ORIGINAL ARTICLE

ULTRASOUND GUIDED TUNNELLED CUFFED CATHETER PLACEMENT WITHOUT FLUOROSCOPIC GUIDANCE BY ANATOMICAL LANDMARKS; ACCURACY AND SAFETY

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Background: Chronic kidney disease is a growing disease with high morbidity and mortality. Haemodialysis remains the most common option available for all those not planning for renal transplantation. Vascular access is the most important aspect of haemodialysis. Though not recommended but central venous catheters remain the most common vascular access in starters on haemodialysis. There is a growing trend towards placement of tunnelled cuffed catheters (TCC). TCC placement requires fluoroscopic guidance which is not available in all centres. The rationale of this study was to describe safety and accuracy of a catheter placement technique not dependent on fluoroscopic guidance for resource limited settings. **Methods:** Dialysis dependent patients of a single hospital without long term vascular access were selected over a period of 15 months after getting informed written consent. A new technique was described in which depth of catheter was estimated by superficial anatomical and ultrasound guided measurements for TCC placement which were checked by conventional chest radiography post procedure. **Results:** A total of 209 catheters were placed over a period of 15 months, 189 males and 30 females. Various sites were used predominantly right Internal jugular vein (IJV) (85.6%). Overall success rate was 97.1% (98.3% males, 90% females, $p=0.08$). Right IJV was successful 98.9%, left IJV 87.5% ($p<0.001$). Multiple thrombosed/stenosed veins were associated with higher failure rate ($p<0.001$). **Conclusion:** TCC can be placed successfully and safely in right IJV under ultrasound guidance using anatomical landmark measurement technique without fluoroscopic guidance.

Keywords: Chronic Kidney Disease; Haemodialysis; Central Venous Catheter; Tunnelled Cuffed Catheter; Anatomical Landmarks; Carina; Fluoroscopy; Chest Radiograph

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INTRODUCTION

Chronic kidney disease (CKD) is fast becoming one of the leading causes of morbidity and mortality worldwide among non-communicable diseases. In 1990 CKD was ranked 27th leading cause of death worldwide but jumped up to 17th place by 2010.[1] Worldwide 2.618 million patients received renal replacement therapy (RRT) in 2010 and the number is expected to rise to 5.439 million patients by the year 2030 with maximum growth expected in Asia. An estimated 2.284 million deaths occurred in 2010 because of unavailability of RRT.[2] As number of patients requiring RRT increases, so will be the expected number of deaths due to non-availability of RRT. Vascular access is one of the most important aspects for haemodialysis. Native arteriovenous fistulae (AVF) is the vascular access of choice because of low risk of infection, thrombosis, longer life and adequate flow rates.[3] As per NKF-DOQI 2006 Updates Clinical Practice Guidelines and Recommendations vascular access for selected modality of RRT should be planned in advance. According to guideline 1.3 for haemodialysis a native AVF should be created at least 6 months, whereas an arteriovenous graft (AVG) should be placed at least 2 months prior to anticipated start of haemodialysis to allow adequate time for maturation of vascular access.[3] Despite these recommendations and a Fistula First initiative up to 63.2% of haemodialysis starters in United States had placement of a central venous catheter (CVC) with a further 19.2% starting RRT via CVC while awaiting maturation of AVF/AVG.[4] A study in Pakistan showed 80% patients starting haemodialysis via CVC as compared to 20% via arteriovenous access.[5] This is largely consistent with data from European and US studies.[4,6,7] CVC for haemodialysis are of two types; long term tunnelled cuffed catheters (TCCs) and short term non-cuffed catheters (NCCs). As per NKF-DOQI guidelines use of NCCs for a period of more than 1 week is not recommended (not more than 5 days for femoral catheter) and any patient expected to require long term haemodialysis including patients with acute kidney injury should be switched from a NCC to a TCC within 1 week.[3] TCCs of multiple designs, sizes and material are available in the market but efficacy of one over another has not been definitively demonstrated.[8]

Controversy exists regarding ideal position of tip of catheter placed in upper extremity central veins. As per the Food and Drug Authority, Oncology Nursing Society, National Association of Vascular Access Networks and Infusion Nursing Society recommendations upper extremity catheter tip should be in the superior vena cava (SVC) or the SVC atrial junction and not inside the right atrium.[9–12] However the NKF-DOQI guidelines recommend that tip of the catheter be placed in the right mid-atrium for optimal blood flow rates for TCCs for upper extremity catheters and placement in the IVC for femoral vein catheters.[3] It is recommended that ultrasound guidance be used wherever available to increase accuracy and prevent complications. Experience of physician performing procedure is an important factor in successful CVC placement and this can be extrapolated to TCC as well.[13] Confirming correct placement of catheter tip in desired location is necessary post-procedure. NKF-DOQI guidelines recommend fluoroscopy or chest radiograph post-procedure to confirm correct placement. Various techniques have been proposed for catheter placement including anatomical landmarks and formulas.[14–18] For confirming correct placement and positioning of tip of CVC post-procedure conventional and invasive electrocardiography[19], chest radiography, transthoracic and trans-oesophageal echocardiogram[20] have been used. Many techniques have been described using surface anatomical landmarks to estimate depth and correct placement of CVC pre-procedure.[20–23] Each technique has their own benefits and increased accuracy but has drawback of being invasive, time consuming and expensive in addition to being unavailable in many centres. Although having some drawbacks plain radiograph of chest is an easy, less time consuming and inexpensive way to assess position of catheter tip while also having the advantage of less exposure to radiation. Our study was aimed to evaluate a new safe technique for placement of TCC in ideal position with use of minimal and easily available resources via anatomical landmarks measurement.

MATERIAL AND METHODS

This study was performed in the department of Nephrology Pak Emirates Military Hospital, Rawalpindi after getting approval from Hospital Ethical and research committee. A total of 209 cases were included in our prospective quasi-experimental study with non-randomized consecutive purposive sampling over a period of 15 months from Jan 2018 to March 2019. Study population included all end stage renal disease (ESRD) patients on maintenance dialysis without long term vascular access and acute kidney injury patients requiring dialysis for more than 2 weeks. Bleeding diathesis, sepsis, hemodynamic instability, not consenting for procedure were exclusion criteria. Silicon tunnelled cuffed catheters of various sizes (12Fr to 15.5Fr) and lengths (13–35 cm tip to cuff) were used according to length required and maximum internal diameter of vein being accessed. After informed written consent and completing pre-procedure checklist (as per inclusion and exclusion criteria) patients were shifted to procedure room. Blood pressure, heart rate, oxygen saturation by pulse oximetry were checked. ECG electrodes were attached for in-procedure arrhythmia monitoring. Patients were placed on procedure table in Trendelenburg position at an angle of 15 degrees for adequate vein dilation and preventing air embolism, reverse Trendelenburg position was used for femoral vein catheterization. Ultrasound (USG) venous mapping was done for selecting appropriate vein and to rule out venous thrombosis/stenosis and findings were documented. Venepuncture site was marked by obtaining cross sectional view of selected vein and marking skin directly above middle of vein, depth of selected vein from skin was measured and documented. Skin marking was done at 4cm below manubrio-sternal junction (angle of Louis) (Mark A), mid-point of sternal notch (Mark B) and venepuncture site (Mark C). A measuring tape was used to find total length and depth of vein from venepuncture site measured via USG (D) was added to this length. For femoral catheter length was measured by marking at umbilicus, mid-point of inguinal ligament, venepuncture site, and depth from skin. Appropriate length catheter was selected and rest was calculated as tunnel length (Mark E) and marking for tunnel exit site was made (6–12 cm). Diameter of catheter was calculated according to internal diameter of vein (internal diameter of vein in mm multiply by 3) for maximum possible catheter diameter. Largest diameter catheter available was 15.5 Fr whereas smallest was 12 Fr. Skin was sterilized with povidone iodine solution. Sterile drapes were used. Local anaesthesia with adrenaline was used in all cases (dose according to weight), sedation was used only for paediatric or uncooperative patients. USG guided venepuncture was done and guide wire inserted. Subcutaneous tunnel was created via tunneler device and catheter passed in vein through peel away sheath with valve after dilating with 3 dilators of increasing size. Free flow was confirmed after aspiration and catheters were flushed with saline and locked with standard heparinized antibiotic lock solution (as per departmental protocol). Incision sites were sutured and aseptic dressing was done. Post-procedure blood pressure, pulse and oxygen saturation was checked and documented. Post-procedure chest radiograph was done and checked personally by one of the authors, measurement below carina was measured on digital chest radiograph as per scale in cm and documented. For upper extremity catheters 4 categories were made based on average depth of mid-atrium from carina. The measurements were divided into 4 categories for post-procedure management purpose. 1) Ideal position (2–4 cm below carina), 2) Not ideal but does not need readjustment (0–2 cm below carina OR 4–6 cm below carina), 3) Needs readjustment (above carina OR more than 6 cm below carina, 4) Other/not in venous structure. For femoral catheters only 2 categories were made: within IVC, short of IVC. If a catheter was labelled as not being in ideal position it was re-adjusted before use for haemodialysis. If a catheter was found to be not in venous structure an immediate contrast enhanced computerized tomography (CT) chest was done to confirm position and track and if no injury was seen in major vascular structures the catheter was removed and patient kept under observation for 24 hours. Data analysis was done using Statistical Package for Social Sciences (SPSS) for windows version 21.0. Continuous variables were presented as means and standard deviation while discrete variables as frequency and percentages. Chi square test was applied and *p* value was obtained and was considered statistically significant if less than 0.05.

RESULTS

A total of 209 cases were included in the study period. 189 were males and 30 female patients. Age ranged from 12 years to 88 years with a mean age of 52.63 years. Duration of dialysis at time of TCC placement was less than 1 week for 55% (n=115) patients, at 1–2 weeks 16.3% (n=34), at 2–4 weeks 13.4% (n=28), at 1–6 months 10.5% (n=22) and 4.8% (n=10) had been on dialysis for more than 6 months. Out of 209 patients 5.7% had first CVC with TCC placement, 62.2% had 1 previous CVC insertion, 16.3% had 2 CVC insertion, 8.1% had 3 CVC insertion, 6.2% had 4 CVC insertion and 1.4% (n=3) had 5 CVC insertions prior to TCC placement. On pre-procedure USG mapping 73% had no venous thrombosis/stenosis at procedure venous mapping, 16.7% had 1 central vein, 5.3% had 2, 3.3% had 3 and 1.4% had 4 veins thrombosis/stenosis. Selection of vein for TCC was in right internal jugular vein 85.6%, 11.5% in left IJV, 1% in right common femoral vein, 0.5% in left CFV and 1.4% in subclavian veins. Variable length catheters were used ranging from 13–35cm tip to cuff. Similarly, variable diameter catheters were used ranging from 12 Fr up to 15.5 Fr. In 207 out of 209 cases free flow was established post-procedure and only 2 catheters had no flow. On chest radiography 78.9% (n=165) were in ideal position, 18.2% (38) were not in ideal position but did not require any adjustment, 1.9% (n=4) required readjustment whereas 2 (0.9%) catheters were in abnormal position outside the venous system. A total of 6 cases out of 209 (2.9%) were labelled as failed/unsuccessful cases and 4 of the catheters had to be repositioned to an appropriate depth whereas 2 catheters were removed after confirming no pericardial or major vascular injury was seen on CT chest.

In males the success rate was 98.3% (80.4% ideal, 17.9% not needing readjustment) and 1.7% unsuccessful catheters. In females the success rate was 90 % (70% ideal, 20% not needing readjustment) and 10% unsuccessful catheters. Right IJV catheterization had 98.9% success rate, left IJV had success of 87.5% and subclavian vein had success rate of 66.7%, CFV catheterization was 100% successful. There was a significant difference between catheters placed in Right IJV compared to left IJV catheters ($p<0.001$). There was no statistical difference based on gender ($p=0.08$). Difference between right and left sided catheters was similar in both male and female cases. There was also statistical significance between number of thrombosed/stenosed vessels and successful catheter placement ($p<0.001$).

Table-1: Relation of position of tip of catheter to site of placement

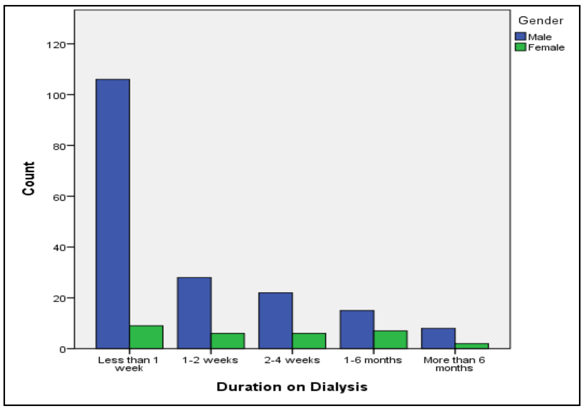
			Tip position on CXR			
			Ideal	**Not ideal but does not require readjustment**	**Requires readjustment**	**Other/not in venous system**
Site of tunnelled cuffed catheter insertion	**Right IJV**	Count	158	19	2	0
		% within Site of TCC Insertion	88.3%	10.6%	1.1%	0.0%
	Left IJV	Count	5	16	1	2
		% within Site of TCC Insertion	20.8%	66.7%	4.2%	8.3%
	Right CFV	Count	2	0	0	0
		% within Site of TCC Insertion	100.0%	0.0%	0.0%	0.0%
	Left CFV	Count	0	1	0	0
		% within Site of TCC Insertion	0.0%	100.0%	0.0%	0.0%
	Right SCV	Count	0	2	1	0
		% within Site of TCC Insertion	0.0%	66.7%	33.3%	0.0%
Total		Count	165	38	4	2
		% of total	78.9%	18.2%	1.9%	1.0%
Chi-square 92.7, df = 12			***p*=0.000 statistically significant**			

Table-2: Relation of gender to position of tip of catheter

			Tip position on CXR			
			Ideal	**Not ideal but does not require readjustment**	**Requires readjustment**	**Other/not in venous system**
Gender	**Male**	**Count**	144	32	2	1
		% Within gender	80.4%	17.9%	1.1%	0.6%
	Female	**Count**	21	6	2	1
		% Within gender	70.0%	20.0%	6.7%	3.3%
Total		**Count**	165	38	4	2
		% Of total	78.9%	18.2%	1.9%	1.0%
CHI square = 6.6		***p*-value = 0.08**	**DF= 3**			**Not significant**

Table-3: Relation of tip position to duration on haemodialysis

		Tip position on CXR			
		Ideal	**Not ideal but does not require readjustment**	**Requires readjustment**	**Other/not in venous system**
Duration on dialysis	**Less than 1 week**	96	18	1	0
	1-2 weeks	29	4	1	0
	2-4 weeks	23	4	0	1
	1-6 months	14	6	1	1
	More than 6 months	3	6	1	0



Demographics of sample cases and distribution according to gender and duration on haemodialysis

Figure-2: Mark A is 4 cm below manubrio-stternal notch, Mark B is mid-point of sternal notch, Mark C is puncture site, Mark D (not shown here) is depth of vein from puncture point measured with ultrasound guidance. All measurements are added and suitable length TCC selected and remaining length (at least 6cm) is Mark E which is length of tunnel.

DISCUSSION

In a resource poor region and country with a growing burden of CKD and limited number of patients opting for renal transplantation, haemodialysis remains the lifeline for majority of patients. Single most important factor and the backbone for haemodialysis remains a healthy vascular access. Due to inadequate referral system and resistance to early native AVF formation majority of patients start haemodialysis via central venous catheters. NCCs although useful in emergency settings are harmful in the long run with high rate of complications such as infections, thrombosis, stenosis, low flow velocities and high rates of recirculation. TCCs act as a bridging gap between start of haemodialysis and maturation of native AVF or synthetic AVG. As per NKF-DOQI recommendations NCCs should not be used for a period of more than 1 week (not more than 5 days for femoral catheters).[3] NCCs should be converted to TCCs if duration of haemodialysis is expected to exceed 1 week and all efforts should be made to ensure patients have TCC placed before going home. Absence of expertise and limitation of resources are a big hurdle for TCCs placement. We wanted to describe an easy, safe, cost effective method not requiring fluoroscopy for placement of TCCs under ultrasound guidance with confirmation by chest radiograph post-procedure.

There are three major challenges faced during placement of a CVC. The first one is selecting an ideal site and depth, second is the procedure in itself, ensuring there is good backflow and no immediate complications and third is confirmation of tip position. The debate regarding ideal site and depth has been going on for as long as CVC placement has existed.[9–12] Various guidelines including nursing and anaesthesia associations have preferred placement in SVC but not inside atrium. Similarly, ideal site for placement remains a topic for debate to date with no consensus winner between IJV, SCV and CFV. Each has some benefits over the other but all sites have their drawbacks as well.[24] During this study we followed the NKF-DOQI guidelines for vascular access which recommends that Right IJV should be preferred site for CVC insertion whereas ideal tip position should be inside the right atrium to ensure adequate flow rate.[3] In our study we found that safety and success in right internal jugular vein is higher as compared to left internal jugular or subclavian catheter placement. This is probably due to the fact that the path of left IJV is angulated as compared to right IJV which runs a straight course to right atrium and risks of catheter placement failure are higher, this point has already been described in previous studies.[25] For right sided IJV catheters the success rate is comparable to earlier studies in other populations. A history of multiple catheterizations leading to multiple thrombosed/stenosed vessels is also associated with risk of catheter failure. This is explainable by altered venous anatomy in cases of central venous obstruction. TCC can be placed successfully and safely in right IJV under ultrasound guidance using anatomical landmark measurement technique without fluoroscopic guidance. For left sided catheters and in patients with multiple thrombosed/stenosed veins caution is advised and it would be recommended to use live fluoroscopic guidance. The second challenge is to perform an uncomplicated procedure. The accuracy of central venous catheterization has been greatly improved by initially introduction and now recommending live USG guidance for venepuncture. However even with USG guidance the complication rate remains high with values ranging from 1-26% in various studies.[26] Operator experience,[13] USG guidance and regular training courses are some of the factors highlighted to minimize complication rates.[27] Only 2 major complications were observed during the study with both cases having catheter misplacement outside the venous system. In both cases contrast enhanced CT scan was done to rule out injury to major vascular structures and both catheters were removed and patients admitted for observation. Both patients remained stable and were subsequently passed TCC in another site. There were no cases of arterial catheterization, cardiac tamponade, pneumothorax, haemothorax, air embolism, cardiac arrhythmias, guidewire embolism, catheter breakage, neurologic injury or haemorrhage from other sites during the study. Data regarding long term complications was lacking due to loss to long term follow up hence rates of infection, venous thrombosis and central venous stenosis could not be ascertained. The third challenge is ideal placement and confirmation of tip position. As discussed earlier the ideal position as per the NKF-DOQI guidelines is that tip of the catheter be placed in the mid-atrium for optimal blood flow rates for TCCs for upper extremity catheters and placement in the IVC for femoral vein catheters and fluoroscopy or chest radiograph post-procedure to confirm correct placement.[3] Multiple studies including cadaveric and radiological (MRI, plain radiographs) have documented that the right tracheobronchial angle/carina has been found to correlate best to position of SVC and right atrium (RA), with an average distance of 2.9cm between tracheobronchial angle/carina and SVC-atrial junction.[14–32] Combining the average RA dimensions[33,34] to the average distance between carina and SVC-atrial junction the average ideal depth range was calculated. In our study we have achieved a 97.1% success rate (78.9% ideal, 18.2% not ideal but does not require adjustment) with only 6 unsuccessful cases (2.9%) out of which 4 required repositioning whereas 2 had to be removed.

The study was limited by large number of cases for catheter insertion in right IJV as compared to other sites however this is in accordance to NFK-DOQI guidelines recommendations favouring right IJV as preferred site for TCC placement.

CONCLUSION

Although live fluoroscopic guidance remains the standard for TCC placement but as our study demonstrates USG guidance and anatomical landmark method can be a safe alternative in a resource limited setup. As demonstrated right sided IJV catheterization can be safely and successfully performed by using anatomical landmarks and measurements. Further studies with longer duration of study, large population and multicentre involvement are required to validate these results further.

Conflict of interest: None

AUTHORS' CONTRIBUTION

Azam MN, Rahman MK, Raja KM, Wahaj conceived and designed the study. Wahaj, Butt B, Salahuddin, Tahir T, Mir AW performed all the procedures and collected data. Khan NJ helped in data entry and analysis. Wahaj, Butt B and Azam MN drafted the manuscript. All the authors read and suggested changes to manuscript.

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