally, retrograde catheters take longer to insert – but that is dependent on proceduralist experience. Our findings also highlight the importance of enabling proficiency in antegrade and retrograde inserted THDCs within nephrology training programmes, to preserve flexibility in clinical decision-making and potentially enhancing patient outcomes.

In summary, in this single-centre, multi-operator retrospective study of antegrade vs retrograde THDCs, antegrade THDCs were associated with shorter catheter survival, with no significant difference in 30 day mortality or catheter removal due to infection. The association with shorter catheter survival did not reach statistical significance after multivariable adjustment. Sub-group analyses identified SVC tip position and railroad exchange as independent predictors of catheter dysfunction, adding to existing literature. Retrograde catheters were associated with significantly higher mean URR compared to antegrade catheters, consistent with higher flow rates and improved HD adequacy. While this study was limited by relatively small sample size, low event rates and potential residual confounding, it provides novel comparative data for catheter survival between antegrade vs retrograde catheters, with clinical and research implications. We propose that larger, multi-centre studies are warranted to more precisely quantify this relationship, perhaps utilising renal registries or a randomised controlled trial.

References

1. Richards K, Davies C, Bateman S, Chen J, Clayton P, Forcey D, et al. 48th Report, Chapter 9 [Internet]. Adelaide, Australia: Australia and New Zealand Dialysis and Transplant Registry; 2025. Available from: https://anzorrg.org.au/reports/anzdata-48th-annual-report-2025-data-survey-2024

2. Lopez-Vargas PA, Craig JC, Gallagher MP, Walker RG, Snelling PL, Pedagogos E, et al. Barriers to Timely Arteriovenous Fistula Creation: A Study of Providers and Patients. Am J Kidney Dis. 2011 Jun 1;57(6):873–82. doi:10.1053/j.ajkd.2010.12.020

3. Abdelfattah M, Mohamed E, Kader A, Abbas R, Shorbgy M. Comparative Study between Arteriovenous Fistula and Tunneled Hemodialysis Catheter in Dialysis Efficiency. Al-Azhar Int Med J. 2024 Oct 31;5. doi:10.58675/2682-339X.2702

4. Fry AC, Stratton J, Farrington K, Mahna K, Selvakumar S, Thompson H, et al. Factors affecting long-term survival of tunnelled haemodialysis catheters—a prospective audit of 812 tunnelled catheters. Nephrol Dial Transplant. 2008 Jan 1;23(1):275–81. doi:10.1093/ndt/gfm582

5. Engstrom BI, Horvath JJ, Stewart JK, Sydnor RH, Miller MJ, Smith TP, et al. Tunneled Internal Jugular Hemodialysis Catheters: Impact of Laterality and Tip Position on Catheter Dysfunction and Infection Rates. J Vasc Interv Radiol. 2013 Sep;24(9):1295–302. doi:10.1016/j.jvir.2013.05.035

6. Weber E, Liberek T, Wołyniec W, Rutkowski B. Catheter tip malposition after percutaneous placement of tunneled hemodialysis catheters. Hemodial Int. 2015;19(4):509–13. doi:10.1111/hdi.12303

7. Sohail MA, Vachharajani TJ, Anvari E. Central Venous Catheters for Hemodialysis—the Myth and the Evidence. Kidney Int Rep. 2021 Oct 11;6(12):2958–68. doi:10.1016/j.ekir.2021.09.009 PubMed PMID: 34901568; PubMed Central PMCID: PMC8640568.

8. Kanchanasuttirak W, Lekhavat V, Kanchanasuttirak P. Long-Term Tunneled Hemodialysis Catheters: Achieving Efficiency Through Tip Position Optimization. Ann Vasc Surg. 2024 Aug 1;105:158–64. doi:10.1016/j.avsg.2024.01.018

9. Morgan D, Ho K, Murray C, Davies H, Louw J. A Randomized Trial of Catheters of Different Lengths to Achieve Right Atrium Versus Superior Vena Cava Placement for Continuous Renal Replacement Therapy. Am J Kidney Dis. 2012 Aug 1;60(2):272–9. doi:10.1053/j.ajkd.2012.01.021

10. Maggiani-Aguilera P, Chávez-Iñiguez JS, Navarro-Gallardo JG, Navarro-Blackaller G, Flores-Llamas AM, Pelayo-Retano T, et al. The impact of anatomical variables on haemodialysis tunnelled catheter replacement without fluoroscopy. Nephrology. 2021;26(10):824–32. doi:10.1111/nep.13909

11. Adwaney A, Lim C, Blakey S, Duncan N, Ashby DR. Central Venous Stenosis, Access Outcome and Survival in Patients undergoing Maintenance Hemodialysis. Clin J Am Soc Nephrol CJASN. 2019 Mar 7;14(3):378–84. doi:10.2215/CJN.07010618 PubMed PMID: 30765534; PubMed Central PMCID: PMC6419278.

12. Al-Balas A, Almehmi A, Varma R, Al-Balas H, Allon M. De Novo Central Vein Stenosis in Hemodialysis Patients Following Initial Tunneled Central Vein Catheter Placement. Kidney360. 2021 Oct 21;3(1):99–102. doi:10.34067/KID.0005202021 PubMed PMID: 35368564; PubMed Central PMCID: PMC8967595.

13. Schröppel B, Bettac L, Schulte-Kemna L, Kächele M. Placement of tunnelled haemodialysis catheters—interventional standard. Nephrol Dial Transplant. 2025 Feb 1;40(2):264–72. doi:10.1093/ndt/gfae181

14. Tampe D, Tampe B. Determinants of Tunneled Hemodialysis Catheter Implantation Time by Ultrasound Guidance: A Single-Center Cross-Sectional Study. J Clin Med. 2022 Jun 19;11(12):3526. doi:10.3390/jcm11123526 PubMed PMID: 35743596; PubMed Central PMCID: PMC9225020.

15. Bream PR. Update on Insertion and Complications of Central Venous Catheters for Hemodialysis. Semin Interv Radiol. 2016 Mar;33(1):31–8. doi:10.1055/s-0036-1572547 PubMed PMID: 27011425; PubMed Central PMCID: PMC4803506.

16. Agarwal AK, Haddad N, Boubes K. Avoiding problems in tunneled dialysis catheter placement. Semin Dial. 2019;32(6):535–40. doi:10.1111/sdi.12845

17. Wheeler RA, Griffiths DM, Burge DM. Retrograde Tunnel: A Method for the Fixation of Long-Term Pediatric Central Venous Catheters. J Parenter Enter Nutr. 1991;15(1):114–5. doi:10.1177/0148607191015001114

18. Davanzo WJ. Efficacy and Safety of a Retrograde Tunneled Hemodialysis Catheter: 6-Month Clinical Experience with the Cannon Catheter™ Chronic Hemodialysis Catheter. J Vasc Access. 2005 Jan 1;6(1):38–44. doi:10.1177/112972980500600109

19. Daugirdas JT, Depner TA, Inrig J, Mehrotra R, Rocco MV, Suri RS, et al. KDOQI Clinical Practice Guideline for Hemodialysis Adequacy: 2015 Update. Am J Kidney Dis. 2015 Nov 1;66(5):884–930. doi:10.1053/j.ajkd.2015.07.015

20. Williams A. Renal Reality (REALITY). New Plymouth, New Zealand: Simcart Ltd; 2025. (Real-time Entry of Renal Events Accumulating in a Live Interactive Timeline).

21. Auer J, Braun J, Lenk J, Gollrad J, Ro SR, Hamm B, et al. Tunneled hemodialysis catheter insertion: Above, within, or below the right atrium—Where is the tip? Acta Radiol Open. 2022 Sep 1;11(9):20584601221122421. doi:10.1177/20584601221122421

22. Tapping CR, Scott PM, Lakshminarayan R, Ettles DF, Robinson GJ. Replacement tunnelled dialysis catheters for haemodialysis access: Same site, new site, or

exchange — A multivariate analysis and risk score. Clin Radiol. 2012 Oct;67(10):960–5. doi:10.1016/j.crad.2012.03.002

23. Shanaah A, Brier M, Dwyer A. Fibrin Sheath and its Relation to Subsequent Events after Tunneled Dialysis Catheter Exchange. Semin Dial. 2013;26(6):733–7. doi:10.1111/sdi.12074

24. Oliver MJ, Mendelssohn DC, Quinn RR, Richardson EP, Rajan DK, Pugash RA, et al. Catheter Patency and Function after Catheter Sheath Disruption: A Pilot Study. Clin J Am Soc Nephrol. 2007 Nov;2(6):1201. doi:10.2215/CJN.01910507

25. Chan MR. Hemodialysis Central Venous Catheter Dysfunction. Semin Dial. 2008;21(6):516–21. doi:10.1111/j.1525-139X.2008.00495.x

26. Lazarus B, Kotwal S, Gallagher M, Gray NA, Coggan S, Talaulikar G, et al. Replacement Strategies for Tunneled Hemodialysis Catheters with Complications. Clin J Am Soc Nephrol CJASN. 2024 Sep;19(9):1148–58. doi:10.2215/CJN.0000000000000495 PubMed PMID: 38913437; PubMed Central PMCID: PMC11390028.

27. Mandolfo S, Galli F, Costa S, Ravani P, Gaggia P, Imbasciati E. Factors influencing permanent catheter performance. J Vasc Access. 2001;2(3):106–9. doi:10.1177/112972980100200304 PubMed PMID: 17638270.

28. Iman Y, Bamforth R, Ewhrudjakpor R, Komenda P, Gorbe K, Whitlock R, et al. The impact of dialysate flow rate on haemodialysis adequacy: a systematic review and meta-analysis. Clin Kidney J. 2024 Jul 1;17(7):sfae163. doi:10.1093/ckj/sfae163

29. Lazarus B, Lok CE, Moist L, Polkinghorne KR. Strategies to Prevent Hemodialysis Catheter Dysfunction. J Am Soc Nephrol JASN. 2025 May 1;36(5):952–66. doi:10.1681/ASN.0000000666 PubMed PMID: 39977120; PubMed Central PMCID: PMC12059100.

30. Mohazzab A, Khavaninzadeh M, Dehesh P, Abdolvand N, Rahimi Z, Rahmani S. Investigation of risk factors for tunneled hemodialysis catheters dysfunction: competing risk analysis of a tertiary center data. BMC Nephrol. 2022 Sep 2;23. doi:10.1186/s12882-022-02927-z