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【 CASE REPORT 】

Apparent Diffusion Coefficient in the Resolution of Renal Ischemia after Angioplasty on Diffusion-weighted Imaging: Renal Artery Stenosis Caused by Progressive Thrombosis in Residual Chronic Aortic Dissection

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Abstract:

We report a case in which diffusion-weighted magnetic resonance imaging (DWI) demonstrated renal artery stenosis-related renal ischemia and the therapeutic efficacy of revascularization. The patient was a 73-year-old man, who underwent descending thoracic aortic replacement due to DeBakey IIIb chronic aortic dissection, and who showed progressive renal dysfunction due to right renal artery stenosis caused by false lumen thrombosis. DWI demonstrated a decreased apparent diffusion coefficient (ADC) in the right kidney, indicating renal ischemia. Angioplasty with stenting restored renal perfusion and improved the renal function, resulting in the normalization of the decreased ADC in the treated kidney. Thus, DWI can be used to monitor renal ischemia in cases involving advanced renal artery stenosis.

Key words: diffusion-weighted MRI, renal ischemia, renal artery stenosis, renovascular disease, angioplasty

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Introduction

Renal artery stenosis causes renal ischemia, which can cause renal dysfunction due to ischemic nephropathy. Renal revascularization by transluminal renal artery angioplasty is a treatment choice for renal artery stenosis. Although randomized controlled trials have failed to show major clinical benefits from angioplasty in patients with atherosclerotic renal artery stenosis (1, 2), revascularization by angioplasty can still achieve favorable outcomes, such as dramatic recovery of the renal function in cases with reversible renal ischemia (3-5). Thus, a method of selecting patients with renal artery stenosis who would substantially benefit from angioplasty has there been clinically warranted. However, no such methods have been developed. Noninvasive methods to monitor functional renal ischemia derived from arterial stenosis are therefore required.

Magnetic resonance imaging (MRI) has been reported to evaluate renal perfusion and ischemia (6). For example, blood oxygen level-dependent MRI (BOLD-MRI), which reflects changes in tissue oxygenation, was considered to have the potential to identify functionally reversible kidney in patients with renovascular disease (7). In addition, the potential utility of diffusion-weighted MRI (DW-MRI) and the application of the apparent diffusion coefficient (ADC), which is a parameter that quantifies the magnitude of water diffusion in DW-MRI (8), in the assessment of kidney diseases involving renal ischemia and fibrosis has been reported (9-12). Previously, we reported a case of renal artery stenosis in which DW-MRI detected the causative renal ischemic lesion (13, 14). This case also suggests the utility

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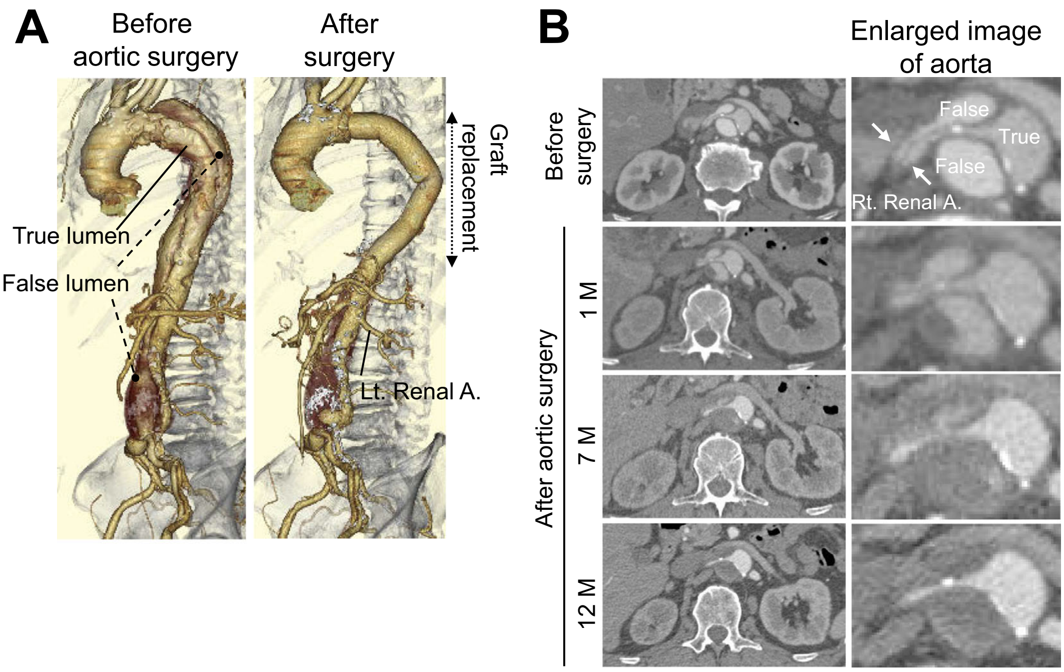

Figure 1. Progressive thrombosis in residual aortic dissection caused right renal artery stenosis in the postoperative period. (A) Three-dimensional computed tomography (CT) angiography images of the aorta before and after aortic surgery. (B) Postoperative change in the right renal artery after aortic surgery. Enhanced CT demonstrated the development of thrombotic change in the false lumen after surgery.

of DW-MRI for evaluating renal artery stenosis-related renal ischemia. However, whether the findings of DW-MRI in the affected kidney with stenosis are reversible and whether the change is normalized by revascularization have not been reported. We herein present a case of renal artery stenosis caused by gradual thrombosis in a patient with residual chronic aortic dissection, in which DW-MRI showed a decreased ADC value in the affected kidney. In this case, a favorable recovery of renal perfusion and the kidney function was achieved after angioplasty, and the decreased ADC value in the affected kidney was normalized after the restoration of the renal blood flow by angioplasty. The present case indicates that the findings of DW-MRI in cases of renal ischemia may be reversible after the resolution of ischemia and that DW-MRI can monitor the resolution of renal ischemia after angioplasty.

Case Report

A 63-year-old man, with a history of hypertension and dyslipidemia from 45 years of a age and a smoking history (20 cigarettes per day for 40 years), presented with DeBakey IIIb acute aortic dissection that affected the distal aortic arch to the left external iliac artery. An intimal tear was identified at the distal aortic arch. Conservative treatment was initially performed; however, over a 10-year period, the diameter of the dissected aorta gradually enlarged from 30 to 56 mm at the distal arch (Fig. 1A). Thus, at 73 years of age, he underwent descending thoracic aortic replacement surgery with a prosthetic graft that covered up to the celiac artery (Fig. 1A). Upon discharge after surgery, his laboratory results were as follows: serum creatinine, 0.7 mg/dL; estimated glomerular filtration rate (eGFR), 70 mL/min/1.73 m^2; and blood pressure, 120/60 mmHg. He was also prescribed the following antihypertensive medications: bisoprolol (2.5 mg, daily), ormesaltan (40 mg, daily), and amlodipine (10 mg, daily). The right renal artery had been perfused from both the false lumen and the true lumen of the dissected aorta before aortic surgery. However, at 1 year after surgery, excluding the original intimal tear, contrast-enhanced computed tomography (CT) demonstrated that progressive thrombosis of the false lumen had blocked the right renal perfusion from the false lumen, and that the thrombosed false lumen compressed the true lumen of the right renal artery (Fig. 1B). Concurrently, the serum creatinine level gradually increased to 1.6 mg/dL, and eGFR decreased to 35 mL/min/1.73 m^2 (Fig. 2A). A ^{99m}Tc-DTPA renogram showed severe right kidney dysfunction (Fig. 2B). In addition, we evaluated the kidney by DW-MRI using a 3T MR scanner (Achieva dStream, Philips Medical Systems, Best, the Netherlands) with 32ch ds-Torso and 32ch posterior coils. DW-MRI, with b values of 0 and 800 sec/mm^2, demonstrated decreased ADC in the right kidney parenchyma, indicating restricted water diffusion resulting from ischemic change of the kidney (Fig. 3). Collectively, we diagnosed him with ischemic nephropathy due to a right renal artery stenosis caused by gradual thrombosis in the residual aortic dissection. We performed transluminal angioplasty to

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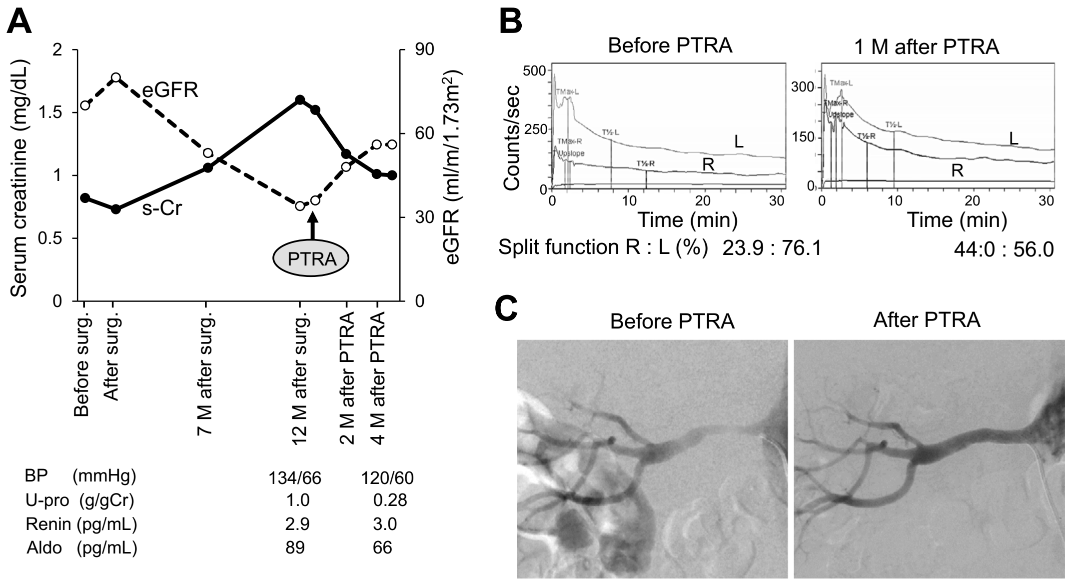

Figure 2. The renal function before and after PTRA treatment. (A) The clinical course. PTRA: percutaneous transluminal renal angioplasty, renin: active renin concentration, aldo: aldosterone, U-pro: urinary protein, eGFR: estimated glomerular filtration rate. (B) ^{99m}Tc-DTPA renograms obtained before and after PTRA. L: light kidney, R: right kidney. (C) Right renal artery angiography before and after PTRA.

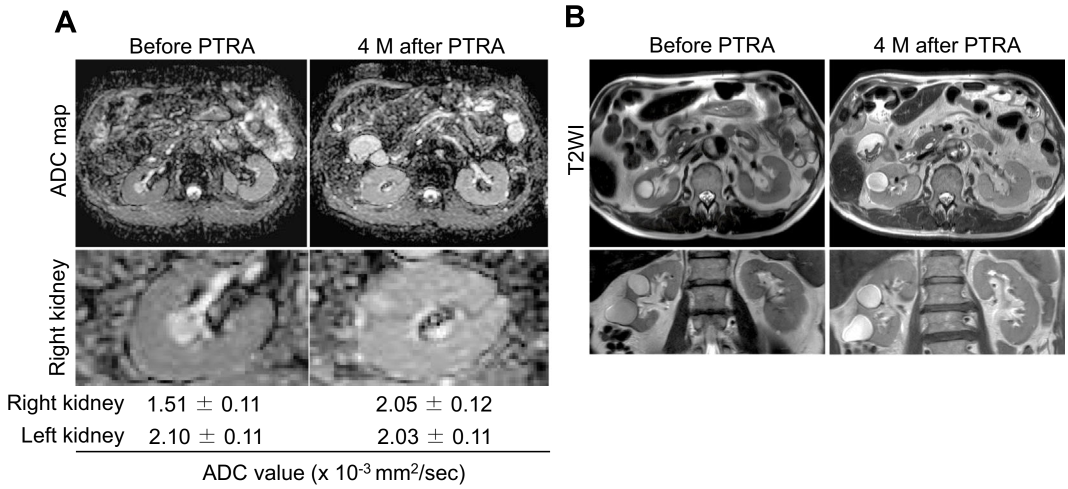

Figure 3. Apparent diffusion coefficient (ADC) mapping of the kidney on diffusion-weighted magnetic resonance imaging. (A) The ADC map. Lower panels show the right kidney. The ADC value was obtained from a cross-sectional image at the middle level of each kidney (mean±SD). P<0.05 between the ADC value of the right kidney before PTRA and that at 4 months after PTRA (*t-test*). (B) A T2-weighted image.

restore the perfusion of the affected right kidney. After balloon dilatation, two stents were replaced in the stenotic lesion (Fig. 2C). At two months after the treatment, his renal function improved with a serum creatinine level of 1.17 mg/dL and an eGFR of 48 mL/min/1.73 m^2, and a renogram showed the improvement of the function of the treated right kidney (Fig. 2A, B). At four months after treatment, his renal function was further improved, with a serum creatinine level of 1.01 mg/dL and an eGFR of 56 mL/min/1.73 m^2, with slight enlargement of the treated kidney (Fig. 3). In addition, DW-MRI demonstrated that the decreased ADC in the right kidney before angioplasty was significantly improved from 1.51×10^{-3} to 2.05×10^{-3} mm^2/sec, which was comparable to that in the left kidney, indicating the resolution of the renal ischemia (Fig. 3).

Discussion

In the present case, during the chronic course of the postoperative distal aortic residual dissection, thrombosis in the false lumen of the renal artery, which developed over long time course, caused renal ischemia and consequent renal dysfunction. Angioplasty with stenting, which restored the blood flow, resulted in the recovery of the renal function. We showed that the ADC on DW-MRI was effective for evaluating the renal artery stenosis-related renal ischemia and the ischemic findings on DW-MRI were normalized after the resolution of renal ischemia by angioplasty. This case indicates that DW-MRI findings of renal ischemia can improve after the resolution of ischemia and that DW-MRI can be used to monitor the resolution of renal ischemia after angioplasty. Unlike contrast-enhanced CT and gadolinium-enhanced MRI, DW-MRI does not require the use of any contrast agents, which are nephrotoxic, and is therefore beneficial for patients with renal dysfunction. Thus, DW-MRI may be valuable for evaluating the therapeutic effects of angioplasty as well as kidney ischemia in patients with renovascular disease.

We revealed that a decreased ADC of the ischemic kidney on DW-MRI normalized after the restoration of the renal blood flow. The ADC, which depends on the impediment of the free diffusion of water molecules, is used to evaluate pathological tissue conditions, including stroke and cancer (15). In this case, we performed DW-MRI and ADC mapping with *b* values of 0 and 800 sec/mm^2. Although *b* values of 0 and 1,000 sec/mm^2 are generally used for brain imaging, the setting is not recommended for abdominal organs because of the signal-to-noise ratio in the tissue region (16). ADC is decreased in the presence of the following factors: i) cellular edema, ii) increased cell density, and iii) interstitial fibrosis (8, 15). Renal perfusion, as well as water molecule handling, can induce changes in the ADC, which is calculated from parameters including a *b* value of 0 sec/mm^2 (17). In patients with chronic kidney disease, the decreased renal ADC is considered to be mainly caused by renal interstitial fibrosis (12). However, the improvement of fibrosis is not a plausible explanation for the normalization of the decreased ADC after angioplasty, because renal interstitial fibrosis is generally considered an irreversible pathological change. Thus, the reversible decreased ADC in the affected kidney may be attributed to decreased renal reperfusion and/or cellular edema induced by parenchymal inflammation, which can be caused by renovascular disease (18). The improvement of renal perfusion and renal inflammation after angioplasty might also be involved in the normalization of the ADC. The improvement of renal parenchymal perfusion was also demonstrated by the increased size of the treated kidney after angioplasty. Although previous studies have reported decreased ADC values in the ischemic kidney, to our knowledge, this is the first study to demonstrate that the resolution of renal ischemia normalized the ADC in the treated kidney. However, the timing of normalization of the decreased ADC after angioplasty remains unknown because post-angioplasty MRI was only performed at 4 months after treatment, when the ADC value had already normalized. Future research should therefore assess the timing at which the renal ischemia on DW-MRI normalizes following the restoration of the renal blood flow.

Renal ischemia is a frequent complication of aortic dissection affecting the renal artery in both the acute and chronic phases (19). In such situations, performing endovascular intervention at an optimal timing is a therapeutic choice to preserve the renal function (20, 21). In the present case, because renal ischemia caused by the postoperative thrombotic change in the false lumen was responsible for the decline in the renal function, the renal function effectively recovered following the revascularization of the stenotic lesion. Thus, when the renal function progressively declines in the course of chronic aortic dissection, clinicians should evaluate the development of renal artery stenosis and new renal ischemia using appropriate modalities, such as DW-MRI.

In conclusion, the present case indicates the benefit of using DW-MRI and the ADC to detect renal artery stenosis-related renal ischemia and to evaluate the therapeutic efficacy of angioplasty; however, it should be noted that this was only a single case report. Further studies are needed to more definitively elucidate the efficacy of DW-MRI in evaluating renal artery stenosis-related renal ischemia.

The patient provided his informed consent. All procedures were performed in accordance with the Declaration of Helsinki.

The authors state that they have no Conflict of Interest (COI).

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