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Original Article

The use of Doppler ultrasonography and double-control method during catheterization for hemodialysis

Hemodiyaliz amaçlı kateterizasyon işlemi sırasında Doppler ultrasonografi kullanımı ve çift kontrol yöntemi

Ozan Onur Balkanay

Department of Cardiovascular Surgery, Manisa Government Hospital, Manisa, Turkey

ABSTRACT

Objectives: In this study, we aimed to evaluate the results of patients undergoing Doppler ultrasonography and double-control method intraoperatively during hemodialysis catheterization.

Patients and methods: A total of 590 consecutive patients (260 males, 330 females; mean age 54.1±18.2 years; range 19 to 97 years) undergoing catheter placement for hemodialysis in our clinic between July 2013 and August 2014 were included in the study. The patients were divided into two subgroups of internal jugular vein and femoral vein catheterization regions. These subgroups were evaluated separately for uncuffed catheters and tunneled-cuffed catheters. Differences of duration of intervention and complication rates of subgroups were evaluated.

Results: A total of 273 patients (46.3%) had tunneled-cuffed and 317 (53.7%) had uncuffed hemodialysis catheter implantation. Early postoperative catheter dysfunction developed in three patients (0.5%) with previous catheterization history from the same vessel. The mean duration of the procedure was 8.1±2.2 min for uncuffed and 15.8±3.4 min for tunneled-cuffed hemodialysis catheter implantation. No arterial puncture was performed in any patient. The mean number of punctures per intervention was 1.1±0.3 puncture per patient. Intraoperative mortality was not observed in any patient. The duration of the procedure and the rates of complications for the internal jugular and femoral vein regions were not different.

Conclusion: Ultrasonography-guided catheterization can be successfully used in both femoral and internal jugular vein regions with similar results. We suggest routine ultrasonography guidance in the hemodialysis catheterization procedures.

Keywords: Catheter; central venous catheterization; Doppler ultrasonography; hemodialysis.

ÖZ

Amaç: Bu çalışmada hemodiyaliz kateterizasyonu sırasında ameliyat sırası Doppler ultrasonografi ve çift kontrol yöntemi yapılan hastaların sonuçları değerlendirildi.

Hastalar ve Yöntemler: Temmuz 2013 - Ağustos 2014 tarihleri arasında kliniğimizde hemodiyaliz amaçlı kateter yerleştirilen ardışık toplam 590 hasta (260 erkek, 330 kadın; ort. yaş 54.1±18.2 yıl; dağılım 19-97 yıl) çalışmaya dahil edildi. Hastalar internal jugüler ven ve femoral ven kateterizasyon bölgelerine göre iki alt gruba ayrıldı. Bu alt gruplar kafsız ve kaflı tünelli kateterler için ayrı ayrı değerlendirildi. Alt grupların işlem süresi ve komplikasyon oranları açısından farklılıklar değerlendirildi.

Bulgular: Toplam 273 hastada (%46.3) tünelli kaflı ve 317'sinde (%53.7) kafsız hemodiyaliz kateteri yerleştirilmişti. Ameliyat sonrası erken kateter disfonksiyonu, aynı damardan daha önce kateterizasyon öyküsü olan üç hastada (%0.5) gelişti. Ortalama işlem süresi kafsız hemodiyaliz kateteri için 8.1±2.2 dk.; tünelli kaflı hemodiyaliz kateteri için 15.8±3.4 dk. idi. Hiçbir hastaya arteriyel ponksiyon yapılmadı. İşlem için yapılan ponksiyon sayısı hasta başına ortalama 1.1±0.3 adetti. Ameliyat sırası mortalite hiçbir hastada gözlenmedi. İşlem süreleri ve komplikasyon oranları internal jugüler ve femoral ven bölgeleri için farklılık göstermedi.

Sonuç: Ultrasonografi kılavuzluğunda kateterizasyon hem femoral hem de internal jugüler ven bölgelerinde benzer sonuçlar ile başarılı bir şekilde kullanılabilir. Hemodiyaliz kateterizasyon işlemlerinde rutin ultrasonografi kılavuzluğunu önermekteyiz.

Anahtar sözcükler: Kateter; santral venöz kateterizasyon; Doppler ultrasonografi; hemodiyaliz.

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Correspondence: Ozan Onur Balkanay, MD. İstanbul Üniversitesi Cerrahpaşa Tıp Fakültesi, Kalp ve Damar Cerrahisi Anabilim Dalı, 34098 Cerrahpaşa, Fatih, İstanbul, Turkey. e-mail: balkanay@doctor.com

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Catheterization plays a key role in the initiation of the treatment regimen in patients in need of hemodialysis.[1] Uncuffed hemodialysis catheters are mainly for transient and short-term use, while tunneled cuffed hemodialysis catheters are placed for the long-term use.[2] In catheterization procedures, the anatomical landmark technique and ultrasonography (USG)-guided technique can be performed during puncture. Main puncture sites for venous catheterization are internal jugular, femoral and subclavian vein regions.[2] However, internal jugular and femoral vein sites are preferred. Although the placement of a central venous catheter (CVC) is a routine procedure for patients requiring central venous access, acute severe complications such as arterial puncture or cannulation, hematoma, hemothorax, or pneumothorax may occur in a relevant proportion of patients. The use of USG has been proposed to reduce the number of CVC complications and to increase the safety and quality of CVC placement.[3] Therefore, ultrasound-guided vein punctures can be accepted as a secure approach of these kinds of interventions.

In our study, we aimed to evaluate patients who were referred to our clinic for hemodialysis access catheterization and in whom we used USG guidance and double-control method intraoperatively during the catheter placement.

PATIENTS AND METHODS

A total of 590 consecutive patients (260 males, 330 females; mean age 54.1±18.2 years; range 19 to 97 years) who underwent USG-guided catheterization for hemodialysis between July 2013 and August 2014 in cardiovascular surgery clinic of Manisa Government Hospital were included in the study after the informed consent was taken. The study was conducted retrospectively and in accordance with the principles of the Declaration of Helsinki. The patients were divided into two subgroups of internal jugular vein (IJV) (n=484) and femoral vein (FV) (n=106) catheterization regions (Table 1). Then, these subgroups were evaluated separately for uncuffed catheters (Table 2) and tunneled-cuffed catheters (Table 3). The data of the patients were evaluated retrospectively. Routine pre-interventional USG evaluation was performed for all patients during the selection of puncture site. The suitability of puncture sites in terms of USG findings determined the primary preferences. Besides, patient-specific decision was taken in all interventions individually. Thus, direct femoral venous catheterization could be preferred in patients who had previous central venous catheterization history and whose both internal jugular veins were not suitable. Examples of unsuitability are the presence of thrombosed segments, total thrombosis, vein wall thickening and lumen narrowing, distal occlusion,

Table 1. Demographics of patient groups and variables of interventions

	Overall (n=590)			Internal jugular vein intervention (n=484)			Femoral vein intervention (n=106)			
Variable	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	*p*
Gender										<0.001
Female	330	55.9		250	51.7		80	75.5		
Male	260	44.1		234	48.3		26	24.5		
Age (years)			54.1±18.2			54.3±18.2			53±18.6	0.51
Side (right)	495	83.9		428	88.4		67	63.2		<0.001
Tunneled cuffed catheters	273	46.3		213	44		60	56.6		0.02
Uncuffed catheters	317	53.7		271	56		46	43.4		0.02
Catheter length (cm)			20.9±6.6			19.9±5.9			25.8±7.4	<0.001
Duration of the procedure (min)			11.7±4.8			11.6±4.9			12.1±4.3	0.33
Total number of puncture			1.1±0.3			1.1±0.2			1.1±0.3	1
Ionizing radiation imaging	0	0		0	0		0	0		1
Complications (total)	3	0.5		2	0.4		1	0.9		0.49
Pneumothorax	0	0		0	0		0	0		1
Arterial puncture	0	0		0	0		0	0		1
Local hematoma	0	0		0	0		0	0		1
External bleeding	0	0		0	0		0	0		1
Early catheter dysfunction	3	0.5		2	0.4		1	0.9		0.49

SD: Standard deviation.

Table 2. Comparisons of uncuffed catheters in terms of side of intervention

	Internal jugular vein intervention (n=271)			Femoral vein intervention (n=46)			
Variable	n	%	Mean±SD	n	%	Mean±SD	*p*
Gender							0.001
Female	136	50.2		37	80.4		
Male	135	49.8		9	19.6		
Age (years)			52.3±19.9			45.4±19.3	0.03
Side (right)	258	95.2		34	73.9		<0.001
Catheter length (cm)			15.2±0.9			18.9±2.1	<0.001
Duration of the procedure (min)			8.1±2.2			8.1±2.3	1
Total number of puncture			1±0.2			1.1±0.3	0.004
Ionizing radiation imaging	0	0		0	0		1
Complications (total)	0	0		0	0		1
Pneumothorax	0	0		0	0		1
Arterial puncture	0	0		0	0		1
Local hematoma	0	0		0	0		1
External bleeding	0	0		0	0		1
Early catheter dysfunction	0	0		0	0		1

SD: Standard deviation.

and the presence of hematoma/pseudoaneurysm. In case of the suitability of both sites of intervention, primary puncture area was IJV and secondary option was FV region. The first choice as the catheter entry route was the right internal jugular vein region due to its straight path through the superior vena cava. We accepted the left internal jugular vein region as the second option, which was shown to have a higher risk of catheter dysfunction and infection, compared to the right internal jugular vein region.[4] This difference in the outcome becomes more prominent, particularly for uncuffed hemodialysis catheters, which were relatively rigid. The main anatomic disadvantage of the left internal jugular vein is the angulation of its path in two different regions. We preferred the femoral vein region as the third choice due to risk of infection especially in critically ill patients, risk of recirculation during hemodialysis, and higher risk of catheter dysfunction due to the necessity of using longer catheter.[5] In the anatomical landmark technique, for the right-handed surgeon, left hand palpated the femoral artery. The manual stabilization of the artery performed laterally, while the right hand making the puncture to the femoral vein medially. Therefore, the primary site of puncture in femoral region is usually the right side. However, contrary to the anatomical landmark method, there is no preference for such an application in USG-guided catheterizations. If USG evaluation of

Table 3. Comparisons of tunneled-cuffed catheters in terms of side of intervention

	Internal jugular vein intervention (n=213)			Femoral vein intervention (n=60)			
Variable	n	%	Mean±SD	n	%	Mean±SD	*p*
Gender							0.01
Female	114	53.5		43	71.7		
Male	99	46.5		17	28.3		
Age (years)			57 ± 15.4			58.9 ± 15.8	0.4
Side (right)	170	79.8		33	55		<0.001
Catheter length (cm)			25.8 ± 3.6			31.1 ± 5.4	<0.001
Duration of the procedure (min)			16 ± 3.5			15.1 ± 2.6	0.07
Total number of puncture			1.1 ± 0.3			1.1 ± 0.3	1
Ionizing radiation imaging	0	0		0	0		1
Complications (total)	2	0.9		1	1.7		0.63
Pneumothorax	0	0		0	0		1
Arterial puncture	0	0		0	0		1
Local hematoma	0	0		0	0		1
External bleeding	0	0		0	0		1
Early catheter dysfunction	2	0.9		1	1.7		0.63

SD: Standard deviation.

both femoral veins is appropriate, both sides have equal preference. However, for the right-handed surgeon, it is preferred to pass to the right side of the patient during the procedure of both left and right femoral vein catheterization and to use the USG probe with his/her left hand. Subclavian region was accepted as one of the exclusion criteria due to the high risk of venous thrombosis and catheter dysfunction.[6] During the catheterization procedure, the puncture was performed with the standard 16G needle, and Seldinger method was used for all patients. The forward and backward movement of the guide wire was controlled. Following the placement of the guide wire, wire position was assessed by USG for the second control, and intraluminal image was assessed by wire manipulation performed with simultaneous intermittent compression (double-control method) (Figure 1). In addition to the demographic data such as age and sex of patients, the type of hemodialysis catheterization, the length of the catheter, the side and region where it was performed were evaluated. The rates of pneumothorax, arterial puncture, local hematoma, external bleeding, and early catheter dysfunction were evaluated as procedural complications. The patients were divided into uncuffed and tunneled-cuffed catheter subgroups and evaluated. For both groups, statistical comparisons were made according to variables between IJV and FV puncture regions.

Catheterization procedures performed by different surgical teams, catheterization procedures performed using anatomical landmark technique, patients younger than 18 years old, patients without informed consent, patients with intraoperative simultaneous different interventions, patients with simultaneous catheter removal, and subclavian venous interventions were accepted as exclusion criteria.

All patients were assessed with Doppler USG (Mindray® portable USG system) for all IJV, FV, and subclavian vein regions before treatment. Responses to vein compressions and flow patterns were assessed. The hematoma-like conditions and their localizations that would increase the risk of intervention were also evaluated. A vascular USG probe was placed in the intervention field with a sterile sheath, allowing the use of USG guidance during the whole procedure.

In addition to utilizing the USG-guided puncture during the procedure, the back and forth movement of the wire was controlled following the insertion of the guide-wire. The guide-wire image, which was usually attached to the edge of the lumen, was stretched in the skin area and forced to move into the middle of the lumen to validate its position and get a clear intraluminal image (double-control method) (Figure 1). In this way, correct intraluminal positioning of the guide-wire was validated, and the other steps of the procedure were performed.

Determination of whether there was any difference between USG-guided catheterization of IJV and FV regions in terms of procedure time and complication rates was accepted as the primary aim. The assessment of the overall success of the USG-guided catheterization of uncuffed or tunneled-cuffed catheters for IJV and FV was the secondary aim.

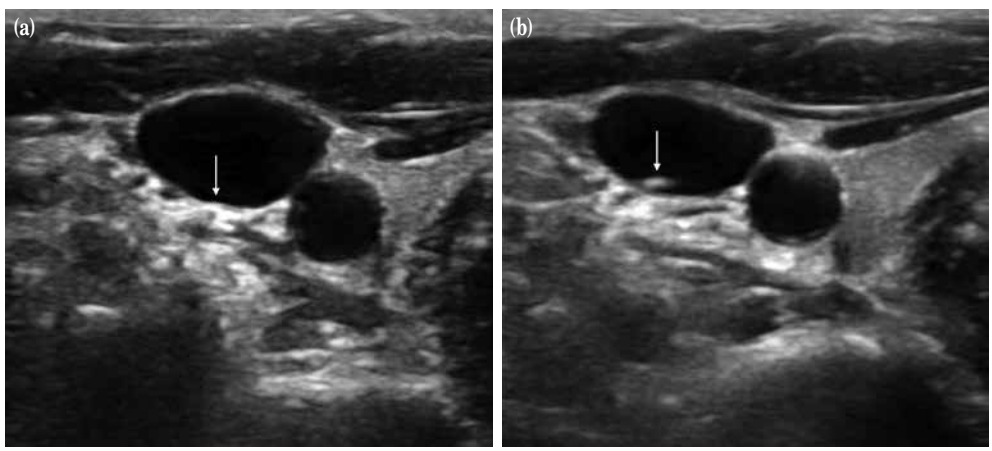

Figure 1. Ultrasound images after puncture and double-control method. **(a)** White arrow indicating an embedded guide wire image in the posterior surface of the internal jugular vein lumen, and **(b)** free-floating image of guide wire which visualized by applying pressure to the guide wire outside the puncture site.

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 21.0 software (IBM Corp., Armonk, NY, USA). Statistical comparisons were made for subgroups of IJV and FV regions. Quantitative data were expressed in mean ± standard deviation, and qualitative data in the number (percent). Continuous variables were compared using the Student's t-test and categorical variables using the chi-square test and Fisher's exact test. A *p* value of less than 0.05 was considered significant.

RESULTS

Demographic features of the patients are given in Table 1. All patients were divided into two subgroups as IJV (n=484) and FV (n=106) intervention. In the comparison of these two groups, there were no statistically significant difference in terms of age, duration of the procedures, total number of punctures, requirement of imaging including ionizing radiation, total complication rates, and rates of complications as pneumothorax, arterial puncture, local hematoma, external bleeding, and early catheter dysfunction (p>0.05) (Table 1). However, female gender ratio was higher in the patients who underwent FV interventions, compared to the IJV region (IJV/FV=51.7%/75.5%) (p<0.001). Most of the interventions of the IJV area (n=428; 88.4%) were performed on the right side, indicating and this made a significant difference, compared to the FV interventions (IJV/FV=88.4%/63.2%) (p<0.001) (Table 1). A total of 273 of the patients (46.3%) had tunneled-cuffed catheters and 317 (53.7%) had uncuffed hemodialysis catheters. Uncuffed catheters were applied more frequently to the IJV region (IJV/FV=56%/43.4%) (p=0.02), whereas tunneled-cuffed catheters were placed more frequently in the FV region (IJV/FV=44%/56.6%) (p=0.02) (Table 1). It was observed that the catheter length was longer in the FV region (25.8±7.4 cm), compared to the IJV region (19.9±5.9 cm) (p<0.001) (Table 1). Early postoperative catheter dysfunction developed in three patients (0.5%) with previous catheterization history from the same vessel. The mean total duration time of uncuffed hemodialysis catheter insertion was 8.1±2.2 min; and 15.8±3.4 min for the patients who had tunneled-cuffed hemodialysis catheter. No arterial puncture was performed in any patient during the procedure. The mean number of puncture performed with the Seldinger needle was 1.1±0.3 puncture per patient. No intraoperative mortality was observed in any patient (0%).

In addition, the IJV and FV intervention subgroups were evaluated separately for uncuffed catheters (Table 2) and tunneled-cuffed catheters (Table 3). For uncuffed catheters, it was observed that the right IJV region was the most preferred localization (IJV/FV=95.2%/73.9%) (p<0.001), and the total number of puncture required in IJV region was less (1±0.2), compared to FV (1.1±0.3) (p=0.004) (Table 2). Uncuffed catheters in FV region more commonly used in females, compared to the IJV site (IJV/FV=50.2%/80.4%) (p=0.001) (Table 2). Internal jugular vein site interventions (52.3±19.9 years) were conducted in older patients, compared to the FV region (45.4±19.3 years) (p=0.03) (Table 2). The catheter length used in was longer in the FV region (18.9±2.1 cm), compared to the IJV region (15.2±0.9 cm) (p<0.001) (Table 2). There were no statistically significant differences between IJV and FV subgroups of uncuffed catheters in terms of duration of the procedure, requirement of imaging including ionizing radiation, total complication rates, and rates of complications as pneumothorax, arterial puncture, local hematoma, external bleeding, early catheter dysfunction (p>0.05) (Table 2).

It was observed that the right side was more preferred localization for IJV region than FV site (IJV/FV=79.8%/55%) (p<0.001) for the tunneled-cuffed catheters but the total number of the puncture required was similar to that of the FV region (IJV/FV= 1.1±0.3 min/1.1±0.3) (p=1) (Table 3). There were no statistically significant differences between IJV and FV subgroups of tunneled-cuffed catheters in terms of age, duration of the procedure, requirement of imaging including ionizing radiation, total complication rates, and rates of complications as pneumothorax, arterial puncture, local hematoma, external bleeding, early catheter dysfunction (p>0.05) (Table 3). Tunneled-cuffed catheters in FV region more commonly used in females, compared to the IJV site (IJV/FV=53.5%/71.7%) (p=0.01) (Table 3). The catheter length was longer in the FV region (31.1±5.4 cm), compared to the IJV region (25.8±3.6 cm) (p<0.001) (Table 3).

DISCUSSION

A venous catheterization of a patent central vein with a suitable diameter is required for effective

hemodialysis.[1] Ultrasonographic evaluation should be performed routinely in all patients as a necessity before catheterization procedures, if an USG device is available. The main goal of this evaluation is to assess the suitability of puncture sites (internal jugular vein, femoral vein, and subclavian vein) for catheterization procedure. In this evaluation, primarily the existence of luminal opening of the venous structure, convenient manual compression, normal USG effect and flow pattern, evaluation of lumen walls in terms of possible thrombotic and fibrotic changes, assessment of the diameter of internal lumen, evaluation of the position of the vein contrary to the adjacent artery, evaluation of hematoma/pseudoaneurysm due to old catheterizations, visualization of proximal site along the venous tract and examination for proximal stenosis (particularly in patients with prominent collateral veins in the skin) should be performed. In case of the detection of any of these evaluation parameters, an attempt should not be planned in this region, if there is a more suitable vein available. There are three main regions used for venous access for hemodialysis catheterization: IJV, FV, and subclavian vein regions.[2] In these catheterization zones, subclavian venous catheterization is associated with increased complication and thrombosis risk. These complications have also the potential to adversely affect subsequent arteriovenous fistula interventions.[6-8] Due to these reasons, the subclavian vein region is not preferred as the primary catheterization zone.[1] In our study, therefore, catheterization of subclavian vein region was accepted as one of the exclusion criteria. The primary interventional region is usually accepted as the right IJV. In our study, 258 (95.2%) of 317 patients who had uncuffed hemodialysis catheters were placed in the right IJV region. The main determinant of this preference is the straight path of the right IJV to the right atrium. The FV region can be used as the other main catheterization region.[1] When considering the problems related to catheter care, the FV region is tried to be not preferred as a priority in terms of infection risk. However, contrary to what is thought to be the risk of infection after FV catheterization could be lower than expected.[9] In addition, the FV region is preferred particularly due to the low risk of complication.[1,10] The main tendency is that the field of FV is easier to use with anatomical landmark method and can be used with low mortality and morbidity rates. However, placement of the tip of the hemodialysis catheter at the right atrium for prolonged use is only possible in jugular and subclavian approaches. The IJV region stands out from these localizations. In our study, it was seen that the most preferred region of the tunneled-cuffed catheters was the right IJV area (Table 3). Using the anatomical landmark technique, there are many complication risks in IJV region such as pneumothorax, carotid artery puncture, bleeding and hematoma.[11] It was found in our study that complications other than early catheter dysfunction did not develop in both regions. It was seen that the catheterizations of the IJV were similar to the FV region catheterizations under the guidance of USG, and the procedure times did not show any significant difference. The duration of the procedure for uncuffed catheters in the IJV and FV regions were 8.1±2.2 and 8.1±2.3 min, respectively; and 16±3.5 and 15.1±2.6 min for tunneled-cuffed catheters, respectively. It was observed that in the IJV and FV sites, the positioning of both uncuffed and tunneled-cuffed hemodialysis catheters placed under the guidance of USG did not lead to a statistically significant difference in terms of procedure time. Thus, it was observed that both FV and IJV region could be easily used for USG-guided catheterization with similar procedure times without any significant difference in terms of complication rates. It is of utmost importance to perform the intraluminal validation of the position of the guide wire with the double-control method. In our study, no patient required validation with a radiological imaging method. Ultrasonography-guided central venous catheterizations have been accepted as safe and effective.[12] Our results, in general, are consistent to these current literature data.[12,13]

There were some limitations in our study including retrospective and single-center conduction. However, our promising results could be accepted as inspiring data to enlighten our daily clinical practices.

In conclusion, the use of USG guidance during hemodialysis catheter placement provides a significant advantage in reducing procedural complication rates, arterial puncture risk, mortality rates, and increasing procedural success, while not increasing the duration of the procedure. It is another factor that provides the technical success in controlling the image of the guide wire in the venous lumen by USG with simultaneous manipulation as a secondary control method. Ultrasound-guided catheterization can be successfully used in both FV and IJV regions with similar results. In consistent with the current literature, we suggest routine USG guidance in the hemodialysis catheterization procedures within the framework of clinical facilities should be included in current targets.

Declaration of conflicting interests

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