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Diagnostic Value of Color Doppler Ultrasonography in Detecting Stenosis and Occlusion of Central Veins in Patients with Chronic Kidney Disease

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ABSTRACT. Venography is an invasive diagnostic test that uses contrast material that provides a picture of the condition of the veins. But, complications, including adverse effects on the kidney, do occur. On the other hand, with the current technological development, application of ultrasound in the diagnosis of obstructive diseases of the veins is gaining popularity, being non-invasive, easy to perform and cost-effective. The aim of this study was to evaluate the diagnostic value of Doppler sonography in the diagnosis of central vein stenosis. In this descriptive–analytical study, 41 hemodialysis patients who had been referred for 50 upper limb venographies to the radiology department of Imam Reza (AS) were included. Patients with chronic kidney disease with a history of catheterization of the vein, jugular or subclavian, and who had established fistulas or synthetic vascular grafts were targeted. Central venous ultrasound was performed on both sides to evaluate stenosis or occlusion. Venography was performed by the radiologist the next day or the day before hemodialysis. Data on demographic characteristics, findings of clinical examination and findings of ultrasound as well as venography were recorded by using the SPSS software, Chi-square test and Spearman correlation, and Kappa agreement was calculated for sensitivity, specificity and predictive values. Twenty-three (56%) patients were male subjects and 18 patients (44%) were female. Twenty-three (56%) patients of the study population were aged <60 years and 18 (43/9%) patients were aged >60 years. The overall sensitivity, specificity and positive predictive value and negative predictive value of Doppler sonography in the proximal veins in hemodialysis patients compared with venography were, respectively, 80.9%, 79.3%, 73.9% and 85.1%. Color Doppler sonography, as a non-invasive method, could be a good alternative for venography in the assessment of the upper limb with central vein stenosis and occlusion.

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Introduction

Chronic kidney disease (CKD) is now recognized as one of the most important causes of death and disability.[1] According to the Center for Special Diseases in the Ministry of Health

and Medical Education, the annual growth rate of this disease in Iran has been approximately 11% and the number of patients had reached about 40,000 in 2009. The annual incidence of the disease and its prevalence rate in Iran are 53 and 250 in one million, respectively,[2] and more than 54% of CKD patients in Iran undergo hemodialysis regularly.[3,4] There are more than 13,000 hemodialysis patients, and around 1,50,000 hemodialyses are conducted each month.[5] Hemodialysis is performed for patients through temporary catheterization of the subclavian and jugular veins prior to creating AV fistula or implanting an AV graft. Catheterization could be associated with severe consequences such as hemothorax, pneumothorax and long-term-use consequences, such as occlusion of these veins.[6,7]

In a study by Naroee Nejad et al (2010) on the prevalence of stenosis, it was concluded that stenosis of the central vein can happen following their long-term catheterization for hemodialysis in patients with CKD.[7] Adequate blood flow is a determining factor for appropriate function of the arterial fistula, which is used as a vascular access for most patients on chronic hemodialysis. Access to the proper vein is also vital for adequacy of hemodialysis.[8,9] Venography is the standard method for assessment of patency of the subclavian and jugular veins. This invasive method has several adverse effects, including sensitivity to contrast substance, thrombosis and undesirable effects on kidney function.[10] Thus, having alternative methods to detect this problem, with minimum adverse effects and maximum detectability, is very important. The current study is aimed at investigating the diagnostic value of Doppler ultrasonography in the assessment of stenosis of the subclavian, jugular and superior vena cava veins as a non-invasive screening test.

Methods

In this current descriptive/analytical study, 41 patients (50 upper limbs) with CKD who were referred to the radiology department of the Imam Reza Hospital in Mashhad, North East of

Iran for upper limb venography were selected through easy sampling. They were recruited from CKD patients who were candidates for creating an AV fistula or implanting a graft at the time of their referral to the hospital. Exclusion criteria included having subclavian or jugular vein catheters, venous hypertension with reverse-function fistula and hypersensitivity to contrast agent. They participated in the study voluntarily.

First, the demographic data, including clinical complaints and signs, were collected. At first, patients were assessed using Doppler ultrasonography and then by venography for any probable stenosis or occlusion, resulting from catheterization of these veins. Sonographic examination was performed using a Siemens G40 ultrasound system. Patients were examined in the supine position with their arms slightly abducted. Using a10 MHz linear probe, the proximal part of the subclavian vein was examined, with middle supraclavicular and distal infraclavicular windows. In overweight patients or those with severe edema in the upper limb, a convex 5 MHz probe was used. The subclavian vein was assessed for stenosis, occlusion, venous flow, cardiac pulsatility and respiratory phasicity. Venous blood flow was assessed during inspiration and expiration and presence or absence of large collateral blood vessels around the subclavian vein were also investigated. Internal jugular vein ultrasonography was performed, first in the transverse axis, to assess compressibility and presence of thrombosis and then in the longitudinal axis, to assess venous flow, cardiac pulsatility and respiratory phasicity and probable stenosis or occlusion. Ultrasonography was performed in both directions to compare venous flow and determine the possibility of proximal or slight stenosis.

All venographies were performed under direct supervision of a radiologist blind to the Doppler results. For safety reasons and to minimize side-effects, venography was performed prior to hemodialysis. In a standard-protocol venography, a superficial vein was punctured using an 18-gauge needle after applying a tourniquet. The arm was positioned supine and

Table 1. Comparison between results of Doppler ultrasonography and venography in diagnosis of stenosis and occlusion of central veins.

Doppler ultrasonography	Venography		Total
	Abnormal	Normal	
Abnormal	17	6	23
Normal	4	23	27
Total	21	29	50

Positive predictive value = 17÷23 × 100 = 73.9
Sensitivity = 17÷21 ×100 =89.9
Negative predictive value = 23÷27 × 100 = 85.1
Specificity = 23÷29 × 100 = 79.3

slightly abducted and then 30–50 mL of non-ionic, low-osmolality contrast substance (Ultravist® 300 mg/dL) was injected at a 4–8 mL/s flow rate. All patients' details, including age, sex, history of the subclavian and jugular vein catheterizations, positive clinical symptoms (e.g., edema, dermatitis, ulcer and venous stasis) and also abnormal findings on Doppler ultrasonography and venography were recorded. Results from Doppler sonographic assessment of the subclavian and jugular veins and venographic findings of the same-side upper limb were combined with data from history and clinical examination.

The K2 and Spearman correlation tests were used for analyzing data and, finally, statistical graphs and tables were used to describe data. Data were statistically analyzed using the K2 test, Spearman's rank correlation coefficient and kappa agreement coefficient. Moreover, sensitivity, specificity and negative and positive predictive values (NPV and PPV) were calculated.

Results

Of 41 studied cases, 23 (56.1%) were male and 18 (43.9%) were female. In the study population, 23 patients (56/1%) were aged less than 60 years old and 18 patients (43/9%) were aged more than 60 years. Some of them had a history of catheterization in more than two veins. Of 21 organs with abnormal venography, the Doppler study could detect 17, which shows an 80.9% sensitivity. Doppler ultrasonography could also detect 23 organs correctly as normal from 29 examined cases with normal venography, which demonstrates a specificity of 79.3%. Moreover, the PPV was 73.9%, which indicates 23 organs with abnormal Doppler ultrasonography results; the venography results were also abnormal in 17 cases. The NPV was 85.1%. In other words, in 27 normal cases, the results of venography and Doppler ultrasonography were consistently normal in 23 patients (Table 1).

When decrease of cardiac pulsatility and respiratory phasicity was used as the criteria for stenosis in ultrasonography, of 21 organs with abnormal venography results for subclavian vein, such a decrease was observed in 16 cases. In addition, of 29 organs with normal venography results, normal cardiac pulsatility and respiratory phasicity were observed in 26

Table 2. Results of subclavian venography and decrease in cardiac/respiratory phasicity in Doppler ultrasonography.

Decrease in cardiac/ respiratory phasicity	Subclavian venography		Total
	Abnormal	Normal	
Yes	11	5	16
No	10	24	34
Total	21	29	50

Positive predictive value = 11 ÷ 16 × 100 = 68.8
Sensitivity = 11 ÷ 21 × 100 = 52.4
Negative predictive value = 24 ÷ 34 × 100 = 70.6
Specificity = 24 ÷ 29 × 100 = 82.8

Table 3. Comparison between the results of venography and Doppler ultrasonography in the diagnosis of stenosis.

Venography	Doppler ultrasonography		
	Normal or stenosis less than 50% No. (%)	Stenosis more than 50% No. (%)	Complete stenosis No. (%)
Normal or stenosis less than 50%	23 (85.2)	5 (29.4)	1 (16.7)
Stenosis more than 50%	2 (7.4)	7 (41.2)	3 (50)
Complete stenosis	2 (7.4)	5 (29.4)	2 (33.3)
Total	27 (100)	17 (100)	6 (100)

cases by the Doppler method (Table 2). In comparison between results of venography and Doppler ultrasonography for determining occlusion rates, Kappa agreement coefficient of 0.38 (P <0.001) showed a statistically significant agreement between these methods (Table 3). Moreover, a Spearman rank correlation coefficient of 0.57 (P <0.001) demonstrated the statistical significance of the agreement between these methods.

Discussion

The reasons for venography were assessment of veins before creating an access for hemodialysis (30 cases; 60%), determining occlusion or stenosis (11 cases; 22%), and both (nine cases; 18%). The most common clinical finding in upper limb examination was inflammation (40%), which was similar to the result of the Passman study (38%). All patients had the history of one- or two-side catheterization in the jugular or subclavian veins. Venography results were abnormal in 44% of the cases. In comparison, in the Passman study, 82% and 38% of patients had a history of one-side vein catheterization and stenosis in venography, respectively.[11] In this study, in patients with abnormal venography, catheterization of the same-side jugular vein and the other-side subclavian vein had the highest and the lowest prevalence rates, respectively. This finding can be due to the higher prevalence of jugular vein catheterization in the studied patients.

In the current study, sensitivity, specificity and PPV and NPV of duplex ultrasonography, compared with venography, in the assessment of proximal veins of hemodialysis patients were

80.9%, 79.3%, 73.9% and 85.1%, respectively. The results were similar to the Passman study, which were 81%, 97%, 94% and 89%, respectively. In the Baxter study, sensitivity was 89%.[11,12] Nack's study reported vein stenosis detection in ultrasonography with 81% sensitivity, 90% specificity, 91% PPV and 78% NPV.[13] In a study by Aywak, sensitivity, specificity and accuracy of ultrasonography in the diagnosis of deep vein thrombosis were 88.9%, 91.8% and 90.9%, respectively.[14,15] These results are in consistence with the results of the current study.

Some studies have shown that difference in accuracy of duplex ultrasonography in assessment of proximal veins can be due to variations in factors, including operator, patient, ultrasonography instrument, the vein under study and the rate of stenosis.[11] In this study, for example, sensitivity of diagnosis of stenosis and occlusion rate in the subclavian and brachiocephalic veins were 77.8% and 33%, respectively. These results are comparable to Marc's study, which reported stenosis and occlusion of these veins with 94% and 36% sensitivity, respectively. In Patel's study, the sensitivity and specificity of ultrasonography in the assessment of the distal subclavian vein were higher than those of its central part and brachiocephalic vein. However, this difference can be related to the higher rate of subclavian vein involvement compared with the brachiocephalic vein in patients with a history of catheterization.[16] Thus, Doppler ultrasonography has the highest reliability when it is technically possible and the involvement is in the subclavian vein, with severe stenosis or complete occlusion.

In the current study, changes in cardiac/respiratory phasicity showed 52.4% sensitivity, 82.8% specificity, 68.8% PPV and 70.6% NPV in the diagnosis of stenosis. These results indicate that the decrease of cardiac/respiratory phasicity of venous flow is beneficial in the assessment of upper limb proximal vein stenosis. In addition to the change in vein frequency in Doppler ultrasonography, absence of color signal, direct observation of lumen stenosis and presence of collateral veins in the upper limb in color-flow duplex and real-time B-mode ultra ultrasonography indicate proximal vein stenosis.[11] Although each of these symptoms can suggest proximal vein stenosis and their combinations can increase the precision of diagnosis. Thus, the precision rate of duplex ultrasonography depends on these combinations.

Conclusion

Results of the current study highlight the benefits of color Doppler ultrasonography in the diagnosis of central vein stenosis as a cost-effective, non-invasive screening test with acceptable sensitivity and specificity. It can be considered as an appropriate alternative for contrast venography.

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