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ORIGINAL PAPER

The outcome of ultrasound-guided insertion of central hemodialysis catheter

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Summary *Objective: To point out our experience and assess the efficacy and safety of real-time ultrasound-guided central internal jugular vein (IJV) catheterization in the treatment of hemodialysis patients.*

Methods: This retrospective study comprised 150 patients with end-stage renal disease (ESRD) who had real-time ultrasonography (US)-guided IJV HD catheters placed in our hospital between March 2019 and March 2021. Patients were examined for their demographic data, etiology, site of catheter insertion, type (acute or chronic) of renal failure, 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 at high-operative risk.

Results: All patients experienced technical success. In terms of patient clinical features, an insignificant difference was observed between the normal and high-risk groups (p-value > 0.05). Of the 150 catheters, 62 (41.3%) were placed in high-risk patients. The first-attempt success rate was 89.8% for the normal 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). There were no serious complications. During the placing of the catheter in the internal jugular vein, four patients (6.4%) experienced arterial puncture in the high-risk group. Two participants in each group got a small neck hematoma. One patient developed a pneumothorax in the high-risk group, which was managed with an intercostal chest tube insertion.

Conclusions: Even in the high-risk group, the real-time US-guided placement of a central catheter into the IJV is associated with a low complication rate and a high success rate. Even under US guidance, experience lowers complication rates. Real-time US-guided is recommended to be used routinely during central venous catheter insertion.

KEY WORDS: *Central HD catheters; Hemodialysis; Central HD catheters; Real-time ultrasound.*

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INTRODUCTION

Two-thirds of end-stage renal disease (ESRD) patients undergo *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 range 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 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, are visible on the US image when utilizing the long-axis view, decreasing posterior venous wall puncture (18).
The current research aimed to assess the complication rate and technical success and provide our center's experience with real-time US-guided IJV central cannulation for HD patients.

Materials and methods

This retrospective study included all patients who had US-guided *internal jugular vein* (IJV) central HD catheters placed at our facility between March 2019 and March 2021. All procedures performed in this study complied with institutional and/or national research council ethical standards as well as the 1964 Declaration of Helsinki and its subsequent amendments or similar ethical standards. Protocols and written informed consent for all participants were approved by the *Research Ethics Committee* of the *Faculty of medicine, Al-Azhar University* (FMG-IRB).
The medical records of 150 participants with ESRD were examined. 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. Vascular surgery consultants or senior specialists carried out all procedures. 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 1). 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 2).

Figure 1.
Visualizing the carotid artery and the IJV using real-time US.

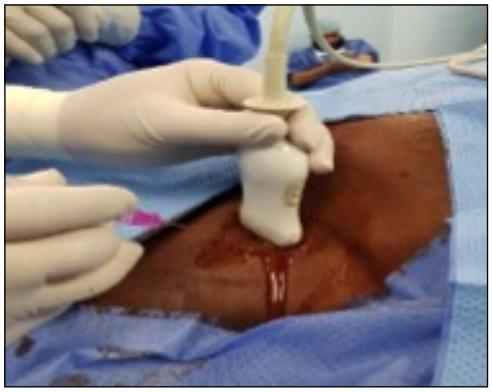

Figure 2.
A needle is directed towards the middle of the probe at a 45° slope to the skin to cannulate the IJV.

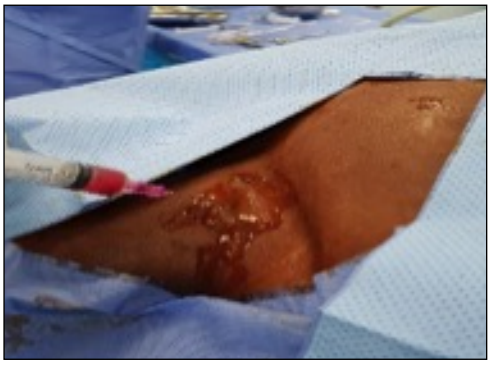

Figure 3.
Detection of a flush of blood coming out of the IJV.

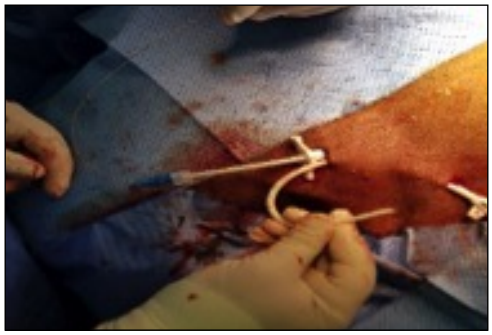

Figure 4A. *Progression of the catheter inside a subcutaneous tunnel.*

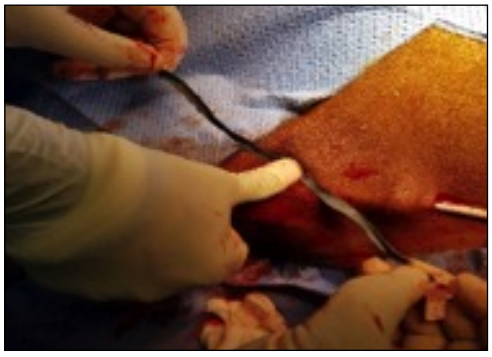

Figure 4B. *Peeling the peel-away sheath.*

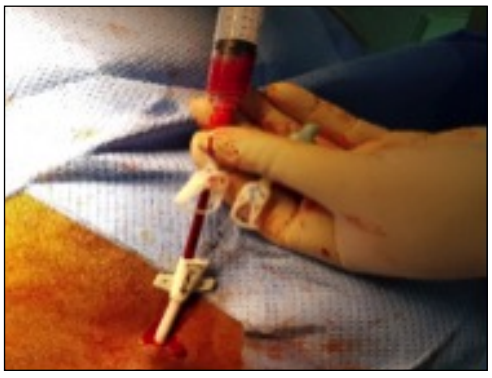

Figure 4C. *Testing the catheter for smooth blood flow (right).*

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 3) and (Figure 4).

Statistical analysis was carried out by SPSS for Windows version 13.0. The mean ± and standard deviation of numerical variables were calculated.

The paired Student, t-test, or Mann-Whitney U test was utilized for intergroup comparisons. P values less than 0.05 was significant statistically.

Results

150 HD patients were categorized into two groups: normal (88) and high-risk (62). Female patients represent (64.7%, and 35.4%) respectively, while male patients represent (65.3% and 64.5%) respectively. The patients' mean ages were 55 (37 to 74) for the normal group and 54 (37 to 75) for the high-risk group. 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 ESRD's most common etiology, 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 percent) were inserted through the right IJV in the high-risk group, while 30 (48.3 percent) were inserted through the left IJV.70 (79.5%) participants within the normal group and 23 (37.1%) participants within the high-risk 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.

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 four patients (6.4%) within the high-risk group during catheter insertion in the IJV (p = 0.017). Two patients in each group got a small neck hematoma. After placing a left IJV tunneled

Table 1.
Patient's clinical characteristics.

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 ▲			0.888
Female	31 (64.7%)	22 (35.4%)	
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

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

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

	Normal group (n = 88)	High-risk group (n = 62)	P-value
Number of attempts ▲			
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**

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

permanent catheter, one patient in the high-risk group developed a pneumothorax, which was managed by inserting an intercostal chest tube.

Discussion

Traditionally, anatomical feature sites have been used for central venous access placement. Despite this, the landmark procedure was associated with a statistically significant risk of complications and failure rate due to the patients' abnormal anatomy and probable vascular pathology, as well as depending on the individual operators' proficiency (19). Prior studies conducted reported a 35% failure rate for central vein catheterization using anatomic landmarks alone, with published complication rates ranging from 5% to 40% (20). The US access guidance has lately become commonly utilized as a quality indicator to prevent procedure-related sequelae. Real-time ultrasonography has been utilized for directing interventional procedures in a variety of situations for many years and has become a clinical practice standard. Because of technological advancements and enhanced image quality, real-time ultrasound allowed for the location of the appropriate target vessel and optimized puncture site. Anatomical variation is easily identified, and venous thrombosis is excluded (21). There is strong evidence that using real-time ultrasound guidance for vascular access increases the procedure's safety and efficacy when compared to anatomical landmarks. Numerous studies have found that using ultrasonography during central venous catheterization improves clinical and technical success and reduces technical difficulties (22). In a study comparing 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 research, we found an insignificant difference 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 the normal group and 72.5 % for the high-risk group). Nine cases (10.2%) in the normal group required more than one attempt, while 17 cases (27.5%) in the high-risk group needed further attempts. In the high-risk group, three cases needed 3 attempts (one 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. Two patients in each group got a minor neck hematoma. In the high-risk group, one 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.*, 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.

Conclusions

Real-time ultrasound has been indicated as a means to improve success rates, shorten operation time, and lower the number of complications associated with HD catheter implantation in IJVs. Even when using US guidance, prior catheter placement experience reduces complication rates. Ultrasound guidance is becoming a standard technique that should be recommend in all cases.

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Conflict of interest: The authors declare no potential conflict of interest.