In Vivo Intravascular Ultrasound Imaging of Fibromuscular Dysplastic Region and Intravascular Pressure Gradient-Guided Percutaneous Transluminal Renal Angioplasty

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Abstract

Fibromuscular dysplasia (FMD) is one of the etiologies of renal artery stenosis (RAS) and secondary hypertension. Balloon angioplasty has emerged as the mainstay of treatment because patients with FMD usually show substantial clinical and anatomic response to renal angioplasty without stenting. We report a 21-year-old male case of FMD-induced RAS treated with intravascular ultrasound- and pressure gradient-guided renal angioplasty. Ultrasonic imaging of the stenotic renal artery clearly visualized adventitial fibrotic band surrounding the negative remodeled renal artery and the accompanied atherosclerotic plaque. The findings suggest that atherosclerotic change can occur in young patients with renal FMD that is basically considered to be *non*atherosclerotic. Pressure gradient measurement is also useful in confirming hemodynamic improvement during angioplasty.

Introduction

Fibromuscular dysplasia (FMD) is one of the causes of renal artery stenosis (RAS), and is generally considered a nonatherosclerotic vascular disease. Although FMD RAS is characterized by angiographic "string of beads" appearance, the typical angiographic morphology is absent in some cases. Also, the optimal endpoint of interventional revascularization for RAS has not been clearly established. Here, we present an interesting case of FMD RAS evaluated by multimodality such as intravascular ultrasound (IVUS), scintigraphy, and intravascular pressure gradient.

Case Report

A 21-year-old man with drug-resistant hypertension was admitted to our institute. Both baseline- and captopril-renoscintigraphy revealed the decrease on the left kidney's glomerular filtration rate (GFR) and captopril-induced additional GFR reduction (Figure 1). A computed tomography, magnetic resonance angiography and renal arteriography (Figures 2 and 3) demonstrated the left RAS that seemed to be accountable for activated renin-aldosterone system (plasma renin activity [PRA, 5.6 ng/ml/hr] and plasma aldosterone concentration [PAC, 233 pg/ml]); thus, he was scheduled to undergo percutaneous transluminal renal angioplasty (PTRA). The distal renal artery and aortic pressures were recorded with a pressure gradient of 70 mmHg (Figure 4). IVUS identified decreased lumen areas and concentric fibrotic band surrounding the stenosis (Figure 3). Also, IVUS visualized that distal part of the stenosis was accompanied with eccentric atherosclerotic plaque. IVUS-derived iMap™ tissue characterization software (Boston Scientific Corp., Natick, MA) recognized the segmental adventitial layer as "fibrotic" hyperplasia. The fibrotic lesion could be easily dilated by 3.0- and 3.5-mm balloons with nominal dilatation pressure. Post-PTRA IVUS revealed an increased lumen area and vessel expansion without any

dissection. The peak-to-peak systolic pressure gradient across the stenosis decreased from 70 mmHg to 10 mmHg. Post-PTRA renoscintigraphy showed the improvement on the GFR, and his activated renin-aldosterone system was promptly normalized (PRA, 0.3 ng/ml/hr; PAC, 18.2 pg/ml).

Discussion

FMD is generally considered a nonatherosclerotic vascular disease that affects the renal and internal carotid arteries commonly. Renal FMD occurs in the middle or distal arterial segments in younger patients with few cardiovascular risk factors, while atherosclerotic RAS typically occurs at the ostium and proximal portions in older patients with multiple risks. In the current case, FMD was easily presumed as a primary cause of RAS from the anatomical and clinical features, however, typical ”string of beads” appearance was not observed on the angiogram. Unlike common medial FMD, adventitial FMD was reported to be very rare and may have a focal stenotic appearance.[1] IVUS imaging of the stenotic renal artery clearly visualized adventitial fibrotic band surrounding the negative remodeled renal artery and the accompanied atherosclerotic plaque, suggesting that atherosclerotic change can occur in young patients with renal FMD that has been basically considered to be *non*atherosclerotic. Consistent with pathologic study which showed that the fibroplastic lesion was characterized by a dense accumulations of elastic tissue,[2] the dysplastic region was homogeneously fibrotic in grayscale IVUS, and was coded as uniformly fibrotic tissue in iMap™ software as well.

The use of stents for FMD has been reserved as a “bailout” procedure in cases in which there are suboptimal results with balloon angioplasty or in which renal artery dissection occurs, because patients with FMD usually show substantial clinical and anatomic response to PTRA without stenting.[3] Especially in the current young case, renal stenting, that necessitates indefinite

aspirin intake, should be avoided to the extent possible. In atherosclerotic RAS, a systolic pressure gradient of >20 mmHg may more accurately detect a clinically significant stenosis.[4] In the current case, the pressure gradient reduction from 70 mmHg to 10 mmHg was associated with the improvement of renal blood flow and normalization of renin-aldosterone system.

Taken together, the combination use of IVUS and intravascular pressure gradient provides us decision-making safety (absence of post-PTRA renal artery perforation/dissection by IVUS) and efficacy (post-PTRA lumen enlargement by IVUS and hemodynamic improvement by intravascular pressure gradient) information during PTRA.

Conclusion

In conclusion, such multimodality work-up could be useful for etiological evaluation in patients with RAS, and might lead to optimal strategy in PTRA for RAS.

Disclosures

None.

Acknowledgment

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Legends to Figures

Figure 1. Baseline- and captopril-renoscintigraphy with Tc-99m diethylene triamine penta-acetic acid (DTPA). **(A)** Before percutaneous transluminal renal angioplasty (PTRA), baseline-99mTc-DTPA renoscintigraphy demonstrated the decrease on the left kidney's glomerular filtration rate (GFR, 22.2 ml/min). Captopril-99mTc-DTPA renoscintigraphy showed that GFR of the left kidney was lowered than that of the control (captopril-induced reduction rate [CRR, 17.4%], which was calculated from the renal uptake before [22.2 ml/min] and after [18.4 ml/min] captopril), while GFR of the right kidney increased by captopril loading. **(B)** Post-PTRA renoscintigraphy showed the improvement on the left kidney's GFR and CRR (2.2% from 17.4% at pre-PTRA)

Figure 2. Noninvasive morphological evaluation of renal artery stenosis. **(A)** A computed tomography angiography visualized tandem lesion at middle segment of the left renal artery. Note the location of stenosis and absence of atherosclerotic change such as arterial wall irregularity and calcification. **(B)** A magnetic resonance angiography demonstrated the severe stenosis at middle to distal segment of left renal artery as well. **(C)** The left kidney was mildly atrophic compared with right kidney.

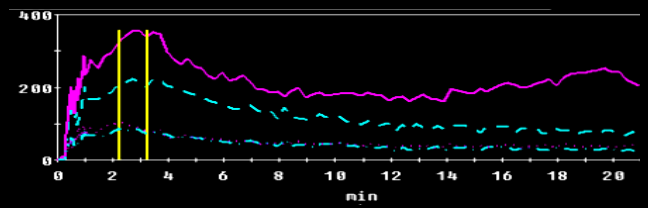
Figure 3. The pre- and post-PTRA selective left renal arteriogram (top and bottom) and serial grayscale IVUS and IVUS-derived tissue component of fibromuscular dysplastic region. Consistent with computed tomography and magnetic resonance angiography, pre-percutaneous transluminal renal angioplasty (PTRA) selective left renal arteriogram (on the top) showed tandem lesion at middle segment of left renal artery. **(A)** At proximal portion of the stenotic

lesion, grayscale intravascular ultrasound (IVUS) visualized severely negative remodeled renal artery and thick fibrotic band surrounding the stenosis. The region was fibrotic and appeared to involve the adventitia. Note the absence of atherosclerotic plaque at the segment. **(A')** The cross-sectional IVUS panel corresponds to pre-PTRA cross-sectional IVUS image "A." The negative remodeled renal artery was dramatically expanded by balloon angioplasty without any renal artery dissection. Note the small renal vein at 9-10 o'clock on the pre- and post-PTRA IVUS images that corresponds to the same small renal vein on the IVUS images. **(B)** At distal portion of the stenotic lesion, grayscale IVUS identified decreased lumen areas and concentric fibrotic band surrounding the stenosis as well as the proximal portion. Unlike the proximal segment, here eccentric atherosclerotic plaque was accompanied with fibromuscular dysplasia at 1-6 o'clock. Newly developed IVUS-based tissue characterization software (iMap™) demonstrates the ability to characterize coronary plaque tissue using an IVUS + radiofrequency system. Using 40MHz mechanical IVUS transducer, iMap™ analysis coded tissue as light-green (fibrotic), yellow (lipidic), pink (necrotic), and light-blue (calcified). The iMap™ tissue characterization software recognized both the atherosclerotic plaque (left panel of (B)) and the segmental adventitial layer (right panel of (B)) as "fibrotic." It is also worth noting that the FMD-associated atherosclerotic plaque was not highly atherosclerotic, such as calcified and necrotic plaque. **(B')** The cross-sectional IVUS panel corresponds to pre-PTRA cross-sectional IVUS image "B." The fibromuscular dysplastic region was successfully dilated by balloon angioplasty without any dissection. Note the small renal vein at 10-11 o'clock on the pre- and post-PTRA IVUS images that corresponds to the same small renal vein on the IVUS images.

Figure 4. Pre- and post-PTRA PressureWire measurement depicting the phasic and mean

proximal renal artery pressure, phasic and mean distal renal artery pressure, and the mean distal to proximal artery pressure ratio. **(A)** Using a PressureWire™ Certus (St. Jude Medical, St. Paul, MN), the distal renal artery and aortic pressures were recorded with a pressure gradient of 70 mmHg. **(B)** After successful percutaneous transluminal renal angioplasty, the distal renal artery to proximal renal artery peak-to-peak systolic gradient across the stenosis decreased to approximately 10 mmHg.

Kidney	Left	Right
GFR	22.23	36.34



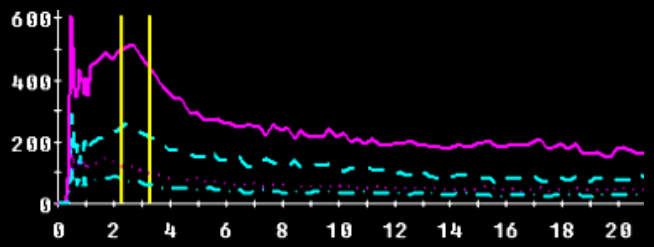
Captopril (-)

Kidney	Left	Right
GFR	18.36	40.38

Captopril (+)

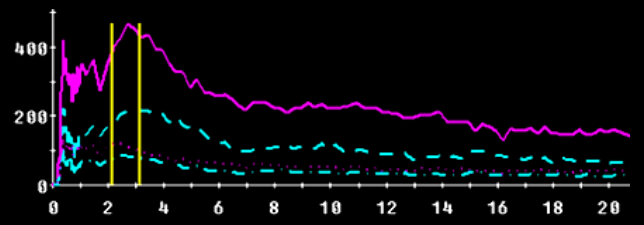
A. Pre-PTRA

Kidney	Left	Right
GFR	17.8	36.72



Captopril (-)

Kidney	Left	Right
GFR	17.43	37.24



Captopril (+)

B. Post-PTRA

Figure 1

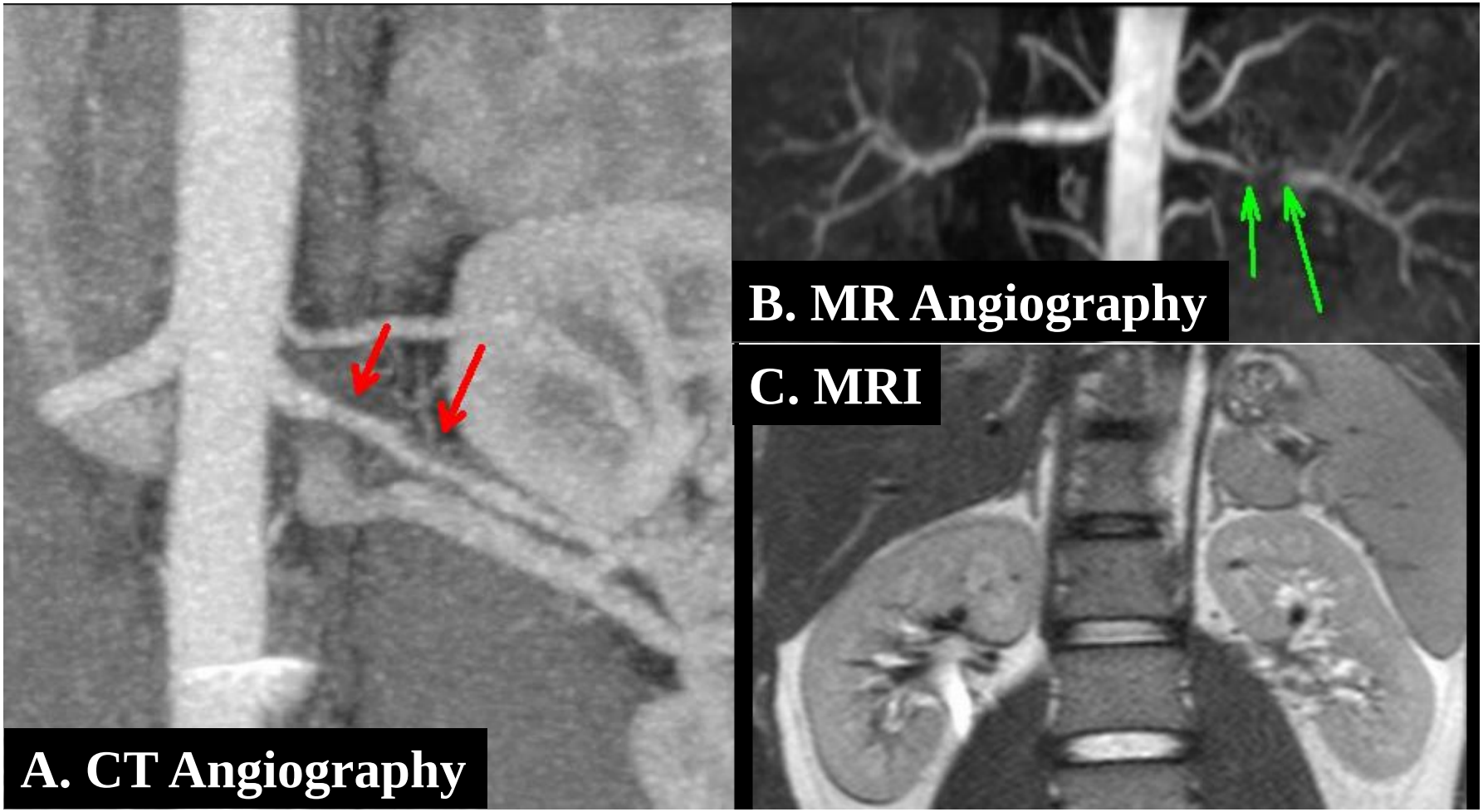


Figure 2

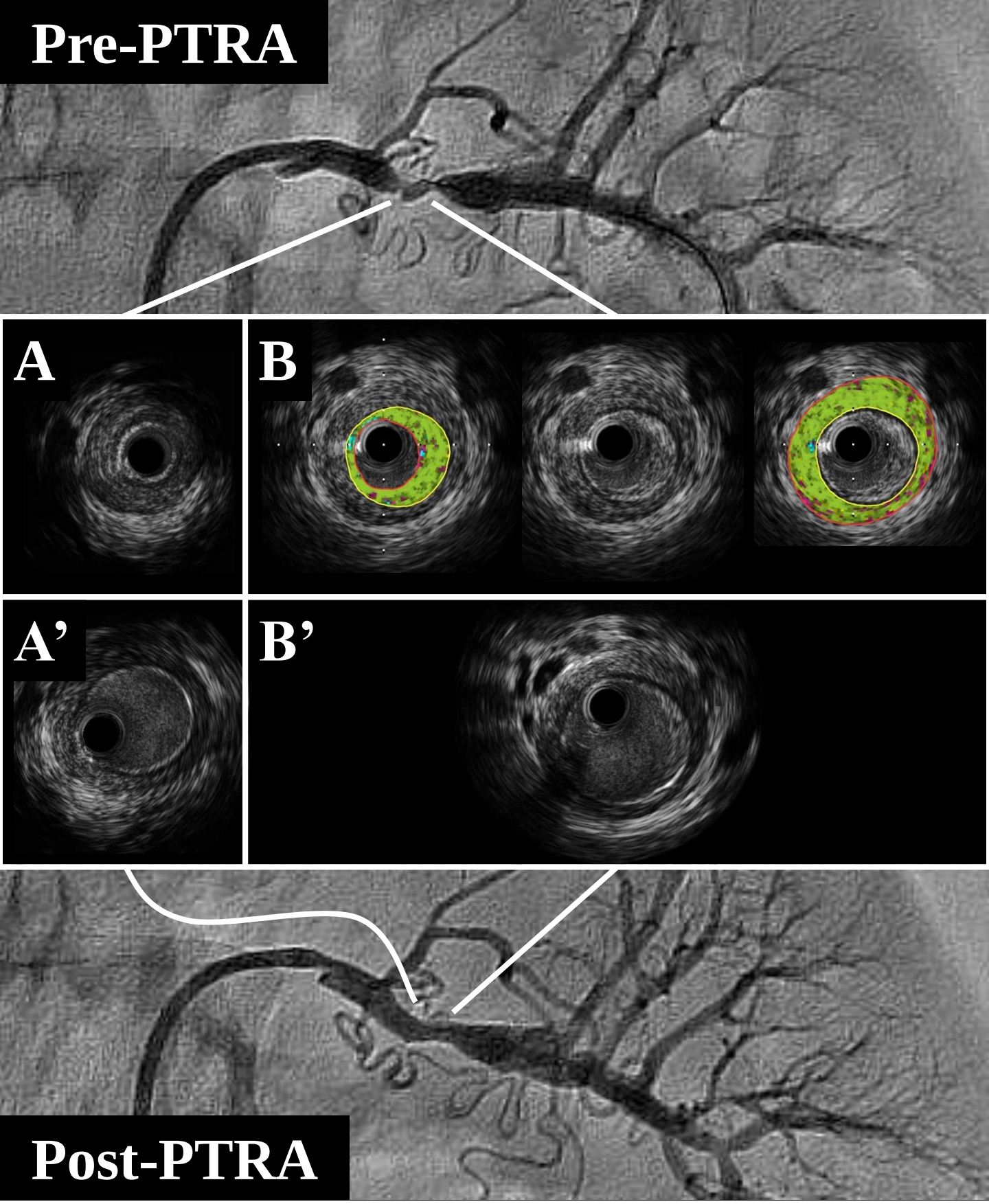
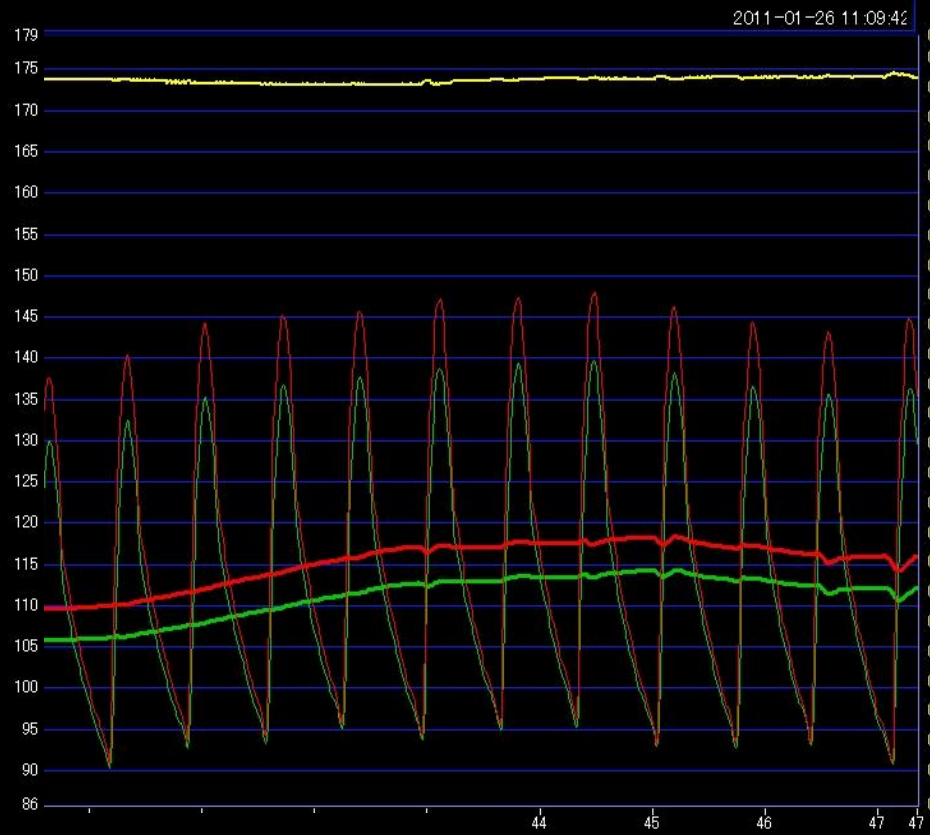


Figure 3

A. Pre-PTRA



B. Post-PTRA

Phasic Proximal Renal Artery Pressure

Mean Proximal Renal Artery Pressure

Mean Distal to Proximal Artery Pressure Ratio

Phasic Distal Renal Artery Pressure

Mean Distal Renal Artery Pressure

Figure 4