DOI: 10.7860/JCDR/2020/43717.13576

Original Article

Internal Medicine Section

Choosing the Right Strategy for Haemodialysis Central Venous Catheter Placement: A Retrospective Study

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ABSTRACT

Introduction: Vascular access is the 'Achilles heel' for patients requiring haemodialysis. The gold standard for vascular access is an Arterio-venous Fistula (AVF). In clinical practice, situations mandating the use of Central Venous Catheters (CVCs) are often encountered. The successful outcome for CVC placement depends on variables like operator experience and use of aids like ultrasonography and fluoroscopy.

Aim: To determine the difficulty level, outcome, and safety profile of the various prevalent modalities of CVC placement.

Materials and Methods: A total of 243, Internal Jugular Vein (IJV), CVC were placed during the study period from March 2014 to September 2017. Depending on the availability and the clinical circumstances, various techniques including landmark guidance (n=99), ultrasound guidance (n=108) and ultrasound plus fluoroscopic guidance (n=36) were used. The data were retrospectively analysed with regards to the difficulty level and the safety profile. The surrogate marker for assessment of difficulty level included the number of passes required for successful cannulation and technique failure. The safety profile was assessed using procedure-related complication. The binomial outcome was assessed using Fisher's-exact test.

Results: The rate of successful first-pass IJV cannulation in the landmark guided arm was 75% which improved to 92% by the second pass. The use of ultrasound guidance significantly improved the rate of first pass successful cannulation to 97.2%. Technique failure requiring the use of an alternative venous sites was noted in 6.1% of patients in the landmark guided arm and two patient in the same group required ultrasound assistance. The common procedure related complication included local haematoma formation and carotid artery puncture. Compared to the landmark technique, the incidence of carotid artery puncture was significantly lower in the ultrasound guided arm.

Conclusion: In a resource poor environment, the use of landmark guided cannulation by a trained operator continues to be a safe procedure. The use of fluoroscopy and ultrasound, if available, is the gold standard. It improves the outcome while reducing procedure related complications.

Keywords: Dialysis vascular access, Fluoroscopic guidance, Landmark guided cannulation, Ultrasound guided cannulation

INTRODUCTION

A functional vascular access is central to the performance of haemodialysis. The nature of the initial vascular access depends on variables like the urgency of the situation, expertise available and the state of blood vessels. Native AVF is universally accepted as the gold standard for dialysis vascular access and provides a superior patient outcome in respect to mortality, infections, hospitalisation rates and requirement of repeated access intervention when compared with arterio-venous graft and CVC [1-2]. The guidelines from National Kidney Foundation-Kidney Disease Outcome Quality Initiative (NKF-KDOQI) recommend CVC use to be restricted to less than 10% of prevalent haemodialysis patients [3]. Many roadblocks exist towards attaining this utopian target. These include late referral, non-preservation of the vein, unsuitable vascular anatomy and lack of expertise. CVC is easy to place, and have the advantage of immediate usability. The large vein cannulation is, however, potentially dangerous and is associated with numerous complications, both operator dependent and operator independent [3].

The traditional approach for CVC insertion is the landmark guided technique. It is based on the fallacious assumption that there is a consistent anatomical relationship between the IJV, carotid artery and the surrounding structures [4]. It also does not cater to variables like the patency of veins and their caliber. Further complicating the picture are the so-called difficult patients; those with obesity, short neck, and prior IJV cannulation [4]. In the real world, many of these factors co-exist, making landmark guided cannulation technically challenging. With the advent of ultrasound, many of these problems were obviated; the IJV could be directly visualised and its patency should be checked. The use of ultrasound guidance to place the CVC has thus become the standard of care [5]. Though ultrasound ensures safe and precise cannulation of the IJV, the subsequent course of various hardware including the guidewire, dilators, and the dialysis catheter remains unguided. In clinical practise, the ease of passage of guidewire is often taken as a surrogate marker; if the guidewire passes smoothly and no resistance is met, the wire is assumed to be within the venous system [5]. Fluoroscopy, by allowing real-time visualisation of the passage of various hardware, ensures appropriate CVC tip placement. This is particularly important while placing a left IJV CVC, which, unlike the right IJV, takes many twists and turns. Thus, the use of these aids improves the outcome and reduce the complications. The major deterrence in resource poor environment is the cost and the availability of equipment. Lack of equipment often compels the operator towards the use of landmark guided cannulation. Not-withstanding, the above, training of the operator plays an important role in the performance of a safe and uncomplicated procedure. Appropriate training, deliberate practice and repeated performance of procedural skill improve the patient's outcome [6]. The aim of the study was to retrospectively analyse the data and compare the various techniques of CVC placement with regards to the safety and efficacy while eliminating the operator skill level bias.

MATERIALS AND METHODS

A retrospective study was conducted in the nephrology department of a tertiary care teaching hospital situated in southern India. Approval was taken from the Institutional Ethics Committee for collation and analysis of the data. The data for 243 CVCs placed by a single operator from March 2014 till September 2017 was extracted and analysed retrospectively. These included patients with end stage kidney disease, acute kidney injury requiring haemodialysis and few patients on Continuous Ambulatory Peritoneal Dialysis (CAPD). Though all efforts were made to place the CVC under guidance, the use of ultrasound and fluoroscopy was limited by the availability of the equipment. Due to variable access to equipments, most of the CVC placed in the evening and night hours were landmark guided. Three cohorts of patients were identified, landmark guided cannulation arm (n=99), ultrasound guided arm (n=108) and ultrasound plus fluoroscopy guided arm (n=36). The data analysed included, the demographic profile, co-morbidities, indication for CVC placement, history of prior IJV cannulation, number of passes (attempts) for successful cannulation and the complications encountered. A complete blood count, blood grouping, and coagulation parameters were obtained before the procedure.

Inclusion and Exclusion Criteria

All consenting patients without a functional vascular access requiring renal replacement therapy were included in the study. Haemodialysis being an obligatory lifesaving therapy, none of the patients were excluded.

The choice of the catheter: The choice between cuffed and uncuffed catheters were dependent on the availability of the hardware and the clinical circumstances. The guiding principle was the anticipated duration of haemodialysis, with cuffed CVC being used when the duration was likely to be more than two weeks. CVC was always used as a bridge to AVF except in occasional patients who had exhausted all vascular access. The uncuffed CVC used was a 12 F, 13.5 centimeters, pre-curved double lumen dialysis catheter (elite-Harsoria, Elite Biomedicals, New Delhi). The cuffed CVC used was 14.5 F, 24 centimeters (tip to cuff), double lumen silicon catheter with split-tip (HaemoSplit, Long Term Haemodialysis Catheter, Bard, Utah, USA).

The choice of the vein: The preferred site for cannulation was the right IJV. In landmark guided cannulation, the procedure was abandoned in the event of either an arterial puncture or failure to cannulate the IJV despite two passes. In such cases, the further course was decided based on the clinical urgency and the availability of an ultrasound machine. In the absence of an ultrasound machine, when the clinical circumstances dictated urgent vascular access, the left IJV was cannulated using a landmark guided technique.

Catheterisation technique: Standard part preparation, cleaning, draping, and aseptic precautions were practiced for all the cases. For the landmark based cannulation, the apex of the Selidotts triangle, formed between the two heads of sternocleidomastoid muscle was the point of insertion. The direction of the needle was towards the ipsilateral nipple. The initial cannulation of the IJV was done using a 21 G x 7-centimeter-micro-puncture needle (Merit Mak mini access kit, Merit Medical System, Utah, USA). The needle tip was deemed to be in the IJV based on the color and the nature of the blood column. Once the position of the micro-puncture needle was confirmed, a 0.018-inchx40 centimeters stainless steel guidewire was introduced, followed by 4Fx10 centimeters co-axial introducer sheath. The guidewire was exchanged over the sheath with a 0.035-inch guidewire followed by removal of the sheath. The CVC was then introduced over the wire and secured.

For the ultrasound guided cannulation, a 7.5 MHz linear probe was placed perpendicular to the long axis of the vein. The IJV and carotid artery were visualised and the compressibility of the vein and pulsatility of the artery was checked. The course of the puncture needle was followed in real-time. When additionally fluoroscopy was available, the course of the guidewire, dilators, and the catheter were followed real time.

In cases of cuffed CVC, to allow a wide-angle tunnel towards the exit site, a low jugular venous entry point was chosen. After the venous puncture and insertion of the guidewire, the exit site was planned using fluoroscopy. The cuffed CVC was kept externally over the body and manipulated so that the tip overlies the right atria and the course mimics the actual final position. A small incision was made at the planned exit-site, and the catheter was negotiated through the tunnel using the tunneling trochar. The soft tissue around the guidewire was serially dilated, followed by insertion of the peel-away sheath and the catheter. A post-procedure chest X-ray was taken in all the cases and complications if any, were recorded.

Outcome assessment: The surrogate markers to assess the difficulty level associated with various cannulation modalities included the number of passes before successful cannulation, the use of alternative venous sites and technique failure. The procedure related safety was assessed using complications encountered. These CVC related complications were classified using the American Society of Diagnostic and Interventional Nephrology (ASDIN) classification [7].

STATISTICAL ANALYSIS

For the purpose of statistical analysis, the patients were divided into two cohorts based on initial cannulation technique i.e., landmark and ultrasound guidance cohort. The numeric values were expressed as mean and standard deviation. The statistical analysis was carried out by manually creating a 2x2 contingency table and using online resources (www.graphpad.com/quickcalcs/contingency1?/). The test of significance applied was two tailed Fisher's-exact test. A p-value of <0.05 was accepted as statistically significant.

RESULTS

A total of 243 patients, who required haemodialysis vascular access during the period were included in the study [Table/Fig-1]. These included 174 males (71.6%) and 69 females (28.4%). The cannulation techniques used included landmark guided, ultrasound guided, and ultrasound plus fluoroscopy guided in 99 (40.8%), 108 (44.4%) and 36 (14.8%) patients respectively. The mean age of these three arms was 48±8.8, 50±9.1, and 56±9.8 years respectively. The most common indication for CVC placement was a presentation with advanced symptomatic azotemia without vascular access. A total of 163 patients (67%) presented in this fashion, highlighting poor AVF awareness. Fistula failure- both primary and secondary, constituted the second most common indication. Thirty-three patients (13.5%), had acute kidney injury requiring renal replacement therapy and six patients (2.4%) had refractory CAPD peritonitis, requiring CAPD catheter removal. A total of 180 (74.1%) un-cuffed catheters and 63 (25.9%) cuffed CVC were placed during the study period. Cuffed CVC was always placed

	Landmark based arm (n=99)	Ultrasound guided arm (n=108)	Ultrasound and fluoroscopic guided arm (n=36)
Gender (Male: female)	1.67:1	5.35:1	1.4:1
Mean age in years (range)	48 (30-68)	50 (42-66)	56 (35-66)
Type 2 diabetes mellitus	51 (51.5%)	45 (41.6%)	23 (62.8%)
Indication for CVC			
AKI	15 (15.1%)	18 (16.7%)	0
CKD			
a Fistula failure*	18 (18.2 %)	21 (19.4 %)	2 (5.6 %)
b No access†	63 (63.6 %)	67 (62 %)	33 (91.6%)
c CAPD failure	3 (3.1 %)	2 (1.9 %)	1 (2.8)
Previous IJV cannulation	9 (9 %)	15 (13.9 %)	3 (8.3 %)
Type of CVC			
Cuffed CVC	0	27 (25 %)	36 (100%)
Uncuffed CVC	99 (100%)	81 (75%)	0

[Table/Fig-1]: Demographic profile, indication and the type of CVC placed.
*Fistula failure included both primary and secondary failure of arterio-venous fistula; †Patient presenting with advanced azotemia without a functional dialysis vascular access; AKI: Acute kidney injury; CKD: Chronic kidney disease

under the guidance, with ultrasound being obligatory and fluoroscopy desirable.

The rate of successful first-pass cannulation in the landmark guided arm was 75.7%, which improved to 92.4% by the second pass [Table/Fig-2]. The corresponding first-pass success for the ultrasound and ultrasound plus fluoroscopy guidance arm was 97.2% and 100%, respectively. The procedure was unsuccessful in eight patients (8.1%) in the landmark guided arm. Of these eight patients, CVC could be placed in six, using the landmark guidance in the left IJV, and two eventually required ultrasound assistance.

	Landmark based arm (n=99)	Ultrasound guided arm (n=108)	Ultrasound and fluoroscopic guided arm (n=36)
Cannulation in 1st pass	75 (75.7%)	105 (97.2%)	36 (100%)
Cannulation requiring 2nd pass	16 (16.2%)	3 (2.8%)	0
Cannulation requiring use of alternative sites,	6 (6.1%)	0	0
Failed cannulation requiring ultrasound guidance	2 (2%)	0	0

[Table/Fig-2]: Comparison of difficulty level between different modalities of central venous cannulation.

The most common complication encountered was ASDIN type I i.e., local haematoma formation [Table/Fig-3]. The incidence was 10.1%, 3.7% and 5.5% in the landmark arm, ultrasound arm, and ultrasound plus fluoroscopy arm respectively. Inadvertent carotid artery puncture (ASDIN type III complication) was noticed in 5 patients; all in the landmark guided arm. Non-sustained ventricular tachycardia (ASDIN type IX complication) was observed in one patient each, of landmark guided and ultrasound with fluoroscopic guided arm. One patient in the ultrasound guided arm had a central vein perforation (ASDIN type II complication) which required endovascular intervention and placement of stent graft [8]. None of the patients developed a pneumothorax, haemothorax, brachial plexus injury or pericardial tamponade.

	Landmark based arm (n=99)	Ultrasound guided arm (n=108)	Ultrasound and fluoroscopic guided arm (n=36)
Local haematoma	10 (10.1%)	4 (3.7%)	2 (5.5%)
Carotid artery puncture	5 (5%)	0	0
Cardiac arrhythmia	1 (1%)	0	1 (2.8%)
Pneumothorax	0	0	0
Venous Laceration	0	1 (0.9%)	0

[Table/Fig-3]: Adverse events observed with different cannulation modalities.

	Landmark based arm (n=99)	Ultrasound guided arm* (n=144)	p-value
Cannulation in 1st pass	75 (75.7%)	141 (97.9%)	<0.0001
Cannulation requiring 2nd pass	16 (16.2%)	3 (2.1%)	0.0001
Cannulation requiring alternative site	6 (6%)	0	0.0042
Failed cannulation requiring ultrasound guidance	2 (2%)	0	0.1650
Local haematoma formation	10 (10.1%)	6 (4.2%)	0.1115
Carotid artery puncture	5 (5%)	0	0.0106
Cardiac arrhythmia	1 (1%)	1 (0.7%)	1.0000
Venous laceration	0	1 (0.7%)	1.0000

[Table/Fig-4]: Comparison between landmark guided and ultrasound guided technique with regards to difficulty level and complications.
*ultrasound guided arm included all patients where ultrasound was used as a guide to initial IJV cannulation Test-Two tailed Fisher's-exact

Based on the modality of initial IJV cannulation, for statistical purposes, the study population was divided into two cohorts: landmark guidance and ultrasound guidance [Table/Fig-4]. The use of ultrasonography significantly improves the first-pass successful cannulation to over 97% (p-value <0.0001).

DISCUSSION

Haemodialysis is the commonest renal replacement modality worldwide. It requires vascular access capable of providing rapid extra-corporeal blood flow. The gold standard for vascular access remains an AVF. Despite the 'Fistula First' initiate, CVC continues to be used in a significant number of patients on haemodialysis. A recent study on haemodialysis vascular access in India showed that less than one-quarter of the patients started dialysis with an AVF [9]. Whether we love it or hate it, CVC will continue to play an important part in the therapeutic armamentarium of a nephrologist. Strategies like the use of ultrasound and fluoroscopy are often employed in a bid to reduce the CVC related acute complications. The existing studies evaluating the safety profile of these aids are confounded by the presence of multiple operators with varying skill levels making the comparison inappropriate. Peculiar local circumstances in the present study made it possible to eliminate this skill level bias.

The initial IJV cannulation is the most critical step in the performance of the procedure. An important finding of the present study is successful landmark guided cannulation of the right IJV in three-fourth of the patient in the first pass and in over 90% by the second pass. Only 8% of patients required the use of either an alternative site, i.e., the left IJV or assistance of ultrasound guidance. The study thus validates the efficacy of the landmark guided technique in a resource-poor environment. The use of ultrasound guidance significantly improves the first pass successful cannulation to over 97%. This improved success with ultrasound is a result of direct visualisation of the blood vessel, mitigating the anatomical variability of the IJV. Similar findings were noted by Farrell J and Gellens M, [10]. In their study, they noted a successful cannulation rate of 96.67% with the use of ultrasound guidance and 82% with use of landmark guidance. The use of ultrasound resulted in a significant reduction in the requirement for the second pass and use of the alternative sites for CVC placement [10].

The optimal CVC tip placement continues to be debated with conflicting recommendations and guidelines. Further confounding the issue is the different CVC tip designs and the role of the side holes. The general guiding principle is to avoid placing it too deep or too high so as to avoid trauma to the floor of the right atrium and the wall of the superior vena cava respectively. Fluoroscopy helps in the appropriate placement of the CVC tip and in the early detection of catheter kink. Though not a part of the present study, the catheter tip placement was more appropriate and the blood flow achieved was superior when additional fluoroscopy was available.

ASDIN defines procedure related complications as an unanticipated adverse event that requires therapy [7]. The most common complication noted in the present study was the formation of a local haematoma. The incidence of local haematoma formation,10.1%, and 4.2%, in the landmark and ultrasound guidance arm, is not statistically significant (p-value 0.1115). The higher-incidence of haematoma, in the landmark guided arm, despite the use of low profile micropuncture needle, was likely a consequence of higher rate of arterial puncture and increased requirement for the second pass. These haematomas were minor, and the only therapeutic intervention required was local compression. The incidence of inadvertent carotid artery puncture was significantly lower with the use of ultrasound guidance; 5% of patients in the landmark guided cohort and none in the ultrasound guided cohort had this complication (p-value-0.0106). Similar findings of higher carotid artery puncture with landmark guidance were observed by others [11-13]. One major difference between the present study and the existing studies is the complete absence of inadvertent carotid artery puncture in the ultrasound guided arm. This is likely due to the improvement in the resolution of the ultrasound over the years and the experience of the operator. Only one major life threatening complication in the form of iatrogenic central venous perforation was noted during the study period. In summary, of the 243 procedures performed, complications were few and required nominal or minor therapy; only one patient required major endovascular intervention.

Limitation(s)

The small sample size, due to the novel design of the study, aimed at eliminating the skill level bias, by compiling data of a single operator.

CONCLUSION(S)

In resource poor environment, landmark guided approach when performed by an experienced operator continues to be a safe alternative for placement of dialysis catheters. The use of aids like ultrasound and fluoroscopy when available further improves the efficacy and the safety profile of the procedure.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Jan 23, 2020
- Manual Googling: Feb 22, 2020
- iThenticate Software: Feb 28, 2020 (4%)

ETYMOLOGY: Author Origin

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? Yes
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: Jan 22, 2020
Date of Peer Review: Feb 14, 2020
Date of Acceptance: Feb 24, 2020
Date of Publishing: Mar 01, 2020