Comparison of Color Doppler Ultrasound with Digital Subtraction Angiography or Magnetic Resonance Angiography in the Diagnosis of Transplant Renal Artery Stenosis

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ABSTRACT

Objective: To compare the sensivity and specificity of color Doppler ultrasound (CDU) with digital subtraction angiography (DSA) or magnetic resonance angiography (MRA) in the evaluation of transplant renal artery stenosis (TRAS).

Methods: A retrospective study of 36 patients with suspected TRAS who underwent CDU at Siriraj Hospital between May 2001-December 2005 were investigated. Both intrarenal vessels and the transplant main renal artery examination were reviewed. TRAS was diagnosed if the peak systolic velocity (PSV) of the main renal artery is more than 150 cm/sec. The result of CDU was confirmed by DSA , MRA or clinical follow up. The Chi-square test was used to determine statistical analysis.

Results: 37 studies of CDU examinations (46.8%) of 77 cases were encountered in this study. 21 studies (56.8%) had diagnosis of TRAS by CDU (PSV ≥ 150 cm/sec) with a sensitivity of 100% and specificity of 80% by comparison to the results of DSA or MRA. Of 17 studies with TRAS, 12 studies had a prolonged acceleration time (AT) and 15 studies had a normal resistive index (RI) in the intrarenal arteries. Almost all patients in this study had no renal to iliac velocity ratio (RIR) measurement, however, the remainder of 3 cases with measurement showed no increased RIR ratio.

Conclusion: The criteria for detection of TRAS using the peak systolic velocity of the main renal artery more than 150 m/sec is sensitive and specific enough to be used as a screening test. Intrarenal vascular study using acceleration time can be used to confirm the diagnosis of severe TRAS but the resistive index is not helpful to evaluate TRAS.

Keywords: Color Doppler Ultrasound; transplant renal artery stenosis

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Kidney transplantation is the most common organ transplantation. It is the treatment of choice for end-stage renal disease. Improvement of surgical techniques and better immunosuppression have led to steadily improving patient and graft survival rates. Despite high graft and patient survivals, a variety of parenchyma, vascular and urological complications can threaten the patient in the post operative period. Transplant renal artery stenosis (TRAS) is a common vascular complication and an important cause of graft dysfunction, hypertension and transplant loss. The prevalence of this disorder varies, ranging from 1%-23%.[1-3] TRAS is a curable cause of hypertension and graft dysfunction. It usually occurs 3 months to 2 years after transplantation, but early or later presentation are not uncommon.[1-3] The clinical presentation includes deteriorating renal function and resistant hypertension. Clinical finding such as graft bruit is uncommon.[1,3]

Early detection of TRAS and treatment with percutaneous renal angioplasty and stent placement can preserve renal function. Digital subtraction arteriography (DSA) remains the 'gold standard' but is invasive, expensive and involves the use of contrast agents and radiation. Due to these disadvantages, there has been a search for a suitable non-invasive alternative diagnosis technique such as captopril renography, magnetic resonance angiography (MRA)[4] and color Doppler

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ultrasound (CDU). MRA has shown a better sensitivity and specificity of 100% and 98% respectively.[5] The sensitivity and specificity of Gadolinium-MRA in revealing more than 50% stenosis were 100% and 75%, respectively.[6] However, MRA is relatively expensive and is not widely available in most parts of Thailand. CDU is the preferred imaging modality with a high diagnostic accuracy for detection of TRAS if peak systolic velocity (PSV) is more than 150 cm/sec.[2] It is a non-invasive, available, inexpensive method and does not require contrast agent and no radiation to the patient.

MATERIALS AND METHODS

A retrospective study was performed in the patients who had clinical signs suggestive of TRAS such as hypertension, deterioration of renal function or physical findings of graft bruit. All the patients underwent CDU in Siriraj Hospital between May 2001-December 2005. Medical record forms and imaging studies which include CDU, MRA, and DSA were reviewed by an experienced vascular radiologist.

This study was approved by the Ethics Committee of Siriraj Hospital.

Clinical data

The patient's age, gender, clinical diagnosis before transplantation, types of transplanted kidney, date of operation, duration of presentation, clinical presentation and laboratory findings were recorded.

CDU criteria

Transplant main renal artery and intrarenal vessels criteria were included :-

1. Peak systolic velocity (PSV) at the stenotic area of the main renal artery more than 150 cm/sec was the positive sign for TRAS. We also defined grading of stenosis as mild (150-200 cm/sec), moderate (200-250 cm/sec) and severe (≥ 250 cm/sec) degrees.
2. Renal artery velocity to iliac artery velocity ratio (RIR) more than 3.5.
3. Indirect sign of intrarenal acceleration time (AT) of more than 0.07 second or the presence of delayed systolic upstroke and diminished peak systolic velocity (so called tardus-parvus waveform).

Location of the stenosis classified as proximal, middle and distal part of the transplanted main renal artery was also analyzed.

DSA and MRA criteria

Presence of TRAS were defined as mild, moderate and severe stenosis with luminal narrowing of 30-50%, 50-75% and more than 75%, respectively. Severity of the stenosis were graded by comparison of the diameter at the narrowed segment to that of more proximal normal artery.

Location of the luminal narrowing by DSA or MRA was compared with CDU reported.

Clinical follow up criteria

For two patients who did not undergo DSA or MRA, clinical follow up was used instead to confirm negative diagnosis. The clinical paramenters used to follow up were blood pressure and serum creatinine level. The patients would be diagnosed of negative TRAS if there was no evidence of rising serum creatinine level or blood pressure for at least 6 months after follow up.

Statistical analysis

The chi-square test was used to determine sensitivity and specificity of PSV ≥ 150 cm/sec and AT mor e than 0.07 second for the detection of TRAS.

RESULTS

A total of 77 patients were scanned with CDU. 40 patients were excluded because of incomplete clinical and imaging data, thus 37 studies (36 cases) were included in this study. Of the 36 patients, 23 (64%) were male and 13 (36%) were female. The age ranges from 7-65 years.

Regarding the type of transplanted kidney, 22 cases were cadaveric and 13 cases were living related kidney and 1 case was unknown. TRAS were diagnosed by CDU in 16 patients (17 studies). Of these 16 cases, 13 cases (81%) presented with rising serum creatinine level, hypertension or both. The other presenting symptoms were graft bruit in 2 cases and oliguria in 1 case.

Concerning the duration of presentation, TRAS occurs from 3 days to 10 years after transplantation. Most of the cases (10 out of 17) showed that TRAS occurred from 2 months to 3 years.

The location of stenosis could be correctly detected by CDU in 12/14 cases (85.7%) but were not identified in the remainding 2 cases. We found that the stenotic sites were anastomosis in 2 studies, proximal part in 6 studies, middle part in 4 studies (CDU showed missed interpretation as proximal part in 2 studies) and distal part in 2 studies (Table 1).

The sensitivity and specificity of CDU for detection of TRAS were 100% and 80%, respectively by using a PSV ≥ 150 cm/sec in the main renal artery and sensitivity 86.7% with specificity 80% by using a prolonged intrarenal AT criteria (Table 2).

DISCUSSION

Stenosis of renal artery is a common vascular complication after kidney transplantation. The range of duration is usually occurs within 3 months to 2 years

TABLE 1. Location of the transplant renal artery stenosis.

DSA, MRA / CDU	Anastomosis	Proximal	Middle	Distal
Anastomosis	2 (12.5%)	-	-	-
Proximal	-	6 (37.5%)	2 (2.5%)	-
Middle	-	-	2 (2.5%)	-
Distal	-	-	-	2 (2.5%)

TABLE 2. Diagnostic accuracy of Doppler measurement in transplant renal artery stenosis.

CDU measurement	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
PSV of main RA ≥ 150 cm/s	17(100)	16(80)	17/21(81)	16/16(100)
Intrarenal AT ≥ 0.07 sec	13(86.7)	16(80)	13/17(76.5)	16/18(88.9)

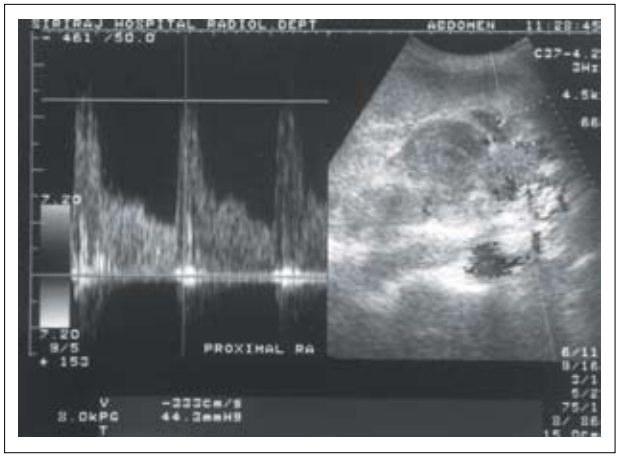

Fig 1A. 38 year-old male post kidney transplantation for 3 years, presenting with rising serum creatinine level

Fig 1A. CDU showed high PSV (333 cm/sec) with spectral broadening (white area under spectral curve) at the proximal part of transplant main renal artery suggesting severe stenosis.

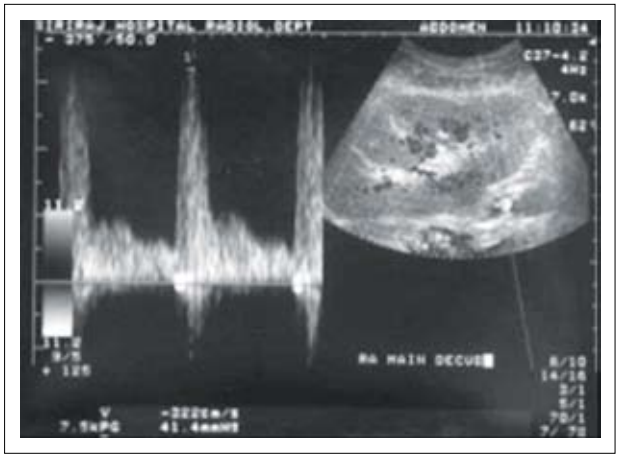

Fig 2. A 43 year-old male post kidney transplantation for 5 years, presenting with rising serum creatinine level

Fig 2A. CDU showed severe stensosis with high PSV (240 cm/sec) at the transplant main renal artery.

after surgery.[1-3] In our study TRAS occurred within 3 days to 10 years post transplantation, but most of the cases occurred at 2 months to 3 years.

The presenting symptoms are hypertension, deterioration of renal function or graft bruit. In our study most cases presented with hypertension or rising of serum creatinine level.

The stenosis may be located before the anastomosis (because of atherosclerotic disease in the donor vessel), at the anastomosis (secondary to vessel perfusion injury, faulty suture technique or reaction to suture material) or after the anastomosis (due to rejection, turbulent flow from kidney malposition, or arterial twisting, kinking or compression).[7] Approximately half of the TRASs occur at the anastomosis, and end-to-end anastomoses have a threefold greater risk of stenosis than end-to-side anastomoses.[8,9] Of the 17 studies with diagnosis of TRAS in this study, the most common location were the proximal and middle parts of the renal artery respectively which were likely due to arterial kinking.

DSA remains the gold standard for detection of TRAS but is an invasive and expensive means with limitations by the use of radiation and the need of contrast agent administration.

Of these disadvantages, CDU is the preferred imaging modality with a high accuracy. CDU is a noninvasive, non-radiation producing imaging modality with high accuracy. It is the method of choice in the assessment of vascular complication after kidney transplantation in children with a detected rate of TRAS in 7/7 cases[10]. In our opinion, CDU examination of a transplanted renal artery is technically much more easy than the study of the native renal artery due to its superficial location. We can trace the whole course of the renal artery within a short study time in almost every case.

In our study, we used both DSA or MRA to be a gold standard test even though MRA is not ideal because it is expensive and not widely available. If we separate the study to compare with CDU, the number of the patients will be very small.

Fig 1B. DSA showed end-to-side anastomosis of renal artery to external iliac artery with nearly 50% luminal narrowing (moderate stenosis) at the proximal part of transplant main renal artery (arrow).

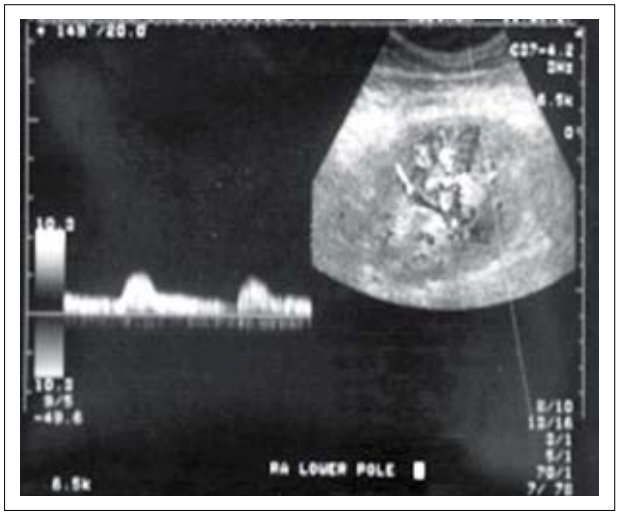

Fig 2B. Intrarenal examination showed delayed AT with tardus-parvus waveform.

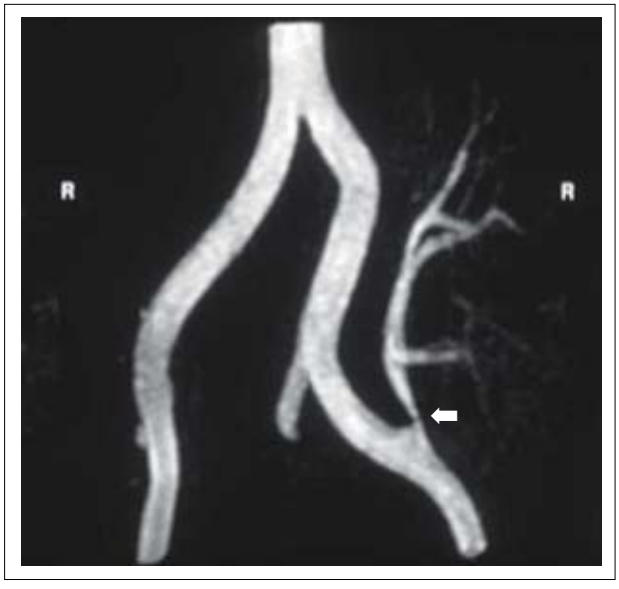

Fig 2C. MRA confirmed severe stenosis (85-90%) at the proximal transplant renal artery (arrow)

CDU demonstrates the stenotic segment as focal areas of color aliasing due to increased flow velocity. Doppler criteria of significant stenoses include (a) focal frequency shifts greater than 7.5 KHz (when using a 3.5 MHz transducer) or velocities greater than 2 m/sec (b) a velocity gradient between stenotic and pre-stenotic segments of more than 2:1 and (c) marked distal disturbance (spectral broadening). In the renal parenchyma, tardus-parvus waveform abnormalities can be observed.[7] To correctly measure systolic velocity, we should place the sample volume within the middle part of the measured artery with a Doppler angle (angle between the insonating sound beam and the vessel axis) less than 60 degrees.

Some authors used a peak systolic velocity of ≥ 2.5 m/sec in the transplant renal artery which showed a sensitivity of 100% and a specificity of 95% for detection of renal artery stenosis[1]. Grenier et al stated that the sensivity and specificity of classifying lesions as greater or lesser than 50% stenosis with 190 cm/sec as the upper normal limit of systolic velocity were 100% and 94% respectively.[11] In our study, we used the PSV of the main renal artery ≥ 150 cm/sec according to the paper of Wong W, et al[2] as the cutoff point showing a sensitivity of 100% and specificity of 80%. The reason may be caused by a lower peak systolic velocity making a lower true negative test. However, even our result had a lower specificity than the other studies, the true positive test was the most important with clinical correlation then confirmation should be done by either DSA or MRA. The patients' renal function could be preserved if proper treatment by percutaneous renal angioplasty or stent placement was performed as soon as possible before the stenosis turned to be occlusion or became irreversible renal impairment.

Concerning grading of stenosis, we did not compare the severity of luminal narrowing between CDU, DSA or MRA because there was no available data in every case.

It may be appropriate to rely not on the velocity of transplanted renal artery to detect stenosis but on the ratio of PSV of the transplanted renal artery to that in the external iliac artery (EIA) because they correlate well with each other. Some authors found that the upper limit of this ratio was 1.5 and the upper limit of PSV in the transplanted renal artery was 183 cm/sec when there was no pronounced vessel tortuousity.[12] Almost all patients in this study had no renal to iliac velocity ratio (RIR) measurement, however, the remainding 3 cases with measurement showed no increased RIR ratio.

The diagnosis of stenosis was never based on direct visualization of a stenotic lumen probably due to the small size of the vessels. The perivascular artifact, related to mechanical vibrations transmitted by turbulence, was the only finding of stenosis on color Doppler flow imaging other than the results of spectral analysis.[11] Nevertheless, high velocity associated with spectral broadening (due to turbulence) were considered major in all cases as shown in our case (Fig 1). However, spectral broadening can be observed in normal vessels at anastomotic sites, curves and kinks.[13] Our study did not mention about spectral broadening in every case so this criteria could not be evaluated.

The intrarenal parameters both acceleration time (AT) and resistive index (RI) were less useful as a discriminating diagnostic test.[1] Some authors found that the tardus-parvus phenomenon of the distal renal artery could be seen in normal arteries, but not found in the case of moderate stenosis so it could not be used as an adequate screening method for detecting RAS.[14] In contrast to our study when using intrarenal AT criteria ≥ 0.07 second, we found a high accuracy for diagnosis of TRAS with a sensitivity and specificity of 86.7% and 80%, respectively (Fig 2). The measurement of intrarenal RI in our study showed a normal value in most cases of both groups. We concluded that RI is a less useful criteria for diagnosis of TRAS.

CONCLUSION

Color Doppler ultrasound is a noninvasive, non-radiation producing imaging modality with high accuracy for diagnosis of vascular complications of a transplanted kidney. Color Doppler ultrasound criteria of peak systolic velocity (PSV) of transplant main renal artery ≥ 150 cm/sec is sensitive and specific enough to be used as a screening test for the detection of transplanted renal artery stenosis (TRAS) after kidney transplantation.

For intrarenal examination, acceleration time ≥ 0.07 second is also helpful to diagnose TRAS. However, intrarenal resistive index is a less useful criteria for confirming TRAS in our study.

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