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Outcome of Ultrasound-guided Insertion of Internal Jugular Vein Permanent Hemodialysis Catheters

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ABSTRACT

Background: Vascular access is critical for hemodialysis (HD) patients. Traditional catheter insertion techniques rely on anatomical landmarks, which correlated with higher failures and increased rates of complications. The procedure's efficacy and safety could be optimized by utilizing real-time ultrasound guidance during HD central venous catheter placement. **Objective:** The aim of the current study was to evaluate the effectiveness and safety of ultrasound-guided permanent internal jugular vein (IJV) catheterization in serving hemodialysis patients.

Patients and methods: A total of 150 patients suffering from end-stage renal disease (ESRD) who had ultrasonography (US)-guided IJV permanent HD catheters implanted in our university hospital, from March 2015 to March 2016 were recruited. Patients were examined for their catheter insertion site, technical success, operative time, number of needle punctures, and procedure-related complications. Patients who have had multiple catheter insertions, prior catheterization challenges, poor compliance, obesity, bony deformity, and coagulation disorders were considered high-operative risks. **Results:** All patients experienced the technical success of the 150 catheters, and 62 (41.3%) were placed in high-risk patients. The first-attempt success rate was 89.8% for the normal-risk group and 72.5% for the high-risk group (P=0.006). IJV cannulation took less time in the normal-risk group compared to the high-risk group (21.2±0.09 minutes vs 35.4±0.11 minutes, P<0.001). No serious complications were reported. Only 4 (6.4%) patients experienced arterial puncture in the high-risk group. **Conclusion:** A low complication rate and a high success rate are associated with the US-guided placement of a catheter into the IJV, even in the high-risk group.

Keywords: Hemodialysis, Permanent HD catheters, Real-time ultrasound guidance, Retrospective study, Al-Azhar University.

INTRODUCTION

Approximately two-thirds of end-stage renal disease (ESRD) patients receive hemodialysis (HD), one-quarter have kidney transplants, and one-tenth require peritoneal dialysis[1]. For HD, three access procedures are commonly used: an autogenous arteriovenous fistula (AVF), a prosthetic bridging graft (BG), and an indwelling central venous catheter. The ideal access should be durable, easily punctured, provide a sufficient flow rate for efficient dialysis, and have a low complication rate[2]. The autogenous AVF was approved by the Kidney Disease Outcome Quality Initiative (KDOQI) recommendations as to the first-line technique for vascular access since it tends to get closer and closer to meeting these standards[3]. Although AVF is the first option for permanent vascular access, it is required at least 6- 8 weeks pass after its construction before using it[4,5].

Furthermore, persistent respiratory failure, ischemia steal syndrome, and patients with severe cardiac failure may not be suitable for AVF[6,7]. The BGs should not be punctured before 14 days and are not recommended as primary vascular access. As a result, both permanent and temporary cuffed tunneled catheters are used in these cases and in those with acute HD[8,9]. If the patient needs access for longer than a month, tunneled catheters should be used[10]. According to a recent report, approximately 80% of those with ESRD will require a hemodialysis catheter during their long-term treatment[11].

Anatomical landmarks are used in traditional hemodialysis catheter insertion methods. The absence of a pulsatile flow pattern and the dark color of venous blood indicate successful cannulation. Based on landmarks, success rates ranged from 60% to more than 90%, with the reported risk of complications ranging from 5% to 20%[12]. Anatomical landmark methods have a higher failure rate, require more attempts, and have a higher complication rate[13]. Long-term problems such as thrombosis, infections, and central venous stricture, as well as early complications like pneumothorax, arterial puncture, and puncture site hematoma, have been attributed to HD catheters[14].

In 1973, the first description of catheter implantation into the IJVs using US guidance was published[15]. To lower the arterial puncture risk, US guidance has been followed[16]. As a result, the National Kidney Foundation suggested using real-time ultrasound to guide the central venous catheters' insertion, to improve insertion success and reduce placement-related complications as well as fluoroscopic screening for proper catheter tip localization after tunneled catheter

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insertion[5]. In the real-time US, the US probe can be positioned longitudinally, leading to a long-axis view on the screen, or transversely relative to the vessel, resulting in a cross-sectional image of the vessel on the screen. The cross-sectional image offers the advantage of enhanced vein imaging in association with the artery and other anatomic structures, which may help prevent accidental arterial puncture[17]. The needle, on the other hand, is only visible as a hyperechoic point in the cross-sectional picture, which may or may not be the needle's tip. The entire needle, as well as the needle tip depth, is visible on the US image when utilizing the long-axis view, decreasing posterior venous wall puncture[18].

The aim of the current study was to evaluate the effectiveness and safety of ultrasound-guided permanent internal jugular vein (IJV) catheterization in serving hemodialysis patients.

PATIENTS AND METHODS

A total of 150 patients suffering from ESRD who had ultrasonography (US)-guided IJV permanent HD catheters implanted in our university hospital, from March 2015 to March 2016 were recruited.

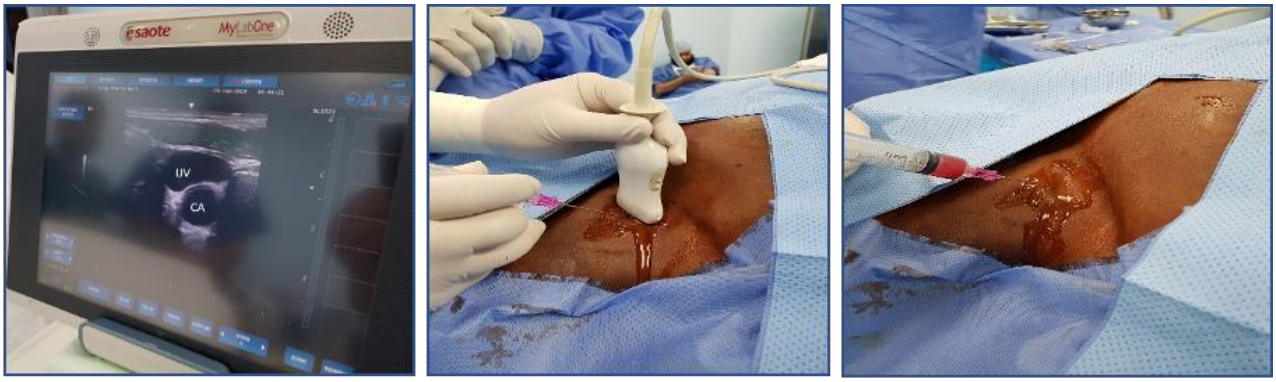
The medical records of the 150 participants with ESRD were reviewed. Demographic data like age and gender were collected and analyzed. Other Information like the etiology and type (acute or chronic) of renal failure, operative time, number of needle punctures, technical success, site of catheter insertion, and procedure-related complications were also collected and analyzed.

Patients were considered high risk if they had multiple catheter insertions, had prior catheter difficulties, had poor compliance, were obese, had disturbed conscious levels, had a bony deformity, or had a blood coagulation disorder. Prior and post-insertion chest X-ray findings were reviewed.

Prior to catheter implantation, all participants underwent full blood count, and coagulation profiles were examined. Fresh frozen plasma was used when necessary. For the procedure, all patients signed a written informed consent form. Permanent tunneled catheters were silicon-based and featured two lumens with a diameter of 14-15 F. Depending on the body size of the participant, the length was optimized (19, 23, or 28 cm). The catheters' Dacron cuffs were around 5 cm away from the exit point, providing a barrier to infections and stability by forming fibrous tissue around them. All procedures were carried out in the main operating room, which has a portable US machine (Esaote MyLab One, MeCan Medical, China) and a portable C-arm machine available all the time. All procedures were carried out by vascular surgery consultants or senior specialists.

The skin overlying the intended insertion location was prepared, cleaned, and draped while the patient was supine. IJVs were used for permanent catheters first on the right and then on the left (in case of thrombosis or stenosis of the right one). If both veins are obstructed, the subclavian vein was utilized.

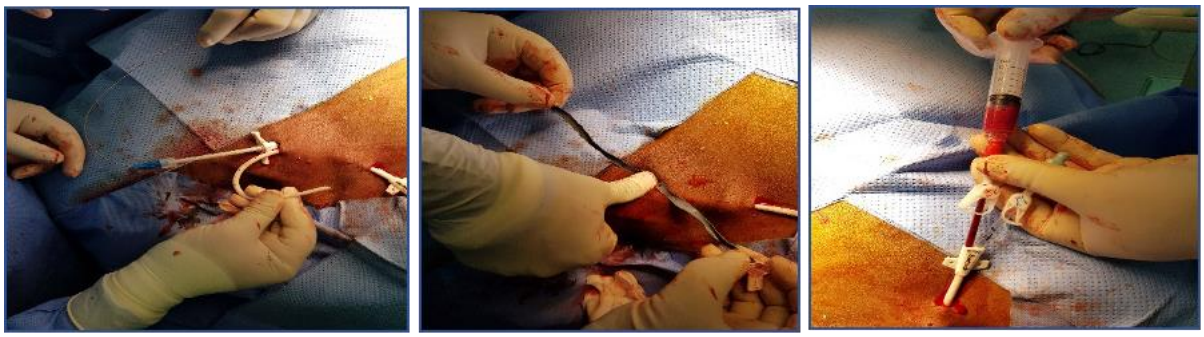
Using a 7 MHz linear probe, the internal jugular vein was visualized horizontally. After monitoring the carotid artery on the medial side and the internal jugular vein on the lateral side, the vein's compressibility and the artery's pulsatility were investigated **(Figure 1A).** Cannulation of the IJV was attempted**.** The operator noticed the needle's pathway while centering a large-bore needle (16 G, 10 cm) under the middle of the probe at a 45° slope to the skin **(Figure 1B).** The needle path shows up as a spot in the horizontal view and a hyperechoic line in the longitudinal view, with ring-down artifacts. When a flush of blood was detected, the US probe was taken down and the conventional Seldinger method was performed under fluoroscopic guidance **(Figure 1C).**



A **B** **C**

Figure 1: Visualizing the carotid artery and the IJV using real-time US (A). A needle is directed under the middle of the probe at a 45° slope to the skin to cannulate the IJV (B). Detection of a flush of blood coming out of the IJV (C).

A minor incision was made on the pectoral region; thereafter a subcutaneous tunnel was made to the guidewire's entrance point, using a tunneller attached to the end of the catheter and continuing the catheter in the tunnel. The catheter was introduced into the atrio-caval junction after dilatation of the tissues around the guidewire and insertion of the peel-away sheath and then the sheath was peeled away. After insertion, all catheters were heparin-locked and were fixed by sutures **(Figure 2 A, B, and C)**. Patients had a post-insertion chest X-ray to determine the catheter position and the possible complications.



A **B** **C**

Figure 2: Progression of the catheter inside a subcutaneous tunnel (A). Peeling the peel-away sheath (B). Testing the catheter for smooth blood flow (C).

Complications that happened after catheter insertion were categorized into three groups concerning the time of onset: periprocedural (if it did occur within the first 24 hours after the procedure), early (after 24 hours and before 30 days), or delayed complications (if it took place after 30 days).

Our study's follow-up was aimed at detecting periprocedural and early complications up to 1 month after any procedure. This study did not cover delayed complications like catheter thrombosis or infection.

Ethical Approval:

This study was ethically approved by the Institutional Review Board [IRB] of the Faculty of Medicine for Girls, Al-Azhar University (Reference: FMG- IRB. 1400). Written informed consent was obtained from all participants. This study was executed according to the code of ethics of the World Medical Association (Declaration of Helsinki) for studies on humans.

Statistical Analysis

The collected data were introduced and statistically analyzed by utilizing the Statistical Package for Social Sciences (SPSS) version 20 for windows. Qualitative data were defined as numbers and percentages.

Chi-Square test and Fisher's exact test were used for comparison between categorical variables as appropriate. Quantitative data were tested for normality by Kolmogorov-Smirnov test.

Normal distribution of variables was described as mean and standard deviation (SD), and independent sample t-test/ Mann-Whitney U test was used for comparison between groups. P value ≤ 0.05 was considered to be statistically significant.

RESULTS

The participants were divided into two groups: Normal-risk (88 patients) and high-risk (62 patients).

Table 1 presents the clinical characteristics of the study patients.

The nephrology clinics referred 126 patients (84%), while other clinics referred the remaining (16%). Diabetes mellitus was the most common etiology of ESRD accounting for 54 individuals (36%), and hypertension in 22 (14.6%).

Other causes like chronic glomerulonephritis, polycystic kidney disease, obstructive uropathy, and unknown accounted for 49.4% of patients.

In the normal group, 79 (89.7%) catheters were inserted through the right IJV, while 9 (10.2%) catheters were inserted through the left IJV. Thirty-two catheters (51.6%) were inserted through the right IJV in the high-risk group, while 30 (48.3%) were inserted through the left IJV.

Table 1. **Clinical characteristics of studied patients.**

Patient's characteristics.	Normal group (n=88)	High-risk group (n=62)	P-value
Age (years)#			
Mean ± SD	55.15 ± 10.96	54.19 ± 10.98	0.598
Range	37-74	37-75	
Gender▲			
Female	31 (64.7%)	22 (35.4%)	0.888
Male	57 (65.3%)	40 (64.5%)	
Comorbidities▲			
IHD	23 (26.1%)	15 (24.1%)	0.782
DM	48 (54.5%)	38 (61.2%)	0.416
HTN	51 (57.9%)	39 (62.9%)	0.540

Using: #Independent Sample t-test; ▲: Chi-square test. P-value >0.05 NS.

Only 23 (37.1%) participants within the high-risk group and 70 (79.5%) participants within the normal group had their first dialysis session after catheterization; the remaining patients were already on regular HD therapy and required new vascular access because of the failed previous one. 21 (33.8%) of the high-risk group referred to us due to catheter malfunction. For the high-risk group, fresh frozen plasma was given to 5 patients prior to the procedures due to abnormalities in the coagulation profile.

IJV cannulation was performed on all patients. The normal group's first-attempt success rate was 89.8%, while the high-risk group was 72.5 % (P=0.006). The high-risk group took longer to cannulate IJV than the normal-risk group (35.4±0.11 minutes versus 21.2±0.09 minutes, P<0.001) **(Table 2).**

Table 2. **The number of venous cannulation attempts and average procedure time**

Number of attempts▲	Normal group (n=88)	High-risk group (n=62)	P-value
1	79 (89.8%)	45 (72.5%)	0.006*
2	9 (10.2%)	14 (22.6%)	0.039*
>2	Non	3 (4.9%)	0.037*
Average procedure time	35.4±0.11 minutes	21.2±0.09 minutes	<0.001**

*Using: #Independent Sample t-test; ▲: Chi-square test; P-value >0.05 NS; *P-value <0.05 S; **P-value <0.001.*

During the study, no serious complications took place. Arterial puncture did not occur in either of the patients in the normal group, but it did occur in 4 (6.4%) patients within the high-risk group during catheter insertion in the IJV (P=0.017). Only 2 patients in each group got a small neck hematoma. After placing a left IJV tunneled permanent catheter, one patient in the high-risk group developed a pneumothorax, which was managed by inserting an intercostal chest tube.

DISCUSSION

Conventionally, central venous access has been conducted using anatomical feature points. Despite this, the landmark technique was related to a statistically significant complication risk and failure rate due to the patients' distorted anatomy and possible vessel pathology, as well as depending on individual operators' competency[19]. Prior studies have published a 35% failure rate for central vein catheterization utilizing anatomic landmarks solo outside the US, with published complication rates ranging from 5% to 40%[20].

The US vascular access guidance has recently been widely used as a quality index to reduce procedure-related morbidities. For many years, real-time ultrasonography has been used to guide interventional operations in a variety of settings, and it has become a clinical practice standard. Real-time ultrasound allowed for the localization of the ideal target vessel and optimized puncture site due to technical advances and improved image quality. Anatomical variability is easily detected, and vein thrombosis is ruled out[21].

There is substantial evidence that utilizing real-time ultrasound guidance for vascular access improves the safety and efficacy of the procedure compared to using anatomical landmarks. Numerous study results have shown that routine use of US during central venous catheterization results in improved clinical and technical success and fewer technical complications[22]. In a study contrasting the US Guided central venous catheterization to the anatomical landmark technique, the total rate of success was estimated to be higher in the US-guided technique (98% vs. 90%), and the first attempt success rate was higher in the US-guided technique (80 vs. 60 %). With US-guided catheterization, the complication rate was also significantly smaller (arterial puncture, 1% vs 8% pneumothorax, 0 vs 4% and neck hematoma, 4% vs 10%)[23]. US guidance was found to significantly minimize the probability of arterial puncture (P=0.002) in a randomized study[9]. The blind technique was not preferred in our study, even in emergencies, because the portable

US machine was available in the operating room around the clock. Furthermore, only the real-time method was used, rather than the static technique, as European Best Practice Guidelines strongly suggested that real-time ultrasound guidance, rather than ultrasound assistance, be used routinely for both long- and short-term central venous access (Strong consensus) (100%)[19]. In our study, an insignificant difference was found between the normal and high-risk groups regarding the patient's clinical characteristics (P-value >0.05). The most common cause of ESRD was diabetic nephropathy.

In this current study, the total success rate was 100% and the first attempt's success rate was 82.6% (89.8 % for normal-risk group and 72.5 % for high-risk group). Nine (10.2%) cases in the normal group required more than one attempt, while 17 (27.5%) cases in the high-risk group needed further attempts. In the high-risk group, 3 cases needed 3 attempts (1 case was due to obesity, another patient had previous catheter difficulties, and the third was due to poor compliance).

During this research, there were no recorded major complications. The overall rate of arterial puncture was 2.6%. During catheter insertion in the IJV, only individuals in the high-risk group had an inadvertent arterial puncture. Only 2 patients in each group got a minor neck hematoma. In the high-risk group, 1 patient developed pneumothorax after placing a left IJV tunneled permanent catheter which was managed with an intercostal chest tube insertion. Our results regarding higher success rate and low complication rate were comparable to the results of the above-mentioned studies[9,22].

The current study's high success rate and low complication rate could be attributed to the use of US guidance, the procedures being performed by competent physicians and the preferential use of IJVs as access sites. Even under US guidance, the physician's experience, according to ***Tordoir et al.***[4] is an important determinant of the complication rate[4]. No difference was found by Geddes et al. between experienced and inexperienced physicians when US advice was utilized[24].

In our report, we exclusively utilized subclavian veins in patients with IJV occlusions because they are no longer used routinely due to the risk of central venous stenosis.

CONCLUSION

Real-time ultrasound has been recommended as a way to enhance success rates, reduce operation time, and reduce the number of complications related to permanent HD catheter insertion in IJVs. Even under US guidance, experience with catheter placement improves complication rates. Ultrasound guidance is becoming an ongoing quality of practice and should be used routinely in all cases.

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