Original Article

Effect of puncture position on catheter patency rate during tunnelled dialysis catheter insertion from the right internal jugular vein

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Background: No recommendations have been made regarding the puncture position during tunnelled dialysis catheter (TDC) insertion from right internal jugular vein (RIJV). We investigated the effect of puncture positioning along with other characteristics and clinical factors associated with TDCs to determine their correlation with catheter patency rate.

Methods: We retrospectively reviewed TDC insertion procedures performed between January 2018 and December 2020 at a single institution. Patients were monitored for at least 1 year or until TDC removal or replacement. The distance on the post-operative chest radiography were measured to determine the height of puncture position. End points were freedom from catheter dysfunction.

Results: Total 949 catheters met the eligibility criteria. Catheter dysfunction occurred in 233 patients and catheter infection in 127 patients. By multivariate analysis, female sex [hazard ratio (HR) =1.497, 95% confidence interval (CI): 1.119–2.002; P=0.007] and split-tip catheter (HR =1.453, 95% CI: 1.087–1.944; P=0.012) were associated with an increased rate of catheter dysfunction. Every 10-year increment in age (HR =1.243, 95% CI: 1.123–1.376; P<0.001) and every 1-cm increase in the height of the catheter insertion site (HR =1.270, 95% CI: 1.096–1.473; P=0.001) were also associated with an increased rate of catheter dysfunction. After classifying the height of puncture position into 3 groups, significant worse patency was observed in the catheter with puncture height more than 4 cm (P=0.025). No immediate complications were observed.

Conclusions: TDC insertion at a high puncture site correlates with an increased risk of catheter dysfunction. Puncturing the RIJV close to the clavicle is safe and enhances catheter patency.

Keywords: Tunnelled dialysis catheter (TDC); right internal jugular vein (RIJV); puncture position

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Introduction

Tunnelled dialysis catheter (TDC) insertion is not the first choice of vascular access for patients undergoing long-term haemodialysis because it is associated with high risks of infection, malfunction, insufficient blood flow, occlusion, and central vein stenosis (1-3). In scenarios involving the absence of nephrology visits, the urgent need for haemodialysis, immature arteriovenous fistulas (AVFs), and limited patient awareness, patients undergoing haemodialysis require TDC insertion as a bridge until a functional AVF is established. Nevertheless, despite all efforts advocating the establishment of early AVF, the prevalence of TDC in patients undergoing haemodialysis still ranges from 40% to 80% (4-6).

Long-term TDC use is observed in 10% to 20% of patients undergoing haemodialysis, especially in those with limited life expectancy and poor vessel quality. The longer a TDC remains in place, the higher is the risk of complications, including catheter dysfunction, catheter-related infection, and catheter dislodgement. Many studies have revealed that catheter insertion from the right internal jugular vein (RIJV) is associated with improved patency (7,8). Other studies have reported similar patency with varying TDC tip positions and tip designs (9-11). In all cases, the survival of a TDC at 1-year ranges from 60% to 80% (8,9,12).

During the insertion of a TDC through the RIJV, the catheter is inserted from a skin incision made below the clavicle, and it is then tunnelled underneath the skin to another incision made at the neck and finally to the RIJV. During this procedure, a bend is inevitably created, whose angle is partly determined by the position of the puncture site of RIJV. To date, no recommendations have been made regarding the puncture position of the RIJV. In this study, we evaluated the position of the puncture site and examined other characteristics associated with the configuration of TDCs and other clinical factors to determine their correlation with TDC patency rate. We present this article in accordance with the STROCSS reporting checklist (available at https://qims.amegroups.com/article/view/10.21037/qims-24-417/rc).

Methods

In this study, we retrospectively reviewed TDC insertion procedures performed between January 2018 and December 2020 at a single institution. Patients who underwent their first TDC insertion through the RIJV were exclusively selected. Patients who underwent TDC insertion through other access points, such as the femoral vein or left internal jugular vein, were excluded from the study because of their low patency rate, as confirmed by the findings in the literature. Patients who had previous TDC insertion through the RIJV or who underwent TDC replacement were also excluded to eliminate the likelihood of fibrin sheath formation or central vein stenosis. All patients included in the study were followed up until the time of TDC removal or replacement or for at least 1 year. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Institutional Review Board of Taipei Veterans General Hospital (No. 2018-06-010AC#1) and individual consent for this retrospective analysis was waived.

All procedures were performed by vascular surgeons in the operating room. RIJV puncturing was performed under ultrasound guidance. After serial dilatation, a TDC was inserted using the Seldinger technique through a subcutaneous tunnel from the right upper chest. Subsequently, C-arm fluoroscopy was used to determine the position of the tip and the presence of a kink at the turning point of the catheter above the clavicle. After returning to their respective wards, all patients underwent chest radiography for confirmation.

At our institution, we use only two TDC tip designs: a step-tip (HemoStar; BD Bard, Franklin Lakes, NJ, USA) and a split tip (EQUISTREAM; BD Bard, Franklin Lakes, NJ, USA). The choice of tip design is typically made by the vascular surgeon depending on their preferences and the availability of catheters. Two catheter lengths are used: 19 cm and 23 cm. The decision for the catheter length is also made by the vascular surgeon depending on the patient's height and body mass index.

After the procedure, chest radiography is performed to measure the perpendicular distance from the hinge point of the catheter to the clavicle, which represents the height of the puncture site during catheter placement (*Figure 1*). In addition, chest radiography is used to categorise the catheter tip into superior vena cava (SVC), cavoatrial junction, or right atrium (RA) (7). Subsequently, the cardiothoracic ratio is used to measure the width of the cardiac silhouette and thoracic cavity, with a ratio greater than 0.5 indicating cardiomegaly. Chest radiography is also used to identify other catheters of the SVC or RA category, such as permanent pacemaker leads and port-A catheters.

Elective catheter removal is performed if the patient

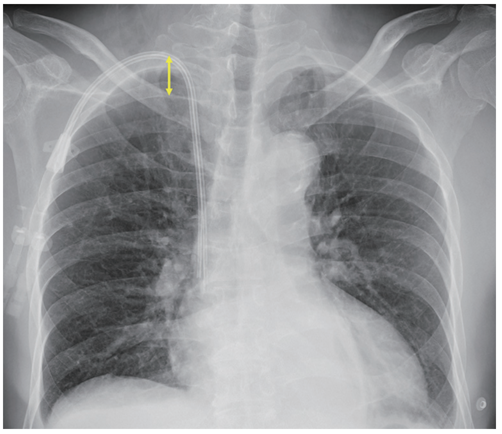

Figure 1 On chest radiography, the yellow line is the perpendicular distance from the hinge point of the catheter to the clavicle, which represents the height of the initial puncture site during catheter placement.

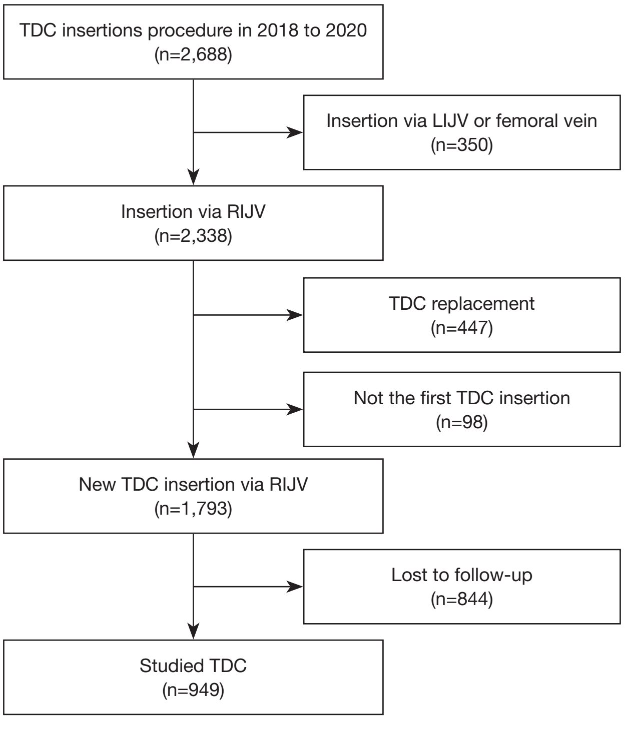

Figure 2 Patient selection flowchart. TDC, tunnelled dialysis catheter; LIJV, left internal jugular vein; RIJV, right internal jugular vein.

no longer requires a TDC as a result of either vascular access maturation, kidney transplantation, or renal function recovery. Catheter dysfunction is defined in a patient when a catheter cannot provide sufficient blood flow during haemodialysis, necessitating its replacement.

Data with a normal distribution are expressed as means and standard deviations, and quantitative data are expressed as percentages. Curves of catheter patency rate was drawn using the Kaplan-Meier method. Univariate and multivariate analyses were conducted using a Cox proportional-hazards model to evaluate the prognostic factors of catheter dysfunction and catheter infection. Multivariate logistic regression was conducted for factors with a P value of <0.1 in a univariate analysis. All statistical analyses were conducted using SPSS version 17.0 (SPSS, Chicago, IL, USA). A P value less than 0.5 was considered statistically significant.

Results

A total of 2,688 TDC insertion procedures were performed during the study period. After the study eligibility criteria were applied, 949 patients were finally included in the study (*Figure 2*). The mean age of the study cohort was 66.8 years, of whom 53.7% were men. *Table 1* presents the baseline demographics of the patients and the characteristics of their TDCs.

TDCs were electively removed in 526 patients, with a median time of 6 months to catheter removal. Catheter dysfunction requiring TDC replacement was observed in 233 patients, with a median time of 6 months to catheter replacement. Nonelective TDC removal was performed in 127 patients as a result of catheter infection. A total of 40 patients experienced catheter dislodgement and underwent catheter revision or replacement, and 23 patients were lost to follow up before catheter removal. The rate of freedom from catheter dysfunction at 6, 12, and 24 months was 81.3%, 66.4%, and 42.3%, respectively.

According to the univariate survival analysis results, female sex [hazard ratio (HR) =1.588, 95% confidence interval (CI): 1.222–2.064; P<0.001], split-tip catheter (HR =1.402, 95% CI: 1.071–1.836; P=0.014), cardiomegaly (HR =1.341, 95% CI: 1.010–1.780; P=0.043), advanced age (HR for each 10-year increment =1.254, 95% CI: 1.137–1.382, P<0.001), and higher puncture site (HR for each 1-cm increase =1.261, 95% CI: 1.095–1.453; P=0.001) were associated with an increased risk of catheter dysfunction. Compared with the 19-cm catheter, the 23-cm catheter was associated with a lower rate of catheter dysfunction (HR =0.727, 95% CI: 0.561–0.942; P=0.016). According to the multivariate survival analysis results, female sex (HR =1.497,

Table 1 Baseline demographics of patients and the characteristics of their tunnelled dialysis catheters

Characteristics	Value
Age, years	66.8±14.8
Male	510 (53.7)
Antiplatelet agent use	217 (22.9)
Anticoagulant use	43 (4.5)
Cardiomegaly	600 (63.2)
Other catheter in place	28 (3.0)
Catheter tip position	
Superior vena cava	193 (20.3)
Cavoatrial junction	358 (37.7)
Right atrium	398 (41.9)
Catheter length	
19 cm	406 (42.8)
23 cm	543 (57.2)
Catheter tip design	
Split-tip	355 (37.4)
Step-tip	594 (62.6)
Catheter height, cm	1.82±0.87

Values are presented as mean ± standard deviation or number (%).

95% CI: 1.119–2.002; P=0.007) and split-tip catheter (HR =1.453, 95% CI: 1.087–1.944; P=0.012) were associated with an increased rate of catheter dysfunction. Every 10-year increment in age (HR =1.243, 95% CI: 1.123–1.376; P<0.001) and every 1-cm increase in the height of the catheter insertion site (HR =1.270, 95% CI: 1.096–1.473; P=0.001) were also associated with an increased rate of catheter dysfunction (*Table 2*).

The catheters were classifying into three groups: puncture height <2 cm, puncture height ≥2 and <4 cm, puncture height ≥4 cm. Significant differences of patency rate were observed between the three groups (P=0.025) (*Figure 3*).

No immediate complications, such as pneumothorax, haemothorax, haematoma, or cardiac tamponade, were observed during any of the procedures. A total of 34 patients (3.6%) experienced bleeding at the catheter insertion site or at the suture holes and were treated with manual compression, and no further intervention was required.

Discussion

TDC insertion is a common and simple procedure with a high technical success rate. TDCs provide an easily manageable high-flow access for haemodialysis. However, their long-term use is associated with certain complications, such as catheter dysfunction and catheter infection. In this study, we discovered that increasing the height of the puncture site during catheter insertion may increase the rate of catheter dysfunction. Although the majority of studies have focused on the effect of the tip position and tip design on catheter durability, our findings indicate that the position of RIJV puncture may also play a key role in maintaining catheter function.

TDC placement requires the catheter to tunnel upwards from the first skin incision below the clavicle, and to turn downwards at the neck where the initial puncture site is. Therefore, the angle of the bend is partly determined by the height of the puncture site. The higher the venipuncture site is, the smaller this angle is. A high pressure and low velocity region inside the catheter are created at the elbow of the bent, and the distribution of this region enlarges with the decrease of the bending angle. That is, a sharp angle may reduce the flow rate and increase the likelihood of thrombus formation within the catheter (13). Consistent with the concept of fluid mechanics, a higher puncture site may result in a higher catheter dysfunction rate. In addition, the higher the position of the catheter is in the neck, the higher the likelihood of kink formation is during head turning. A small crimp in the catheter may result in elevated resistance and decreased flow. Therefore, to gain further insights into the configuration of TDCs, further fluid mechanics research is required.

The first half of a TDC insertion procedure resembles the insertion of a central venous catheter (CVC) through the RIJV. Traditionally, physicians use anatomical landmarks to identify the jugular veins, which lie underneath Sedillot's triangle, which is formed by the sternal and clavicular heads of the sternocleidomastoid muscle and the clavicle. If the puncture site is close to the clavicle and the needle advances too deep, the needle may injure the subclavian artery or lungs, resulting in catastrophic complications. Currently, ultrasound is used either before the procedure for target identification or during the procedure for real-time monitoring to minimise the complications of CVC insertion (14-16). In accordance with the Kidney Disease

Table 2 Univariate and multivariate Cox proportional-hazards models for catheter dysfunction

Variable	Univariate				Multivariate			
	HR	95% CI		P value	HR	95% CI		P value
		Lower	Upper			Lower	Upper	
Age, every increase in 10 years	1.254	1.137	2.064	<0.001	1.243	1.123	1.376	<0.001
Female	1.588	1.222	2.064	<0.001	1.497	1.119	2.002	0.007
Split tip design	1.402	1.071	1.836	0.014	1.453	1.087	1.944	0.012
Catheter length of 23 cm	0.727	0.561	0.942	0.016	1.004	0.722	1.396	0.980
Tip position								
Superior vena cava	1	–	–	–	–	–	–	–
Cavoatrial junction	0.749	0.530	1.060	0.103	0.905	0.626	1.309	0.597
Right atrium	0.676	0.480	0.952	0.025	0.899	0.603	1.342	0.602
Catheter height, every increase in 1 cm	1.261	1.095	1.453	0.001	1.270	1.096	1.473	0.001
Antiplatelet	1.205	0.902	1.610	0.207	–	–	–	–
Anticoagulant	1.586	0.939	2.678	0.084	1.511	0.886	2.575	0.129
Other catheter in place	0.696	0.287	1.690	0.423	–	–	–	–
Cardiomegaly	1.341	1.010	1.780	0.043	1.074	0.794	1.451	0.644

HR, hazard ratio; CI, confidence interval.

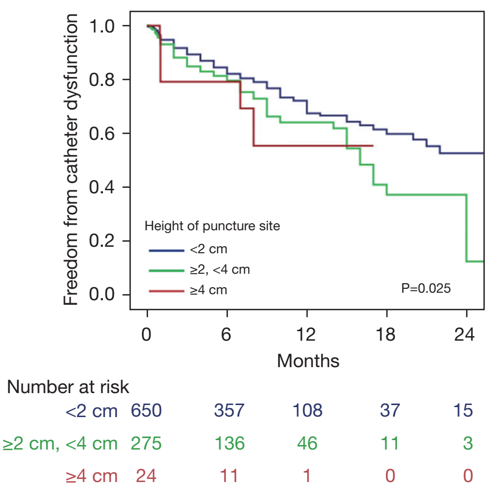

Figure 3 Kaplan-Meier curves demonstrating dysfunction-free survival based on the height of puncture site.

Outcomes Quality Initiative guidelines, our institution has adopted ultrasound-guided puncturing as routine practice. Therefore, no immediate complications were observed during any of our procedures. TDC insertion at a lower RIJV puncture site is associated with a similar risk and should be approached in a similar manner.

Inconsistent with the literature, in this study, we obtained several unexpected results. First, female sex was associated with an increased rate of catheter dysfunction, which has not been reported in the literature. Second, advanced age was associated with an increased rate of catheter dysfunction. Two studies have indicated that advanced age is associated with a low risk of catheter infection and catheter complications (12,17), and other studies have reported no protective effect for age. Third, compared with shotgun-tip catheters, split-tip catheters were associated with a higher risk of catheter dysfunction in this study. Although many studies have examined the relationship between the tip design and catheter dysfunction, none of them has indicated the superiority of a specific tip design over others in terms of maintaining catheter patency (9-11). The unique feature of our study is that we selected only patients who underwent their first catheter insertion exclusively through the RIJV. This selection resulted in unique conclusions compared with those in the literature. Nevertheless, further research is required to validate our findings.

This study has some limitations. First, because all patients were recruited from a single centre, the study population is not representative of the entire population. Second, similar to other retrospective cohort studies, our clinical or technical details may have been inconclusive and may have involved selection bias. Some cases of catheter infection were suspected without actual confirmation. Third, catheter dysfunction may result from various pathologies, including catheter kinking, thrombus formation within the catheter, thrombus formation at the side holes, and fibrin sheath formation around the catheter. Further examining the aetiology of catheter dysfunction may provide additional insights into the importance of the catheter insertion site and its angle. Fourth, we measured our parameters on chest radiographs. Chest radiography is a two-dimensional imaging modality. The lengths and tip positions observed on chest radiographs may be inaccurate if the images are captured from different angles. To minimise interindividual errors, we selected only the posteroanterior view of each patient's chest radiographs for measurement.

Conclusions

In conclusion, inserting a TDC at a higher puncture site is associated with a higher rate of catheter dysfunction. Overall, puncturing the RIJV close to the clavicle during TDC insertion is safe and can improve catheter patency.

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Footnote

Reporting Checklist: The authors have completed the STROCSS reporting checklist. Available at https://qims.amegroups.com/article/view/10.21037/qims-24-417/rc

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://qims.amegroups.com/article/view/10.21037/qims-24-417/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Institutional Review Board of Taipei Veterans General Hospital (No. 2018-06-010AC#1) and individual consent for this retrospective analysis was waived.

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