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Color duplex sonography in severe transplant renal artery stenosis: a comparison of end-to-end and end-to-side arterial anastomoses☆

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Abstract

Objective: The aim of this study was to investigate differences in Doppler parameters between severe transplant renal artery stenosis (TRAS, arterial lumen reduction >80%) with end-to-end (EE) arterial anastomosis and that with end-to-side (ES) arterial anastomosis. **Methods:** We retrospectively reviewed color duplex sonography (CDUS) and digital subtraction angiography (DSA) images in 38 patients with severe TRAS (19 cases with EE and 19 cases with ES) between January 1, 2000, and December 31, 2006. Doppler parameters were analyzed, including peak systolic velocity (PSV) in the iliac artery, PSV at the arterial anastomosis, PSV in the transplant renal artery, PSV ratio of the stenotic artery/artery proximal to the stenosis, and acceleration time (AT) in the artery distal to the stenosis (in the intrarenal artery). All 38 cases with severe TRAS were initially diagnosed with CDUS and confirmed by DSA. **Results:** There were significant differences in PSV in the stenotic artery ($P<.01$), PSV in the iliac artery ($P<.001$), and PSV ratios of stenotic artery/artery proximal to the stenosis ($P<.001$) between arterial anastomosis of EE and that of ES. There was no statistically significant difference in AT in the intrarenal artery between the two types of anastomosis ($P>.05$). **Conclusion:** Significantly different PSVs in the stenotic artery, the iliac artery, and the PSV ratio between EE and ES arterial anastomoses should be considered in the interpretation of CDUS when screening for severe TRAS. Different criteria of CDUS need to be established depending on the type of arterial anastomosis in order to improve the accuracy in diagnosing severe TRAS.

Keywords: Color Doppler; Color duplex sonography; Renal transplant; Transplant renal artery stenosis

1. Introduction

Transplant renal artery stenosis (TRAS) is the most common vascular complication in the 3 years following transplantation [1,2]. It is also one of the causes of graft dysfunction and hypertension in renal transplants. Even though the surgical techniques in renal transplant have been continually improved, the incidence of severe TRAS has increased due to a number of factors including the use of marginal donor kidneys, the increase in the number of elderly transplant recipients (age 65 or older), and prolongation of graft survival time.

Color duplex sonography (CDUS), a noninvasive imaging modality, has been considered the imaging tool of choice for screening severe TRAS. With both direct [peak systolic velocity (PSV) in stenotic artery] and indirect [acceleration time (AT) in the intrarenal artery] parameters, the accuracy of diagnosing TRAS with CDUS may reach as high as 95%

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[1,2]. Since overestimating and underestimating TRAS have been reported [3,4], we evaluated whether type of anastomosis [i.e., end-to-end (EE) vs. end-to-side (ES)] plays a role in these misinterpretations. For investigating the feasibility of the criteria of CDUS currently used in the diagnosis of severe TRAS with different types of arterial anastomoses, we retrospectively reviewed and analyzed diagnostic Doppler parameters, by means of PSV in the external renal arteries and AT in the intrarenal artery in 38 cases of severe TRAS with different arterial anastomoses.

2. Materials and methods

2.1. Materials

Patients with renal transplant undergoing both CDUS and digital subtraction angiography (DSA) from January 1, 2000, to December 31, 2006, were reviewed. There were 38 consecutive patients [25 men and 13 women; age range=21–76 years; mean (±S.D.)=46.7±13.8 years] with severe TRAS, including 19 with the EE and 19 cases with the ES type of anastomosis. Nineteen cases (15 cases of EE and 4 cases of ES) from Peking Union Medical College Hospital (PUMCH) and 19 cases (4 cases of EE and 15 cases of ES) from New York Presbyterian Hospital (NYPH)—Weill Cornell Medical College were reviewed for this study. The time to TRAS diagnosis from transplantation ranged from 1 week to 408 weeks [mean (±S.D.)=66.7±91.3 weeks]. Patients with stenosis in the intrarenal artery or common iliac artery were excluded from this study. Nephrologists and transplant surgeons requested CDUS and DSA due to uncontrolled hypertension, worsening renal function, or both.

2.2. Color duplex sonography

The patient was placed in the supine or slightly oblique position. A 3.5- or 5-MHz curved linear or sector array transducer was chosen. A Sequoia 512 (Siemens Medical Solutions, Inc., USA) was used at NYPH. LOGIQ 9 or LOGIQ 7000 (GE Medical Systems, Milwaukee, WI) and HDI 500 or SONOS 4500 (Philips Medical Systems, Bothell, WA) were used at PUMCH. Doppler angle correction less than 60° was standard in spectral Doppler. Doppler with medium wall filter was initiated for the extrarenal vessels [main transplant renal artery (TRA) and iliac artery] where moderate to fast flow commonly appeared, and Doppler with low wall filter was initiated for the intrarenal vessels where slow flow is usually present.

Routine CDUS of renal transplants consists of measuring size and observing morphology on grayscale images, assessing vascularity with color flow imaging, and quantitatively evaluating hemodynamics of the transplanted kidney by spectral Doppler analysis accomplished by measuring PSV in the iliac artery (internal iliac artery in EE, external iliac artery in ES), PSV at the arterial anastomosis, PSV ratio of the stenotic artery/artery proximal to the stenosis, RI of the main TRA, and RI and AT of the intrarenal artery. A narrowed color Doppler box on the magnified area was helpful in visualizing the arterial anastomosis of the transplanted kidney (Fig. 1). A turbulent flow on color flow imaging was the guidance used to place spectral Doppler for picking up the highest flow velocity at the stenosis. Spectral Doppler tracing was routinely performed proximal, at, and distal to the anastomosis. Doppler spectra from the intrarenal arteries (segmental or interlobar arteries) were sampled at upper, middle, and lower poles of the transplanted kidney. Amplitude of the spectrum was magnified by lowering Doppler scale. The clearest spectrum was used for measuring all Doppler parameters. PSVs at the anastomosis, iliac artery, and TRA were recorded for calculating PSV ratios. On the Doppler spectrum of the intrarenal artery, AT was measured from the beginning of the systole to the first early systolic peak [5] with built-in calculation software of the ultrasound machine.

2.3. Diagnostic criteria for severe TRAS (>80%)

CDUS:

PSV at the artery with stenosis >2.8 m/s

PSV ratio of stenotic artery/artery proximal to the stenosis >3.5

AT >0.08 s

DSA: the percentage of stenosis (S%) was determined using the formula:

$$S\% = (D_o - D_s)/D_o$$

where D_o is the reference diameter and D_s is the diameter at the site of stenosis. D_o was measured at a segment of uninvolved artery proximal to the stenosis.

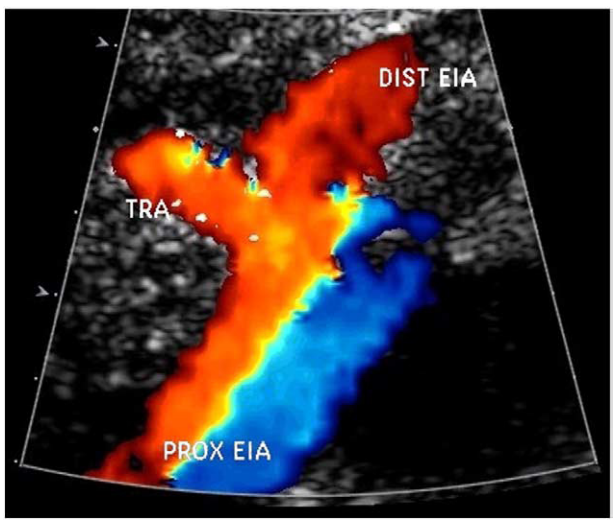

Fig. 1. A normal renal transplant with ES arterial anastomosis on magnified longitudinal color flow image. EIA, external iliac artery. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 1
Doppler parameters between EE and ES arterial anastomoses

Anastomosis type	EE (n=19)	ES (n=19)	P value
PSV at stenotic artery (m/s)	4.62±0.64	3.65±1.33	<.01
PSV proximal to stenosis[a] (m/s)	0.66±0.19	1.18±0.41	<.001
PSV ratio of stenotic artery/artery proximal to stenosis	7.61±2.52	3.25±1.37	<.001
AT in the intrarenal artery (distal to the stenosis) (s)	0.11±0.04	0.12±0.05	>.05

[a] PSV proximal to stenosis was sampled at the internal iliac artery in EE anastomosis and sampled at the external iliac artery in ES anastomosis.

2.4. Statistical analysis

Statistical analysis was performed by SPSS 11.0 software. Continuous variable data were expressed as mean±S.D. A t test or Mann–Whitney test was used to assess the differences in Doppler parameters between the two types of arterial anastomosis. Two-tailed P<.05 was considered statistically significant.

3. Results

In a total of 38 patients with severe TRAS, there were 35 patients with deceased donor transplantations (EE 18 and ES 17) and 3 patients with living donor transplantations (EE 1 and ES 2). Clinical presentations in the 38 cases with TRAS included 30 cases (EE 13 and ES 17) with both uncontrolled hypertension and elevated serum creatinine and 8 cases (EE 6 and ES 2) with hypertension.

In the 38 cases with TRAS, the site of stenosis was located at the iliac artery in 4 cases (EE 2 and ES 2), at the anastomosis in 20 cases (EE 13 and ES 7), and at TRA in 14 cases (EE 4 and ES 10).

The size of transplanted kidneys measured 9.6–12.2 cm [mean (±S.D.)=10.8±0.9 cm]. No hydronephrosis or masses were seen in the transplanted kidneys.

With spectral Doppler, PSV measured 0.66±0.19 m/s in the internal iliac artery in EE and 1.18±0.41 m/s in the external iliac artery in ES. PSV measured up to 4.62±0.64 m/s at the stenotic artery in EE and 3.65±1.33 m/s in ES. PSV ratios of stenotic artery/artery proximal to the stenosis were 7.61±2.52 and 3.25±1.37 in EE and ES, respectively (Table 1).

AT in the intrarenal artery was 0.11±0.04 s in EE and 0.12±0.05 s in ES.

4. Discussion

TRAS is a common complication after renal transplantation. The incidence varies in different reports, increasing in detection from 2.4% to 12.4% after CDUS was introduced [1,2,6,7]. Incidence of TRAS tends to rise with the use of marginal organs or pediatric organs, the increase in the population of elderly recipients, recurrence of chronic rejection and cytomegalovirus infection, and the need for prolongation of graft survival time [8,9]. Of note, TRAS is possibly curable if it is detected early and corrected.

There are multiple factors leading to TRAS, including surgical technique, longer or tortuous graft renal artery, intima damage and vessel lesion during organ preservation, or use of vascular clamps, where arterial narrowing is usually located at the anastomosis [8]. The angulations between donor renal artery and the recipient iliac artery may result in an altered hemodynamic state, turbulent flow, or kinking in the ES anastomosis that develops into stenosis in the postanastomotic site—TRA [10,11]. TRAS related to

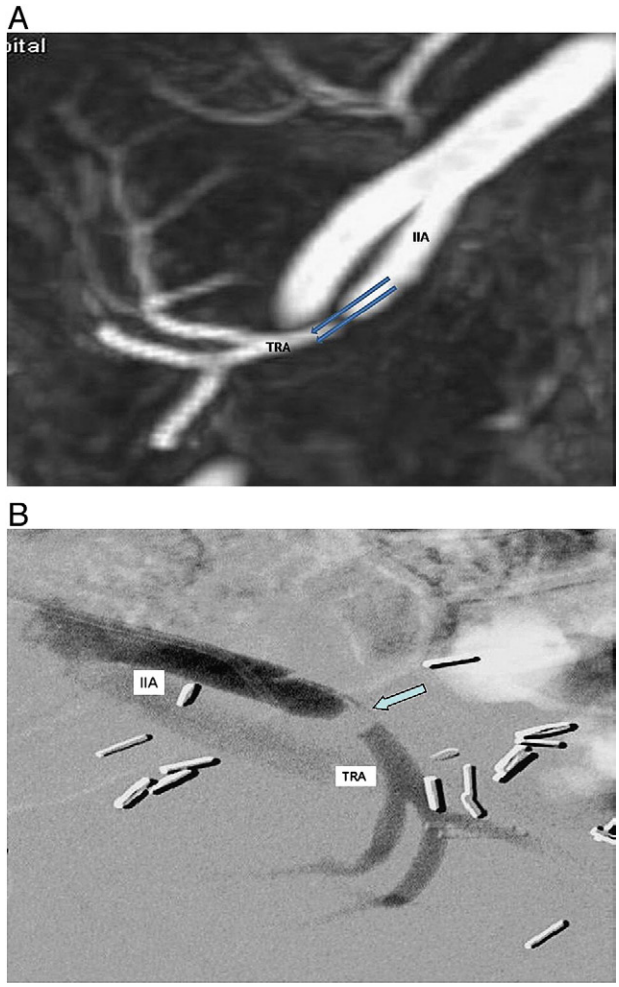

Fig. 2. EE arterial anastomosis. (A) Illustration of longitudinal view of EE anastomosis: main blood flow goes into TRA from the internal iliac artery through anastomosis. Arrows indicate the direction of blood flow. IIA, internal iliac artery. (B) TRAS in a case with EE anastomosis; >90% lumen reduction at the site of EE arterial anastomosis (arrow) on DSA. (C) Increased PSV (6.54 m/s) at the stenotic anastomosis on spectral Doppler. (D) PSV (0.76 m/s) in the internal iliac artery (proximal to the stenosis) on spectral Doppler of longitudinal image.

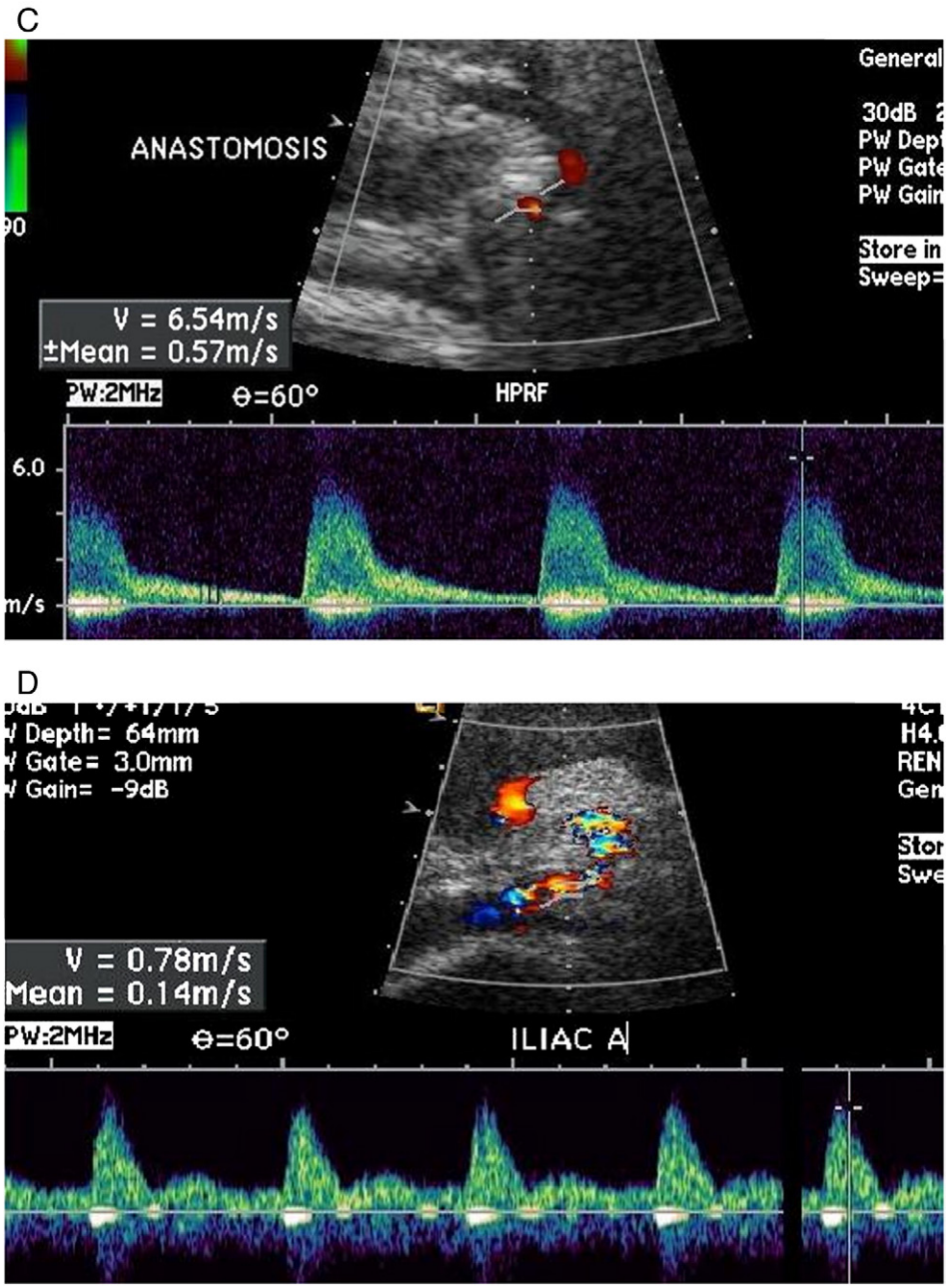

Fig. 2. *(continued).*

chronic rejection and cytomegalovirus infections have also been reported [12]. Atherosclerosis in both donor and recipient further puts these patients at high risk for TRAS. The use of pediatric kidneys in adult recipients leads to greater turbulence due to vessel size mismatch between donors and recipients [13].

The type of anastomosis of the donor renal artery to the recipient iliac artery is mainly determined according to the anatomy of the donor and recipient vessels. EE is the attachment of the end of donor's renal artery to the end of the recipient's internal iliac artery. Normally, there is no flow gradient between the internal iliac artery and TRA since the TRA is considered a continuation from the internal iliac artery (Fig. 2). ES is a technique that allows a donor Carrel aortic patch prepared by appropriate trimming of the aorta around the renal artery to be reconstructed to the side of either the external or common iliac artery. Theoretically, flow volume in the external iliac artery is higher than that in the TRA. Due to the ratio of flow volume divided by lumen diameter of the artery, higher flow volume in the large diameter lumen in the external iliac artery would approximately equal to that of

the lower flow volume in the smaller diameter lumen in TRA; hence, there is no PSV gradient between the external iliac artery and TRA in a normal renal transplant (Fig. 3). The difference of TRAS between PSV in the stenotic artery and PSV in the internal iliac artery in EE can be expressed as this direct hemodynamic relationship: the higher the grade of stenosis, the higher the PSV ratio. Blood flow in the internal iliac artery mostly flows into TRA through the anastomosis, whereas with an increasing degree of stenosis, there is no such relationship between PSV of the stenotic artery and PSV of the external iliac artery in ES. In ES, blood flow of the external iliac artery mainly supplies the ipsilateral lower extremity and it only partially flows into the transplanted kidney [14]. The TRA in ES acts as a branch of the external iliac artery. The difference of TRAS between EE and ES is not only anatomic but also hemodynamic. EE stenotic anastomoses occur at the TRA in the main stream of blood flow. In contrast, the stenotic TRA in ES is located in a branch out of the main flow. This may best explain our findings why PSV at the stenosis and PSV ratio in EE were higher than that in ES.

CDUS has been used for screening of TRAS for decades [1–6]. Due to its noninvasiveness, accuracy, iodine-free nature, portability, repeatability, and low cost, CDUS is an ideal technique in detecting TRAS, as well as monitoring recurrent TRAS after interventional or surgical correction. The grade of TRAS on CDUS is assessed by cutoff values of PSV at the stenosis and PSV ratio of the stenotic artery/artery proximal to the stenosis. In our study, there were statistically significant differences in PSVs and their ratios in severe TRAS between EE and ES, which puts into question whether the diagnostic criteria of CDUS currently used in the diagnosis of severe TRAS are accurate. We have not found distinguishable criteria of CDUS in the diagnosis of severe TRAS for the different arterial anastomoses from the literature [1–8].

Prolonged AT, as parvus tardus Doppler waveform in the intrarenal artery, plays an important role in identifying hemodynamic changes distal to the stenosis [15,16]. Some researchers recommended using AT to select patients for undergoing DSA [17]. The mechanism of developing a parvus tardus distal to the stenosis is complex, as Bude and Rubin [18] reported. In our study, parvus tardus appeared in all 38 cases with severe TRAS. There was no statistically significant difference in AT in the intrarenal artery between EE and ES (0.11±0.04 s and 0.12±0.05 s, $P>.05$). This indicates that the same criterion of AT in the intrarenal artery is suitable for diagnosis of severe TRAS in both EE and ES.

Limitations of CDUS in screening severe TRAS include (a) failure in visualizing the anastomosis and picking up the highest PSV, which may result from poor ultrasound penetration of patients with large fluid collections at the vascular anastomosis site, surgical dressing, bowel obscurity in abdominal transplantation, or obesity, and (b) a high velocity produced by tortuous TRA and angulations between renal artery and recipient iliac artery. Also, an arteriovenous fistula may result in high PSV and turbulent flow in the TRA, mimicking TRAS.

Since there are anatomic and hemodynamic differences between EE and ES, as well as the internal iliac artery and external iliac artery, the CDUS criteria diagnosing TRAS should be established based on the type of arterial anastomosis. Our study indicates that cutoffs of PSV at the stenotic artery and PSV ratio of stenotic artery/artery

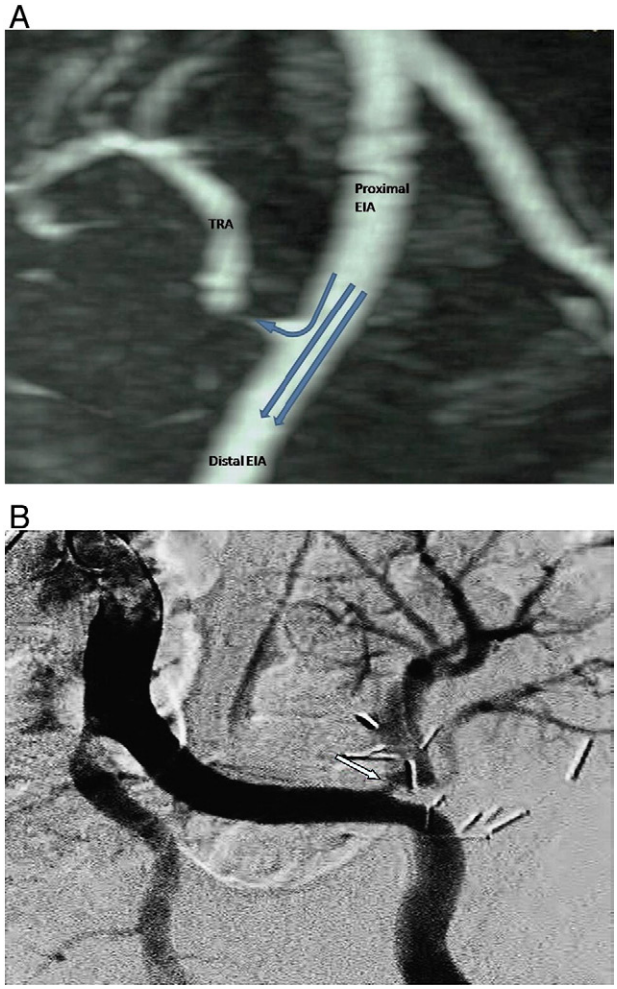

Fig. 3. ES arterial anastomosis. (A) Illustration of ES anastomosis: Arrows show that blood flow of the external iliac artery partially goes into TRA as a branch of the external iliac artery. There is an angle between the donor's renal artery and the recipient's iliac artery. EIA, external iliac artery. (B) Severe TRAS in a case with ES anastomosis; >80% arterial lumen reduction at the proximal transplant renal artery (arrow) on DSA. (C) Increased PSV (3.74 m/s) at proximal TRA indicates a hemodynamically significant stenosis on spectral Doppler. (D) Spectral Doppler with slow slope was used to assess flow velocity in the external iliac artery on a longitudinal image. Normal PSV of 1.29 m/s was measured at the external iliac artery proximal to the stenosis. Prox EIA, external iliac artery proximal to the anastomosis; Dist EIA, external iliac artery distal to the anastomosis; AT anastom, external iliac artery at anastomosis.

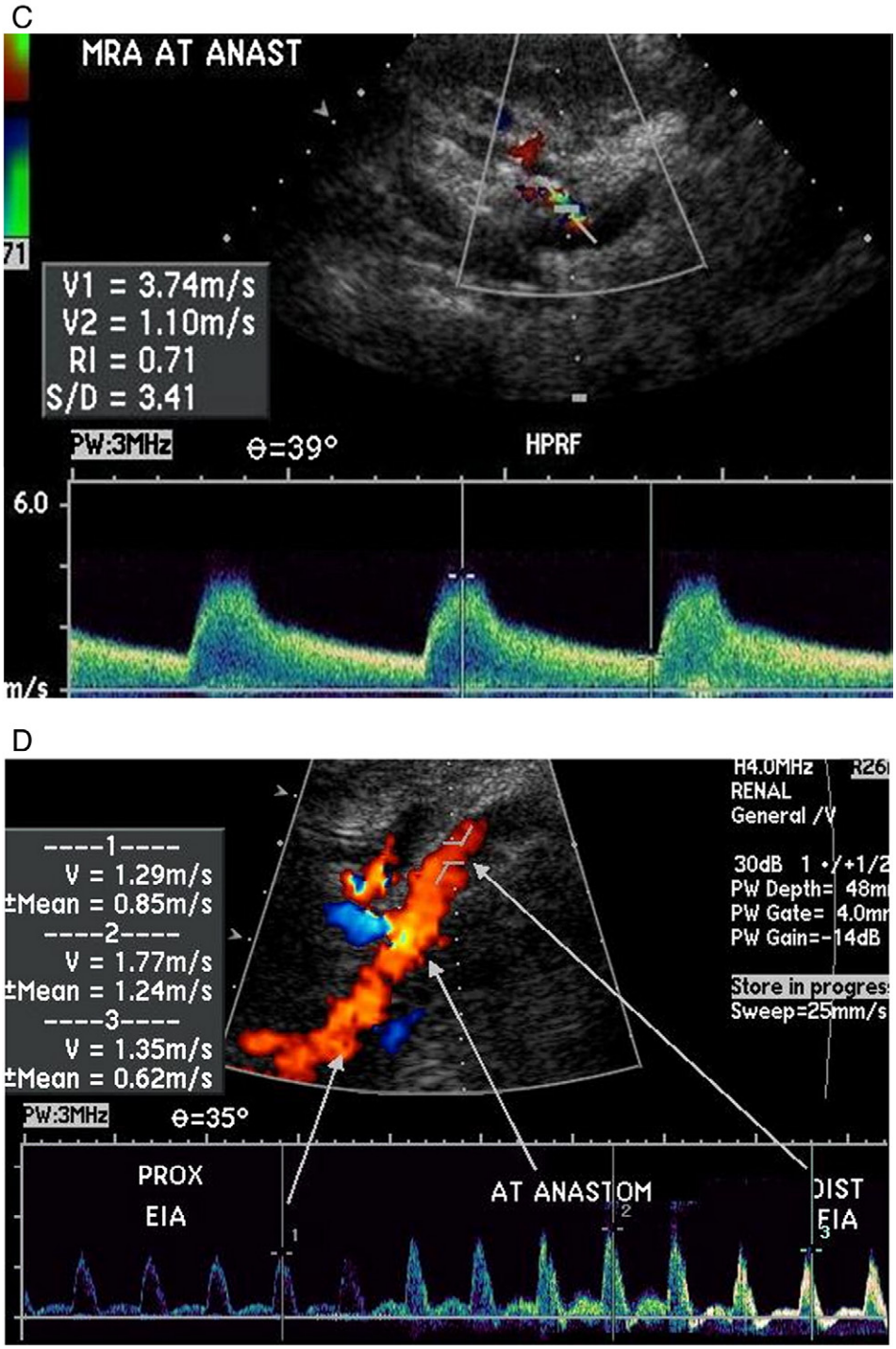

Fig. 3. *(continued).*

proximal to the stenosis in EE should be higher than that in ES. The cutoff value of AT currently used in the diagnosis of TRAS is applicable for both anastomotic types, EE and ES. Further study on the hemodynamics of arterial anastomoses with EE and ES in renal transplantation is needed.

References

[1] De Morais RH, Muglia VF, Mamere AE. Duplex Doppler sonography in transplant renal artery stenosis. J Clin Ultrasound 2003:135–41.

[2] Fervenza FC, Lafayette RA, Alfrey EJ, Petersen J. Renal artery stenosis in kidney transplants. Am J Kidney Dis 1998;31:142–8.

[3] Clerbaux G, Goffette P, Pirson Y, Goffin E. Two kidney-transplant women with therapy-resistant hypertension: diagnostic error of a renal artery stenosis. Nephrol Dial Transplant 2003;18: 1401–4.
[4] Loubeyre P, Cahen R, Grozel F, Trolliet P, Pouteil-Noble C, Labeeuw M, Tran M, Van A. Transplant renal artery stenosis: evaluation of diagnosis with magnetic resonance angiography compared with color duplex sonography and angiography. Transplantation 1996;62:446–50.
[5] Stavros AT, Parker SH, Yakes WF, Chantelois AE, Burke BJ, Meyers PR, Schenck JJ. Segmental stenosis of the renal artery: pattern recognition of tardus parvus abnormalities with duplex sonography. Radiology 1992;184:487–92.
[6] Wong W, Fynn SP, Higgins RM, Walters H, Evans S, Deane C, Goss D, Bewick M, Snowden SA, Scoble JE, Hendry BM. Transplant renal artery stenosis in 77 patients: does it have an immunological cause? Transplantation 1996;61:215–9.
[7] Polak WG, Jezio D, Garcarek JJ, Chudoba P, Patrzatek D, Boratyriska M, Szyber P, Klinger M. Incidence and outcome of transplant renal artery stenosis: single center experience. Transplant Proc 2006;38:131–2.
[8] Bruno S, Remuzzi G, Ruggenenti P. Transplant renal artery stenosis. J Am Soc Nephrol 2004;15:134–41.
[9] Becker BN, Odorico JS, Becker YT, Leverson G, McDermott JC, Grist T, Sproat I, Heisey DM, Collins BH, D'alessandro AM, Knechtle SJ, Pirsch JD, Sollinger HW. Peripheral vascular disease and renal transplant artery stenosis: a reappraisal of transplant renovascular disease. Clin Transpl 1999;13(4):349–55.
[10] Benedetti E, Troppmann C, Gillingham K, Sutherland DE, Payne WD, Dunn DL, Matas AJ, Najarian JS, Grussner RW. Short- and long-term outcomes of kidney transplants with multiple renal arteries. Ann Surg 1995;221(4):4406–14.
[11] Buturovic-Ponikvar J. Renal transplant artery stenosis. Nephrol Dial Transplant 2003;18:74–7.
[12] Pouria S, State OI, Wong W, Hendry BM. CMV infection is associated with transplant renal artery stenosis. Q J Med 1998;91:185–9.
[13] Stanley P, Malekzadeh M, Diament MJ. Posttransplant renal artery stenosis: angiographic study in 32 children. AJR Am J Roentgenol 1987;148:487–90.
[14] Li JC, Ji ZG, Cai S, Jiang YX, Dai Q, Zhang JX. Evaluation of severe transplant renal artery stenosis with Doppler sonography. J Clin Ultrasound 2005;33:261–9.
[15] Ripolles T, Aliaga R, Morote V, Lonjedo E, Delgado F, Martínez MJ, Vilar J. Utility of intrarenal Doppler ultrasound in the diagnosis of renal artery stenosis. Eur J Radiol 2001;40:54–63.
[16] Malatino LS, Polizzi G, Garozzo M, Rapisarda F, Fatuzzo P, Bellanuova I, Cataliotti A, Brozzetti A, Neri S, Malfa PA, Cotroneo GB. Diagnosis of renovascular disease by extra and intrarenal Doppler parameters. Angiology 1998;49:707–21.
[17] Bardelli M, Veglio F, Arosio E, Cataliotti A, Valvo E, Morganti A. New intrarenal echo-Doppler velocimetric indices for the diagnosis of renal artery stenosis. Kidney Int 2006;69:580–7.
[18] Bude RO, Rubin JM. Effect of downstream cross-sectional area of an arterial bed on the resistive index and the early systolic acceleration. Radiology 1999;212:732–8.