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Original Article

3D B-flow sonographic evaluation of stenosis in forearm hemodialysis fistulas

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Abstract: Objective: To evaluate the forearm arteriovenous fistula stenosis in hemodialysis patients using 3D B-Flow imaging technique. Methods: GE E8 ultrasound diagnostic unit was used to three dimensionally reconstruct the image of stenosis segments in 45 hemodialysis patients by executing CT angiography (CTA) confirmed forearm fistula stenosis, 3D color Doppler flow imaging (CDFI), 3D power Doppler (PDI) and 3D B-flow imaging (B-Flow), respectively; the diameters of stenosis were measured and compared with the diameters measured by CTA. Results: Stenosis diameter measured by 3D CDFI was 2.1 ± 0.6 mm; by 3D PDI, 2.3 ± 0.5 mm; by 3D B-Flow, 1.7 ± 0.3 mm; by 3D CTA, 1.8 ± 0.5 mm. The stenosis diameter measured by 3D B-Flow differs significantly from those measured by 3D CDFI and 3D PDI, but does not differ much from that measured by CTA. There is an obvious positive correlation between the diameters measured by 3D CDFI, 3D PDI, 3D B-Flow and those measured by 3D CTA respectively. The diameter measured by B-Flow can be best correlated with that measured by CTA. Conclusion: 3D B-Flow is a new way for the evaluation of forearm arteriovenous fistula stenosis in hemodialysis.

Keywords: Hemodialysis, fistula, stenosis, B-Flow

Introduction

Internal arteriovenous fistula is the lifeline of patients with hemodialysis [1]. This is because repeated and long-term puncture, vein extremity and fistula pork may come with many kinds of complications, with the most common ones being the thrombosis and the stenosis caused by plaques. These complications may result in inadequate flow in hemodialysis, causing the decrease of the effects of hemodialysis. Clinically, the CT angiography (CTA) is usually used for detecting the pathological changes of fistula, but CTA is high in price and requires use of a contrast medium, which may cause damage to the residual renal functions.

B-flow Technique is a new type of blood flow imaging technique. Compared with the conventional color doppler ultrasound, the B-flow does not rely on the scanning angle, nor needs adjustment of the complicated blood control indexes. As the B-flow has no colors overlapping, no sample frame is needed. Studies at home and abroad show that B-flow exhibits higher frame frequency, higher resolution and better panoramic display in the detection of fistula, free from pseudomorphism like the overflow of blood flow. And the inner diameter of blood vessels measured by the B-Flow is in good correlation with that measured by CTA [2, 3]. But the studies above were conducted under the two-dimensional conditions. The purpose of this study is using the B-Flow Technique to evaluate the fistula stenosis on the forearms of patients with hemodialysis.

Methods

Subjects

45 patients with hemodialysis, including 25 males and 20 females, with the average age being 52 ± 2.3 years of age. The service time of fistula is about 2~5 years, averaged at 3.8 years, and the flow size is not enough during the therapeutic process of hemodialysis. The detection of CTA proves that the stenosis on the

venous end-to-side of hemodialysis fistula is subsistent.

Tools

GE Corporation, Voluson E8 Diasonograph, with RSP6-16-D volumetric probe, at a frequency of 6~18 MHz.

Method of 3D ultrasound imaging: The probe is placed on the stenosis position. The volume information about CDFI, PDI and B-Flow is collected respectively. In the process of collection, the images of CDFI and PDI are so adjusted that they have the minimum sign of colors overflow. Then after-treatment of images is done under the 3D Render Mode (rebuild mode) to observe the stenosis positions. And under the Omni View Mode, the stenosis positions can be accurately measured.

The inner diameter of 3D rebuilding on the stenosis positions are measured under conditions of CDFI, PDI and B-Flow, respectively, and then compared with the inner diameter measured by CTA, to observe the accuracy of the inner diameters on stenosis positions under these three conditions. For each diameter, three measurements are done to obtain the average value.

3D imaging of CTA

16-layer Spiral CT (TOSHIBA, Aquilion, Japan) is employed. First, the Multi-slice Spiral CT (MSCT) is used for parallel scanning, and then run the contrast-enhanced scaning, is done. The contrast medium is iohexol that is injected at the peripheral vein of upper limb at a rate of 3 ml/s in a total volume of about 50 mL, 25~30 s delay before starting the MSCT. Scanning range: the vascular system extending from wrist joints to shoulder joints, including the whole inflow ports of artery and the outflow ports of vein. Technical parameters of scanning are: 120~135 kV, 300 mA, 0.5 s/rot, 1 mm thickness of layer, interval of rebuilding of 0.8 mm. 3D data rebuilding is done through workstation, and the stenosis positions are also measured [4].

Statistical method

All the analyses are conducted using the software of SPSS 16.0. Measurement data are represented by $x \pm s$; *t* testing is used to compare the two groups; the relevant analysis will be done by *pearson* testing, with $P < 0.05$ representing a significant difference.

Results

Presentations of 3D ultrasound

The presentation of CDFI-3D ultrasound on the stenosis positions: Sufficient yet uneven blood flow in the residual cavities on the stenosis positions, colorful and disordered blood flows on the stenosis sections, and colorful pseudomorphism visible from around the tissues (**Figure 1A**).

The presentation of PDI-3D ultrasound on the stenosis positions: Sufficient yet uneven colors in the residual cavities on the stenosis positions, and colorful pseudomorphism visible from around the tissues (**Figure 1B**).

The presentation of B-Flow-3D ultrasound on the stenosis positions: Slender edges of blood stream, strong gray level of blood echo, enhanced blood flow gray scale, no blood overflow visible from around the tissues (**Figure 1C**).

Comparison between 3D imaging-measured inner diameter and CTA-measured inner diameter under different conditions

The inner diameter measured by use 3D imaging under B-Flow condition differs considerably from that measured under CDFI and PDI conditions, but does not differ much from the inner diameter measured by CTA (**Table 1**, **Figure 1D**).

The correlation between the inner diameter measured by three ultrasound 3D imaging methods and that measured by CTA

There is an obvious positive correlation between the inner diameter measured by three ultrasound 3D imaging methods and that measured by CTA. The coefficient of correlation between the inner diameter measured by CDFI-3D imaging and that measured by CTA is: $r = 0.7662$; the coefficient of correlation between the inner diameter measured by PDI-3D imaging and that measured by CTA is: $r = 0.9250$; the coefficient of correlation between the inner diameter measured by B-Flow-3D imaging and that measured by CTA is the best.

Discussion

B-Flow Technique adopts the numbers code technique, directly forms the information of

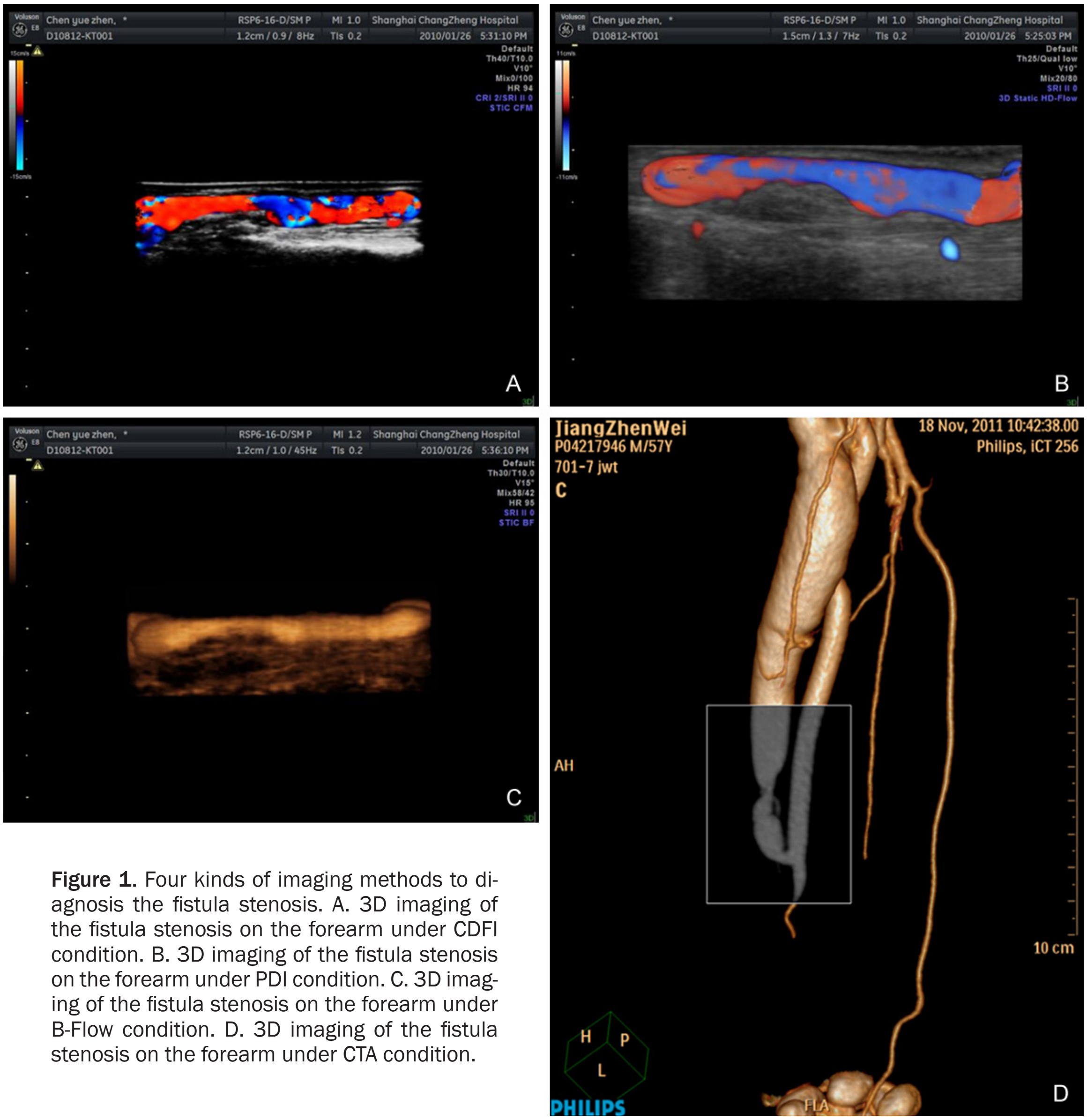

Figure 1. Four kinds of imaging methods to diagnosis the fistula stenosis. A. 3D imaging of the fistula stenosis on the forearm under CDFI condition. B. 3D imaging of the fistula stenosis on the forearm under PDI condition. C. 3D imaging of the fistula stenosis on the forearm under B-Flow condition. D. 3D imaging of the fistula stenosis on the forearm under CTA condition.

Table 1. Comparison between 3D imaging-measured inner diameter and CTA-measured inner diameter under different conditions

Method	Inner diameter (mm)
CDFI-3D imaging	2.1 ± 0.6*
PDI-3D imaging	2.3 ± 0.5*
B-Flow-3D imaging	1.7 ± 0.3
CTA-3D imaging	1.8 ± 0.5

*Comparison with the inner diameter measured by B-Flow condition: $P < 0.05$.

hemocyter in blood vessels, not need to conduct the color and 2D overlap, which promotes the frame frequency and resolution, direct display the changes of hemodynamic and control index of blood flow, not have colors mixed overlaps, not need to color sampling frame, that is a new kind of imaging technique of blood flow.

In China, Chen Yue *et al.* found that the B-Flow Technique can clearly show the blood flow of hemodialysis fistula and adjacent background tissues, and when used in combination with CDFI and PDI, can improve the rate of image display for abnormal images. B-Flow produces higher frame frequency, higher resolution and better panoramic display [2] compared with CDFI and PDI. Yücel C found that B-Flow can directly display hemodynamic changes, vascular walls and anatomical structure of surrounding tissues in the determination of internal arteriovenous fistula, without the pseudomorphism of blood overflow. With more user-friendly images, B-Flow serves as a better display method for blood flow in hemodialysis fistula [3]. Jung EM *et al*. found that B-Flow could better display the anatomical structure of hemodialysis fistula. Compared with CDFI and PDI, the inner diameter of stenosis measured by B-Flow measures has a good correlation with that measured by DSA [5], but these diameters were all measured under 2D imaging.

K.Pfister's study of carotid artery stenosis suggested that that compared with CDFI-3D and PDI-3D, B-Flow can better display the carotid artery stenosis, with a good correlation with the carotid artery stenosis measured by CTA/MRA [6], suggesting that B-Flow can better display the stenosis of hemodialysis fistula.

Through studies we found that under B-Flow condition, the inner diameter measured by 3D imaging is considerably different from that measured by CTA under CDFI and PDI conditions, but not so much different from that measured by CTA. There is an obvious positive correlation between the inner diameter measured by three ultrasound 3D imaging methods and that measured by CTA, whereas the correlation between the inner diameter measured by B-Flow-3D imaging and that by CTA is the best. This suggests that B-Flow-3D imaging provided a new pathway for the evaluation of hemodialysis fistula stenosis on forearms.

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Disclosure of conflict of interest

None.

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