O r i g i n a l i n v e s t i g a t i o n s / c o m m e n t a r i e s

The effect of tunnel length and catheter tip placement on thrombosis and dislodgement of tunneled jugular venous access

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Abstract. Background: Renal failure is a major debilitating disease with high mortality risk if not cured. Hemodialysis venous access is a main line of treatment and can be used as a bridge therapy towards other lines of treatment such as kidney transplantation and hemodialysis access via arterio-venous fistula. However, a significant proportion of these patients have complications related to the hemodialysis access. In this study, we will study relation of tunnel length and catheter tip position with occurrence of complications. Objective: This study aimed to measure rate of thrombosis and dislodgement of tunneled jugular venous access and to evaluate relation between tunnel length and catheter tip position with occurrence of these complications. Patients and Methods: 65 chronic kidney disease (CKD) adult patients who had no history of previous tunneled jugular venous access device insertion were enrolled in the study for the tunneled jugular venous access device insertion procedure with assessing the catheter tip position by measuring the tunnel length and also the distance between the tip and both the carina and the cardiomediastinal angle. Then follow up of 6 months after the procedure took place for detecting complications which were assessed and managed. Results: A total of 65 catheters were properly placed in 65 patients (100% technical success) under imaging guidance and were followed for 6 months. Mean ± standard deviation for below carina distance was 3.61 ± 1.57 and for below cardiomediastinal angle was 5.66 ± 1.87 and for tunnel length was 6.44 ± 2.14. 14 patients (21.54%) had developed thrombosis and 18 patients (27.69%) developed catheter dislodgement. 29 patients (44.62%) developed catheter related infections. Onset of catheter malfunctioning occurred mostly in the first 3 months (77.8%). Thrombosis was correlated to dislodgement and early catheter removal. Both catheter tip position and tunnel length in their corresponding measured ranges have no statistical significance relation with thrombosis nor dislodgement. Below cardiomediastinal distance is correlated with development of catheter related infections. Conclusion: The tunneled jugular venous access is considered in many times as an effective bridge therapy for CKD patients before other more reliable interventions like renal transplantation and arteriovenous fistula creation. Yet it is not free from complications with most of them occurred in the first three months. Close follow up is highly recommended for early detection and management of these complications.

Keywords: CKD, Hemodialysis, tunneled catheter.

Background

Renal failure is a major debilitating disease that represents a huge burden on the community. Along with its high morbidity, there is also high prevalence which explains its high economic burden on the society. It is estimated in 2017 that the earlier stages of the chronic kidney disease are prevalent in 14.8 % of the population in the US. (1) Renal failure is also a major public health problem in Egypt. The incidence of dialysis is estimated in 2019 to be 19 per 100000 people and with prevalence estimate of 61 per 100000 people. (2)

Patients with renal failure must be managed with a good replacement of their lost renal function. Most efficient method of replacement is by a transplanted kidney from a compatible donor. Yet, it is not suitable for patients with no compatible match or for patients who can't afford the cost of the procedure. Other proportion is managed by hemodialysis through iatrogenic arterio-venous fistula made between the arteries and veins of the upper limb. This operation takes time to mature for proper functioning, and sometimes is contraindicated in some patients. For those patients who are waiting for renal transplantation or arterio-venous fistula maturation or who can't have either, they must remove wastes from the blood by either hemodialysis via the central venous system or via the peritoneum. Tunnelled hemodialysis access device is considered a suitable option for those patients which can withstand for relatively long duration in good state to carry its function. (3)Although its necessity, tunnelled hemodialysis access device insertion is associated with several complications. It can cause several forms of infection. Forms include insertion site infection, bacteraemia and septicaemia. It acts as a potential source of septicaemia especially in those very-ill patients. Gabriele Donati, et al reported 20 % infection rate in 2020. (4)

Other complications related to the functionality of the device and the ability of the venous site to carry the hemodialysis procedure are reported. Device can be improperly positioned and/or dislodged and needs to be replaced. It can cause also venous thrombosis and / or venous stenosis which affect the quality of the hemodialysis sessions making them non-sufficient. Other venous access sites must be sought to undertake the hemodialysis more efficiently. (5)

Different factors can affect the risk for tunneled hemodialysis access device related complications. There are personal risk factors such as age and sex. Other factors are those related to the technique of device insertion and to the medical condition of the patient. (5)

Aim of the study

This study aimed to measure rate of thrombosis and dislodgement of tunneled jugular venous access and to evaluate relation between tunnel length and catheter tip position with occurrence of these complications.

Patients and Methods

This prospective study was approved by the Local Ethics Committee, and written informed consent was obtained from all patients included in our study. The study was approved by the Ethics Board of Ain Shams University and an informed written consent was taken from each participant in the study. 65 CKD adult patients who had no history of previous tunneled jugular venous access device insertion were enrolled in the study for the tunneled jugular venous access device insertion procedure between September 2021 and August 2023 at interventional radiology unit of Ain Shams university hospitals with follow up of 6 months after the procedure.

Inclusion criteria:

- All adult patients who underwent the tunneled jugular venous access device insertion procedure at our institute.
- No sex predilection.

Exclusion Criteria:

- Those with history of previous tunneled jugular venous access device insertion.
- Patients below age 18.

Study Tools:

- Full history taking including history of previous catheters insertion of either tunnelled and non-tunnelled devices and the venous access (es) used.
- Obtaining a written consent from the patient or his guardian.
- Physical examination.
- Duplex examinations, to verify patency of chosen jugular vein for hemodialysis catheter.
- Laboratory tests: CBC including platelets count as well as PT, concentration and INR were obtained within one week prior to the procedure.
- The procedure was performed by Interventional radiology specialist with more than 3-year experience in interventional radiology under supervision of interventional radiology consultant with more than 10-year experience in interventional radiology unit at Ain Shams university hospitals.

Technique:

Patient preparation:

- Detailed explanation of interventional procedure.
- Obtaining a written consent from the patient or his guardian.

Procedure duration:

The study takes about 45-90 minutes.

Machines used:

- Mindray DC-60 Exp, Shenzhen Mindray Bio-Medical Electronics Co., Ltd., Shenzhen, China.
- Philips, Model: Allura Xper FD20, Serial number: 7220281703, Agent Company: Philips Egypt.

Method:

1. Patients lie in supine position, and the skin of the neck and upper chest was sterilized with Betadine® Solution (Povidone-iodine, 10%).
2. The procedure was done under local anesthesia with injection of 5 ml lidocaine at the site of venous puncture within the skin of neck. Another 5 ml lidocaine was given at the site of tunnelling.

3. The Puncture of the needle was done by the US (Mindray, DC-60 Exp) guidance using the linear probe at lower end of the internal jugular vein just above its uniting with the subclavian vein.
4. Then under fluoroscopic guidance (Philips, Allura Xper FD20), a hydrophilic guide wire was introduced to reach the inferior vena cava passing through superior vena cava and right atrium.
   Tunneling of the skin was done followed by catheter gliding over the wire, and peeling of the covering sheath were done before positioning the catheter tip around the atrio-caval junction. Tunnel length and position of the tip were different due to the length of the catheter that was used and the built of the patients. (Figures from 1-4)
5. The catheter was sutured to the skin using silk sutures (2/0).
6. The catheter two lumens were flushed with heparin and aspirated to ensure patency. And now the catheter can be used directly after its insertion.

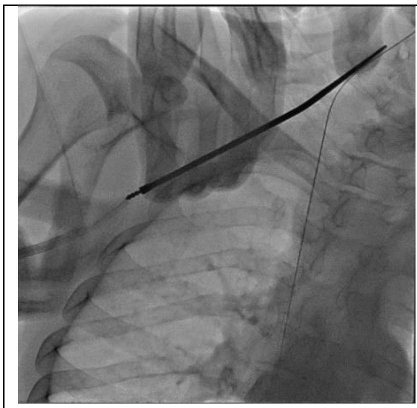

Figure 1. Wire placement and tunneling

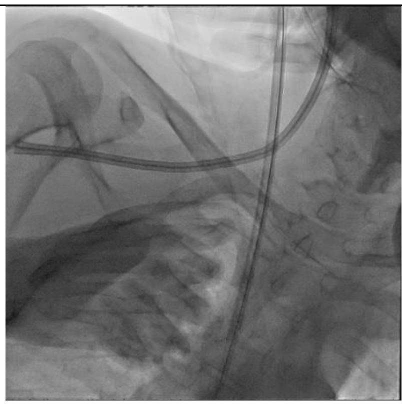

Figure 2. Gliding the catheter over the wire

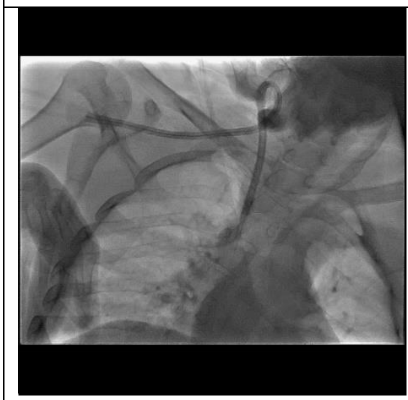

Figure 3. Peeling of the covering sheath

Figure 4. Placing the catheter in its position

7. Measurement of the tunnel by a ruler was done.
8. Post procedural images were taken to measure the tip positioning. After calibration using the catheter caliber, two measurements were measured, one from the tracheal bifurcation (the carina) to the tip of the catheter, and the other one from the junction between the superior vena cava and right atrium (estimated by the angle between right cardiac line and right mediastinal border). (Figure 5)

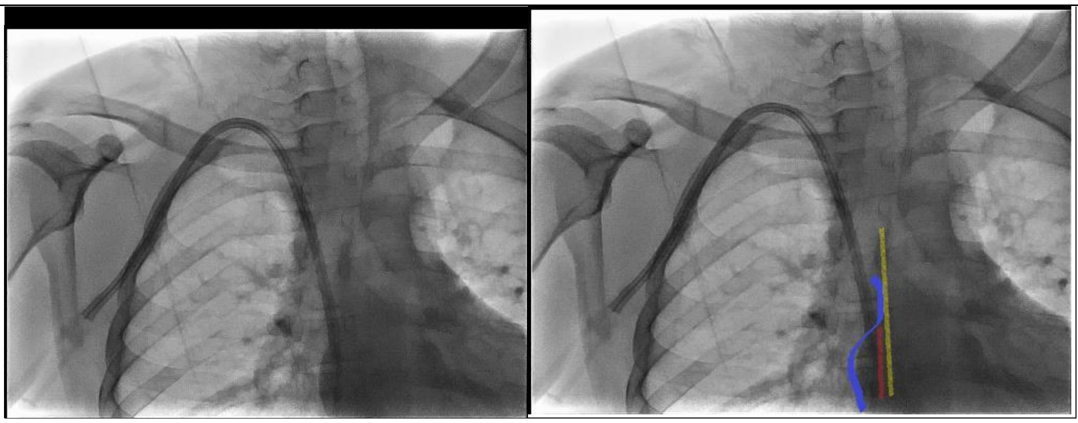

Figure 5. Shows measurements taken, with yellow line represents the distance between carina and catheter tip, and red line represents the distance between the cavoatrial junction and catheter tip. (The blue curved line represents the angle between the right cardiac and right mediastinal borders)

Aftercare

- Post-procedural heparin 5000 units was recommended to be administered after the hemodialysis through the ports of the catheter.
- Paracetamol 500 mg/8 hrs was advised for pain.
- Post-procedural instructions included care to the catheter and the entrance site of the tunnel site by avoiding contamination and water during bathing.

Follow up

- Regular follow up with the patients once per month for 6 months was done by checking with them through the mobile phone which was interrupted in some instances due to difficulty of reach to the patients.
- Follow up included checking of good catheter function and signs of infection.
- If suboptimal function reported by the nephrologist at the dialysis center occurred as defined by decreased blood flow rates, poor conductance or frequent pressure alarms, patient was referred to us for assessment and management by checking the catheter positioning by Xray, assessing blood flow from the catheter ports, iodinated contrast injection and/or trial of blood clot removal.
- Thrombosis is diagnosed by inability to aspirate or flush the catheter and by contrast hold up or filling defect.
- Mechanical complications included dislodgement of the catheter in form of migration of the catheter internally, its expulsion externally or improper catheter positioning, and they are assessed by the imaging.
- Catheter infection was diagnosed on follow up calls or by the nephrologists at the dialysis centers by presence of fever or leukocytosis without known other causes, bacteremia confirmed by two blood cultures, or tunnel infection signs such as redness, tenderness or drainage.

Statistical Analysis

The collected data was revised, coded, tabulated, and introduced to a PC using Statistical package for Social Science (SPSS 25).

Results

This study included 65 CKD patients with no history of previous tunneled jugular venous access device insertion between September 2021 & August 2023 at interventional radiology unit of Ain Shams university hospitals for jugular tunneled catheter insertion with 100% technical success achieved in all cases and patients were followed for 6 months.

Demographic data:

The mean age of the study participants was 53.74 (± 15.9) years with a female predominance representing 55.68% and 44.62% males. About 23.08% of the participants were diabetic and 24.62% were hypertensive. (Table 1)

	Mean ± SD	Median (IQR)	Min-Max

		N (%)		
Age		53.74 ± 15.9	52 (42 - 70)	22 - 76
Gender	Male	29 (44.62%)		
	Female	36 (55.38%)		
DM	No	50 (76.92%)		
	Yes	15 (23.08%)		
HTN	No	49 (75.38%)		
	Yes	16 (24.62%)		

Table 1. Shows characteristics of the study participants

Independent factors and complications of the jugular tunneled catheter in the study participants

The tip position of the catheter was at a mean of 5.66 (± 1.87) cm below cardiomediastinal angle and 3.61 (± 1.57) cm below carina. The mean tunnel length was 6.44 (± 2.14) cm.

Regarding complications, 21.54% of the participants had thrombosis and 27.69% experienced dislodgement with 22.2% of them occurring within first 3 months. About 44.62% of the participants had infection and 47.7% had early removal of the catheter, from which 61.3% removed it at 3 months or less. (Table 2)

		N (%)	Median (IQR)	Min-Max
Below cardiomediastinal angle		5.66 ± 1.87	5.5 (4.6 - 6.7)	1.6 - 10
Below carina		3.61 ± 1.57	3.7 (2.7 - 4.5)	-2 - 7.7
Tunnel length (cm)		6.44 ± 2.14	6 (5 - 7.5)	2.5 - 11
thrombosis	No	51 (78.46%)		
	Yes	14 (21.54%)		
dislodgement	No	47 (72.31%)		
	Yes	18 (27.69%)		
Malfunction time	Less than 3 months	14 (77.8%)		
	more than 3 months	4 (22.2%)		
Infection	No	36 (55.38%)		
	Yes	29 (44.62%)		
Early catheter removal	No	34 (52.3%)		
	Yes	31 (47.7%)		
Removal time	Full	34(52.3%)		
	first month	4(6.1%)		
	2nd month	8(12.3%)		
	3rd month	7(10.8%)		
	4th month	5(7.7%)		
	5th month	7(10.8%)		
Time of catheter removal	≤3 month	19 (61.3%)		
	>3 months	12 (38.7%)		

Table 2. shows independent factors and complications of the tunneled catheter in the study participants

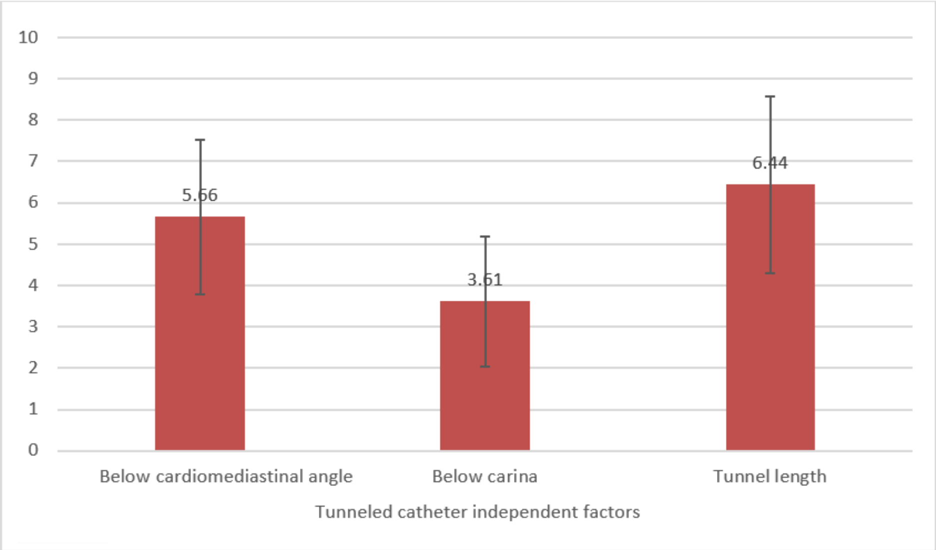

Figure 6. Shows tunneled catheter independent factors

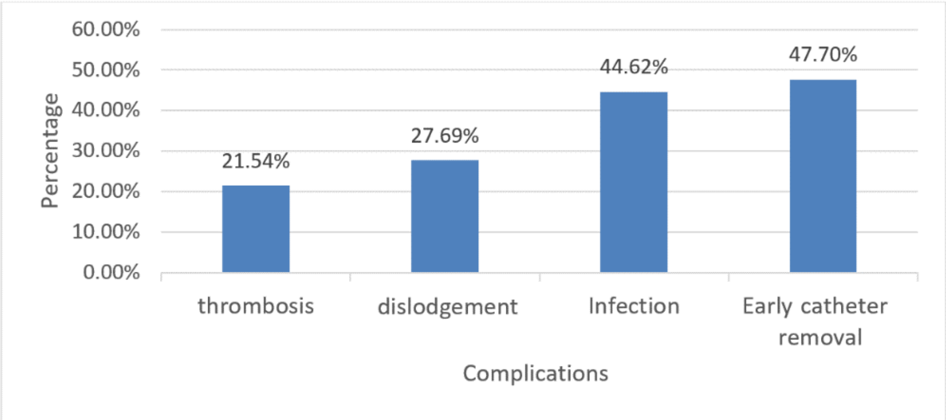

Figure 7. Shows percentage of tunneled catheter complications

Relation between thrombosis and other factors:

1. **Regarding demographics:** There was no statistically significant association between thrombosis and neither of age, gender, DM nor HTN with p value (>0.05). (table 3)
2. **Regarding the independent factors:** There was no statistically significant association between thrombosis and tip position or tunnel length with p value (>0.05). (table 4)
3. **Regarding other complications:** Half of the patient who experienced thrombosis also had dislodgement compared to only 21.57% of the patient with no thrombosis yielding a statistically significant association between thrombosis and dislodgement with p value (0.047). Also, there was a statistically significant association between thrombosis and early catheter removal as 71.43% of the participants with thrombosis had their catheter removed early compared to only 41.18% of the participants with no thrombosis with p value (0.045). However, there was no statistically significant association between thrombosis and neither of infection nor malfunctioning time with p value (>0.05). (table 4)

		Thrombosis		Test of significance		
		No	Yes			
		Mean ± SD N (%)	Mean ± SD N (%)	Value	p-value	Significance
Age		53.88 ± 16.3	53.21 ± 14.9	**t=** 0.138	0.891	NS
Gender	Male	23 (45.1%)	6 (42.86%)	$\mathbf{X^2}$= 0.022	0.881	NS

	Female	28 (54.9%)	8 (57.14%)			
DM	No	41 (80.39%)	9 (64.29%)	FE	0.282	NS
	Yes	10 (19.61%)	5 (35.71%)			
HTN	No	39 (76.47%)	10 (71.43%)	FE	0.732	NS
	Yes	12 (23.53%)	4 (28.57%)			

Table 3. Relation between thrombosis and characteristics of the study participants:

Student t-test of significance (t)
Fisher's Exact test of significance (FE)
Chi-Square test of significance (X^2)

		Thrombosis		Test of significance		
		No	Yes			
		Mean ± SD N (%)	Mean ± SD N (%)	Value	p-value	Significance
Below cardiomediastinal angle		3.59 ± 1.69	3.7 ± 1.08	**t=** -0.239	0.812	NS
Below carina		5.71 ± 2.09	5.49 ± 0.75	**t=** 0.607	0.546	NS
Tunnel length (cm)		6.54 ± 2.26	6 ± 1.55	**t=** 0.982	0.336	NS
Infection	No	29 (56.86%)	7 (50%)	**X^2=** 0.209	0.647	NS
	Yes	22 (43.14%)	7 (50%)			
Dislodgement	No	40 (78.43%)	7 (50%)	FE	0.047	S
	Yes	11 (21.57%)	7 (50%)			
malfunctioning time	≤3 month	7 (70%)	6 (85.71%)	FE	0.603	NS
	≥3 month	3 (30%)	1 (14.29%)			
Early catheter removal	No	30 (58.82%)	4 (28.57%)	**X^2=** 4.03	0.045	S
	Yes	21 (41.18%)	10 (71.43%)			

Table 4. Shows relation between thrombosis and tunneled catheter independent factors and complications:

Relation between dislodgement and other factors:

1. **Regarding demographics:** There was no statistically significant association between dislodgement and neither of age, gender, DM nor HTN with p value (>0.05). (table 5)
2. **Regarding the independent factors:** There was no statistically significant association between dislodgement and tip position or tunnel length with p value (>0.05). (table 6)
3. **Regarding other complications:** There was no statistically significant association between dislodgement and infection nor early catheter removal with p value (>0.05). (table 6)

		Dislodgement		Test of significance		
		No	Yes			
		Mean ± SD N (%)	Mean ± SD N (%)	Value	p-value	Significance
Age		52.53 ± 16.41	56.89 ± 14.44	**t=** -0.988	0.327	NS
Gender	Male	21 (44.68%)	8 (44.44%)	**X^2=** 0.47	0.986	Ns
	Female	26 (55.32%)	10 (55.56%)			
DM	No	38 (80.85%)	12 (66.67%)	FE	0.323	NS
	Yes	9 (19.15%)	6 (33.33%)			
HTN	No	36 (76.6%)	13 (72.22%)	FE	0.753	NS

	Yes	11 (23.4%)	5 (27.78%)			

Table 5. Shows relation between dislodgement and characteristics of the study participants:

		Dislodgement		Test of significance		
		No	Yes			
		Mean ± SD N (%)	Mean ± SD N (%)	Value	p-value	Significance
Below cardiomediastinal angle		3.62 ± 1.71	3.59 ± 1.2	**t**= 0.054	0.957	NS
Below carina		5.78 ± 1.92	5.38 ± 1.75	**t**= 0.767	0.446	NS
Tunnel length (cm)		6.18 ± 2.06	7.06 ± 2.26	**t**= -1.475	0.145	NS
Infection	No	23 (48.94%)	13 (72.22%)	X^2= 2.856	0.091	NS
	Yes	24 (51.06%)	5 (27.78%)			
Early catheter removal	No	28 (59.57%)	6 (33.33%)	X^2= 3.593	0.058	NS
	Yes	19 (40.43%)	12 (66.67%)			

Table 6. Shows relation between dislodgement and tunneled catheter independent factors and complications:

Relation between infection and other factors

1. **Regarding demographics:** There was no statistically significant association between infection and neither of age, gender, DM nor HTN with p value (>0.05). (table 7)
2. **Regarding the independent factors:** Participants with infection had the tip of the catheter closer to the cardiomediastinal angle compared to patients with no infection yielding a statistically significant association between infection and tip position below cardiomediastinal angle with p value (0.043). However, there was no statistically significant association between infection and neither of tip position (measured in relation with carina) nor tunnel length with p value (>0.05).
3. **Regarding other complications:** There was no statistically significant association between infection and early catheter removal with p value (>0.05). (table 8)

		Infection		Test of significance		
		No	Yes			
		Mean ± SD N (%)	Mean ± SD N (%)	Value	p-value	Significance
Age		52.08 ± 14.46	55.79 ± 17.57	**t**= -0.934	0.354	NS
Gender	Male	16 (44.44%)	13 (44.83%)	X^2= 0.001	0.975	NS
	Female	20 (55.56%)	16 (55.17%)			
DM	No	28 (77.78%)	22 (75.86%)	X^2= 0.033	0.855	NS
	Yes	8 (22.22%)	7 (24.14%)			
HTN	No	27 (75%)	22 (75.86%)	X^2= 0.006	0.936	NS
	Yes	9 (25%)	7 (24.14%)			

Table 5 .shows relation between Infection and characteristics of the study participants:

		Infection		Test of significance		
		No	Yes			
		Mean ± SD N (%)	Mean ± SD N (%)	Value	p-value	Significance
Below cardiomediastinal angle		4.08 ± 1.65	3.14 ± 1.59	**t**= 2.077	0.043	S
Below carina		5.69 ± 2.05	5.63 ± 1.65	**t**= 0.144	0.886	NS
Tunnel length (cm)		6.51 ± 2.02	6.33 ± 2.32	**t**= 0.337	0.737	NS
Early catheter removal	No	21 (58.3%)	13 (44.8%)	X^2= 1.17	0.279	NS
	Yes	15 (41.7%)	16 (55.2%)			

Table 6 .shows relation between infection and tunneled catheter independent factors and complications:

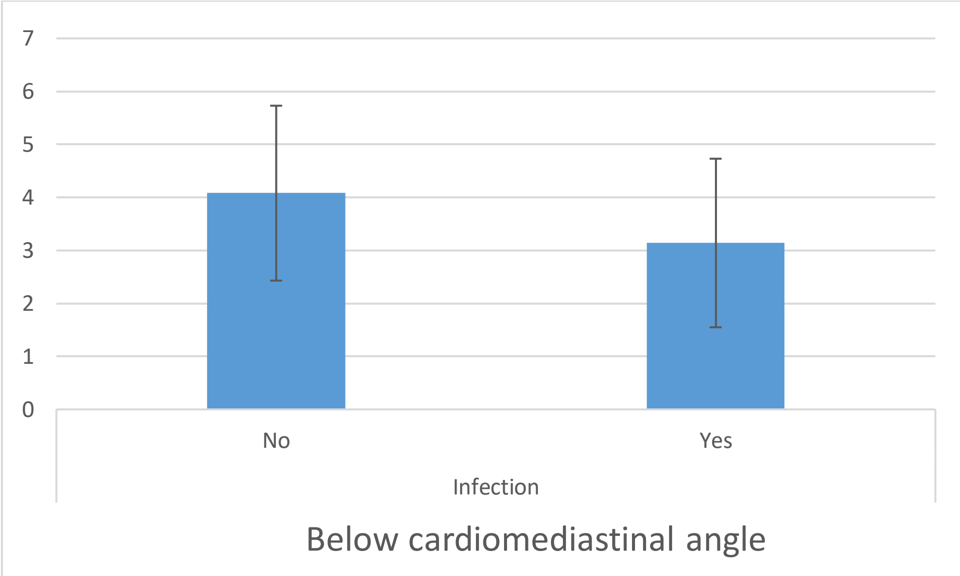

Figure 8. shows a statistically significant relation between infection and catheter tip position measured in relation with cardiomediastinal angle

Discussion

In this study we have 65 patients who underwent de novo tunneled catheter insertion in the internal jugular vein and followed for 6 months. 34 patients (52.3%) completed the follow up period with good catheter function. 31 patients (47.7%) had early catheter removal due to improper functioning or infection with most of them (19 patients; 61.3%) occurred in the first 3 months. Onset of malfunctioning mostly occurred in the first 3 months and that for 18 patients (77.8%).

Thrombosis was recognized as a complication in 14 patients (21.5%). It was statistically significant correlated with dislodgement and early catheter removal. There was no evidence of correlation between thrombosis or dislodgement with the independent factors; the tunnel length and catheter tip position measured as distances from carina and cardiomediastinal angle. On the other hand, infection was correlated to tip position as measured from the cardiomediastinal angle.

One of the important variables of this procedure is the location of the catheter tip. The National Kidney Foundation recommends that the tip of tunneled catheters be placed in the mid-right atrium to maximize flow rates, as showed by study by Mandolfo et al, 2001 which indicated that flow rate is better when catheter tip is positioned in the right atrium than superior or inferior venae cava. We wanted to study the relation between tip location and tunnel length with thrombosis and dislodgement. [6 and 7]

The location of the tip was classified by Engstrom et al, 2013 as caval, at pericavoatrial junction or at mid-to-deep right atrium in their study. In contrast, in our study we used a numerical quantification of the tip location by measuring the distance between the tip and both the carina and the atriocaval junction represented by the angle formed between the right cardiac and right mediastinal borders. Of note, although this angle does not represent accurately the atriocaval junction based on a study by Aslamy et al, 1998 that used cross-sectional imaging which showed that the atriocaval junction lies 0.5 – 4.5 cm below this angle with a median of 1 cm below, we used this angle and we figuratively called it “below junction distance” as an approximate estimate because it can serve as a landmark for the interventional radiologist in the fluoroscopy imaging during the procedure and for the purpose of this study to use a numerical quantification of the tip location. [8 and 9]

In comparison with Engstrom et al, 2013 and Soh et al, 2022 studies, our study was prospective and with smaller population (n = 64) while studies of Engstrom et al and Soh et al were retrospective and with larger population (n = 532) and (n= 993) respectively. The mean age in our study (= 53.7 years) is nearly similar to Engstrom et al study (= 54.9 years) yet is less than that of Soh et al study (62.2 years). [8 and 10]

Engstrom et al, 2013 showed that there was no statistical difference in catheter dysfunction requiring catheter exchange or removal as a result of concern for catheter infection, yet when comparative assessment was done, they showed that catheters placed in the SVC or pericavoatrial junction exhibited a significantly higher rate of either event (ie, infection or dysfunction) compared with catheters placed in the mid- to deep right atrium. Their finding is compatible with our finding that below junction distance is correlated in a statistically significant way with incidence of infection, being the closer to junction or hence more superiorly located catheter tips show more infection than inferiorly situated tips. We added another dimension to the Engstrom et al study findings. They showed that catheters with tips situated superiorly (in SVC or pericavoatrial junction) are associated with more catheter dysfunction than inferiorly situated in the right atrium. While in our study, nearly all catheters are situated in the pericavoatrial or right atrial zones with only one catheter situated in the SVC. We showed that neither below junction nor below carina distances are statistically significant to predict catheter thrombosis or dislodgement. [8]

On the contrary, Soh et al study showed a different outcome. It showed that catheter tip location in the SVC was associated with lower incidence of catheter dysfunction as compared with the tip position at the cavoatrial junction or the right atrium. Although this conflicts with the concept of deeper is better postulated by Engstrom et al findings, we in our study can't contradict either findings due to lack of sufficient cases with catheter tip in the SVC (one case). But our study didn't show correlation between thrombosis, dislodgement or malfunctioning and below junction and below carina distances suggesting equivocal outcomes if catheters tips placed in this zone (cavoatrial junction and right atrium). [8 and 10]

Soh et al showed also that catheter replacement due to dislodgement or infection showed no statistically significant relation to the catheter tip. This contradicts with our finding that infection is correlated with below junction distance and agrees with our finding that dislodgement doesn't correlate with catheter tip position. [10]

In the literature, the tunnel formation is discussed to ensure appropriate length. Funaki B. suggested the tunnel length to be 8-10 cm in 2008. Bream PR Jr. in 2016 preferred the tunnel length to be about 6 cm with cuff being positioned 2 cm away from the exit site, not too long which may increase catheter mechanical complications as migration and kinking or too short which may put cut cuff near to the clavicle with irritation to the patients. [11 and 12]

A recent randomized controlled trial by Li et al, 2023, assessing the tunnel length effect on complication of peripherally inserted central catheters (PICCs), reached to that patients with 4-6 cm tunnel lengths had a longer catheter dwell time and fewer PICC-related complications. [13]

Yet in this study which studied tunneled central venous catheters inserted in the jugular veins, we didn't find evidence of relation between length tunnel and complications like thrombosis or dislodgement. That may be because most of the tunnels that the patients had in our study are above 4 cm with tunnel length mean ± standard deviation of 6.44 ± 2.14, so in this range of tunnel length distances, the statistical significance does not exist.

Conclusion

In conclusion, the tunneled jugular venous access is considered in many times as an effective bridge therapy and very essential for CKD patients in the initial period of diagnosis before other more reliable interventions like renal transplantation and arteriovenous fistula creation and if these interventions temporarily become suboptimal. Although it can be performed with good technical success, it is not free from complications like thrombosis, dislodgement or infection with most of them occurred in the first three months. Close follow up of the catheter and adherence to relevant instructions are highly recommended for early detection and management of these complications.

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