Clinical Case Report

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Utilizing flat-panel detector parenchymal blood volume imaging (FD-PBV) for quantitative kidney perfusion analysis during the process of percutaneous transluminal renal angioplasty (PTRA)

A case report

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Abstract

Rationale: Traditional digital subtraction angiography (DSA) provides lumen morphology of renal artery as indicators for vascular patency in patients with renal artery stenosis (RAS). It, however, lacks hemodynamic information toward target kidney. To solve this shortcoming, a novel technique, flat-panel detector parenchymal blood volume imaging (FD-PBV), is introduced, which is able to evaluate hemodynamic changes of target kidney intraoperatively.

Patients concerns: A 77-year-old female presented with hypertension, intermittent dizziness, nausea, and fatigue.

Diagnoses: Ninety-nine percent stenosis of left RAS was found.

Interventions: Percutaneous transluminal renal angioplasty was performed, along with FD-PBV acquisition protocol.

Outcomes: Her symptoms relieved gradually after procedure. Intuitive FD-PBV maps showed her renal perfusion improved remarkably. Quantitative analysis of FD-PBV showed her kidney volume was 47.02 and 75.61 cm^3 with average density of contrast medium (CM) 58.1 HU and 311.5 HU before and after stenting. Follow-up at 6 months showed patency of the stent and stable kidney blood perfusion.

Lessons: FD-PBV technique possesses a remarkable value in quantitatively assessing the changes of kidney blood perfusion and can be a useful auxiliary technique for DSA.

Abbreviations: ARAS = atherosclerotic renal artery stenosis, CTA = computed tomography angiography, DSA = digital subtraction angiography, DUS = duplex ultrasound, FD-PBV = flat-panel detector parenchymal blood volume, GFR = glomerular filtration rate, MRA = magnetic resonance angiography, PTRA = percutaneous transluminal renal angioplasty, RAS = renal artery stenosis.

Keywords: quantitative kidney perfusion analysis, renal artery stenosis

1. Introduction

Renal artery stenosis (RAS), mostly due to atherosclerosis, results in decreased blood flow and perfusion pressures in the poststenotic kidney, and is recognized as a main cause of secondary hypertension and renal function insufficiency. RAS is a common problem with an approximate 7% prevalence among the elder older than 65 years.[1] The prevalence for patients in risk groups is even higher, reaching 20% in patients with hypertension and diabetes, 25.3% with peripheral vascular disease, 40.8% with end-stage renal failure, and 54.1% with congestive heart failure.[2] Percutaneous transluminal renal angioplasty (PTRA) is one of the standard treatments for RAS.[3] Traditional 2D digital subtraction angiography (DSA) used in PTRA, however, relies strictly on lumen morphology of renal artery, providing little hemodynamic information of target kidney. Herein, we apply a new technique, flat-panel detector parenchymal blood volume imaging (FD-PBV) during PTRA. FD-PBV is a method of post-processing data from flat-panel computed

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tomography (FD-CT). In FD-CT, 1 target kidney of interest is imaged using a rotational acquisition over an angular range of approximately 200°, resulting in a series of 2D projection images, which then are reconstructed to create a 3D volume and be analyzed by FD-PBV intraoperatively. In the end, blood volume images with their quantitative data from FD-PBV show hemodynamic changes such as changes of blood volume and blood perfusion for renal parenchyma, which offers new evaluation indicators for surgeons.

2. Case report

A 77-year-old female patient complained of hypertension with intermittent dizziness, nausea, and fatigue. Her blood pressure reached 180/60 mm Hg, and 5 mg Amlodipine BID (twice a day) lowered it to 130/68 mm Hg. Both DUS and CTA indicated severe left renal arterial stenosis. Chronic kidney insufficiency was also her comorbidity but stable.

The patient was then transferred to the operating room for endovascular treatment according to the PTRA procedures and FD-PBV protocol. Diagnostic DSA (Fig. 1A) demonstrated 99% stenosis of the ostium of the left renal artery. Pre-operative FD-PBV was performed, showing almost no blood perfusion (Fig. 1C, D), with an average density of contrast agent 58.1 HU and kidney volume 47.02 cm^3. Revascularization was achieved by stent deployment (Fig. 1B). Immediate postoperative FD-PBV measurement depicted significant improvement of blood perfusion with average density of contrast agent 311.5 HU and kidney volume 75.61 cm^3, increasing 436.1% and 60.8%, respectively (Fig. 1E, F). Follow-up FD-PBV performed 6 months after the intervention showed stable blood perfusion of the target kidney (Fig. 1G, H) with average density of contrast agent 325.1 HU and kidney volume 74.24 cm^3. Also, her blood pressure decreased to normal range without antihypertensive drugs and her kidney function remained stable.

3. Endovascular procedures

3.1. Treatment strategy

The case presented above is the first case in the clinical trial (NCT03252639, clinicaltrials.gov) approved by The Ethics Committee of our hospital. Patients diagnosed of more than 80% RAS via duplex ultrasound (DUS), computed tomography angiography (CTA), or magnetic resonance angiography (MRA) were treated with PTRA with the procedures as follows. An appropriate introducer sheath was anterogradely inserted into the common femoral artery. Then, the advanced guiding catheter and wire guide unit was inserted into the ostium of the target renal artery through fluoro assistance. A series of 2D-DSA acquisitions were then performed to clearly show the lesion region. After that, a preoperative FD-PBV acquisition was run to generate perfusion analysis. The contrast-enhanced dataset was acquired following intra-arterial injection of radiographic contrast material (Visipaque 320; GE Healthcare, Milwaukee, WI) using a power injector. During the revascularization process, balloon angioplasty, stenting, or both were performed according to the lesion. If a stent was implanted, patency of the arteries and stent deployment would be verified by traditional 2D-DSA images. After the treatment, a postoperative FD-PBV acquisition was once again performed for perfusion improvement assessment. In the end, the 6F sheath was removed and a vascular closure device was used for hemostasis.

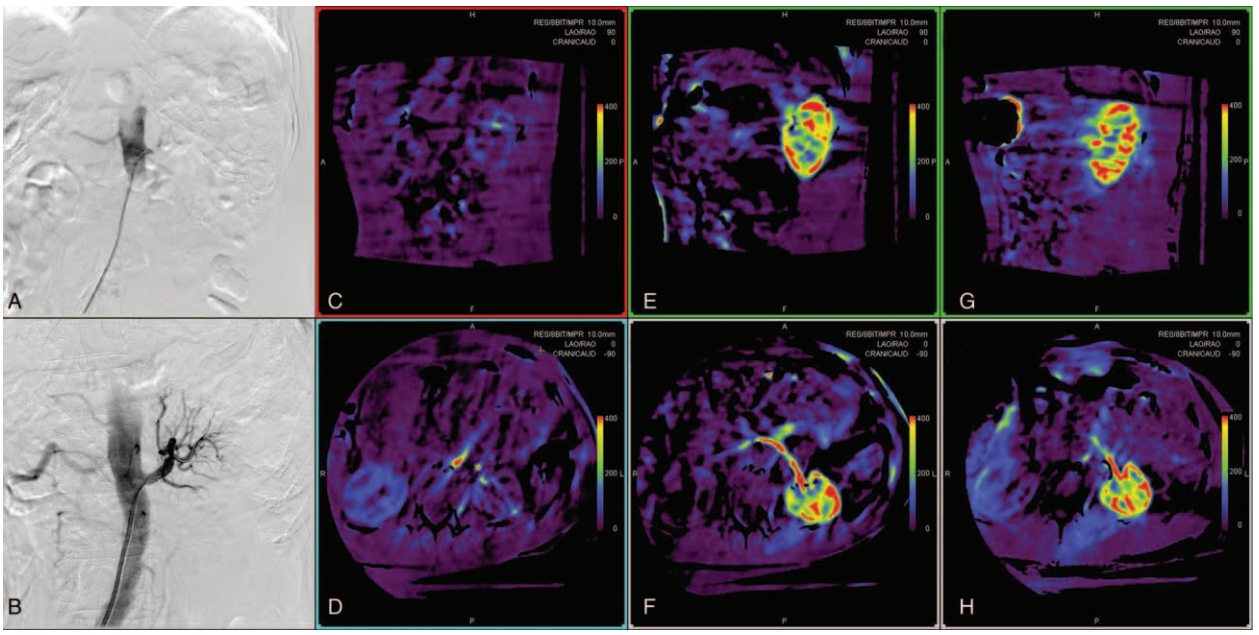

Figure 1. (A) Diagnostic DSA confirmed sever stenosis of the ostium of the left renal artery. (B) Revascularization was achieved by stent placement. (C–F) Comparison of parenchymal blood volume and density of contrast agent between the pre- and poststentic target kidney. Average density of contrast agent was 58.1 HU and kidney volume was 47.02 cm^3 before stent implantation. Immediate postinterventional FD-PBV measurement depicted normalization of blood perfusion, with average density of contrast agent 311.5 HU and kidney volume 75.61 cm^3, increasing 436.1% and 60.8%, respectively. (G, H) FD-PBV repeated at 6-month follow-up. Follow-up FD-PBV showed patency of the stent and stable blood perfusion of the target kidney, with average density of contrast agent 325.1 HU and kidney volume 74.24 cm^3. DSA = digital subtraction angiography, FD-PBV = flat-panel detector parenchymal blood volume, HU = house unit.

3.2. FD-PBV acquisition and image analysis

FD-PBV acquisition was performed on the flat panel detector angiographic system (Artis zeego; Siemens Healthcare, Forchheim, Germany) with the following imaging parameters: acquisition time 5 seconds; tube voltage 70 kV; matrix 616 × 480; flat panel detector size 30 cm × 40 cm; rotational angle 200°; 0.5°/frame; 400 frames in total; dose 0.36 μGy/frame. The acquisition protocol was on the basis of a 5-second 3D-DSA acquisition with 2 rotational runs, namely mask run and fill run. A mask run would start before the contrast medium injection. After the return of the C-arm to the starting position, automatic fluoroscopy was performed with the beginning of the contrast medium injection. A fill run would then be manually started by the operator the moment opacification of kidney parenchyma was seen, which was considered as a surrogate marker for steady-state filling for renal parenchyma. Twenty milliliter diluted contrast media (CM) (CM10 mL + Saline10 mL = 20 mL) was injected through a catheter at a rate of 4 mL/s. It should be noted that, in order to obtain the necessary steady-state contrast medium opacification of the kidney parenchyma for PBV data acquisition, the catheter should be put at the ostium of the renal artery in the same place and patient should hold a deep breath to eliminate disturbances of artifact. Acquired images were automatically transferred to the post-processing workstation (syngo X-Workplace; Siemens Healthcare GmbH, Forchheim, Germany) for PBV reconstruction. Postprocessing of FD-PBV data was performed by using commercial available imaging software (syngo Neuro PBV; Siemens AG Healthcare Sector, Germany) installed on the dedicated workstation. Images were visually evaluated by at least 2 doctors in consensus.

4. Discussion

To the best of our knowledge, this is the first report that utilized FD-PBV technique to quantitatively assess the hemodynamic changes in the process of endovascular treatment for RAS. Evaluation of kidney perfusion as well as renal function after PTRA is of great significance in endovascular treatment. None of the main diagnostic imaging techniques, such as DUS, CTA, or MRA, is able to implement real-time quantitative evaluation during the process. They are more suitable in selecting patients who may benefit from the intervention. Although capable of directly providing the improvement of RAS via lumen morphology, DSA lacks information concerning hemodynamic alterations of target kidney, which could be more intuitive and precise.[4] Compared with all imaging modalities mentioned above, FD-PBV technique owns its superiorities. It is competent in deriving real-time quantitative information during the treatment and providing information of hemodynamic changes in pseudocolor images and through precise data within minutes after the data acquisition, which facilitates doctors in evaluating the outcomes of PTRA and predicting the prognosis.

FD-PBV technique was first introduced to treat patients with acute symptoms of cerebral ischemia in 2010 with the conclusion that vascular images and cerebral blood volume measurements provided by this technique were comparable with those by using standard CT techniques.[5] Shortly after this, further studies suggested baseline pre-intervention cerebral blood volume as a predictor of outcomes in patients undergoing intra-arterial stroke therapies,[6] and that this technique may substitute for multisection CT imaging to some extent in selected patients with acute stroke for the sake of saving time.[7] Apart from brain, new studies demonstrate that FD-PBV technique is useful in post-treatment assessment of transarterial chemoembolization in hepatocellular carcinoma with predictive potentials in prognosis[8] and detecting early functional response to transpulmonary chemoembolization.[9] Our preliminary data show that it could provide quantitatively assessment toward hemodynamic changes of kidney blood perfusion before and after endovascular treatment for RAS. Thus, FD-PBV could be a useful auxiliary technique for DSA.

To conclude, the FD-PBV technique possesses a remarkable value in quantitatively assessing hemodynamic changes of kidney blood perfusion before and after endovascular treatment for RAS and can be a useful auxiliary technique for DSA. Studies with more patients are needed for further conclusions.

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