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Minimally invasive percutaneous transluminal renal artery stenting

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ABSTRACT

Background: Minimally invasive percutaneous transluminal renal artery stenting (MIPTRS) is a method that prevents complications to the greatest extent possible. The present study aimed to investigate the safety and efficacy of MIPTRS performed in cases of renal artery stenosis with an estimated glomerular filtration rate (eGFR) ≤ 45 mL/min.
Methods: Cases of patients who underwent MIPTRS at our hospital between December 2010 and June 2015 in whom eGFR was ≤45 mL/min were retrospectively analysed. MIPTRS was performed as follows: 1) using a 4Fr sheathless guiding catheter in a trans-radial approach and 2) using a guiding catheter non-touch technique. The amount of contrast agent used was maintained at ≤10 mL with 3) carbon dioxide enhancement and 4) intravascular ultrasound guide stenting, and 5) a distal protection device was used.
Results: MIPTRS was performed in 22 patients (32 lesions). The pre-MIPTRS creatinine level and eGFR were 2.01 ± 0.88 mg/dL and 29.2 ± 9.0 mL/min/1.73 m^2, respectively. On postoperative day 2, they were 1.78 ± 0.73 mg/dL and 35.1 ± 12.3 mL/min/1.73 m^2; at 1 month after the procedure, they were 1.80 ± 0.74 mg/dL and 33.3 ± 12.3 mL/min/1.73 m^2. Creatinine level did not change significantly, but eGFR was significantly elevated after versus before the procedure, both 2 days later ($p < 0.01$) and 1 month later ($p < 0.05$).
Conclusion: The results of this study demonstrated the usefulness of MIPTRS for protecting renal function. This method can be safely used in patients with decreased renal function.

1. Background

The American College of Cardiology and American Heart Association (ACC/AHA) guidelines [1] set forth the indications for percutaneous transluminal renal artery stenting (PTRS). PTRS is indicated in cases of unilateral and bilateral renal artery stenosis (RAS) presenting with heart failure or unstable angina; PTRS is also indicated in cases of bilateral RAS with refractory hypertension or chronic renal dysfunction. PTRS is not indicated in cases of asymptomatic bilateral RAS or unilateral RAS involving chronic renal dysfunction. However, PTRS itself is often especially difficult in cases with advanced chronic renal dysfunction. Careful attention must be paid to the indications for PTRS since the procedure can cause complications. The results of the CORAL trial [2] reported that the incidence of perioperative complications from stenting was dissection in 2.2%, branch vessel occlusion in 1.2%, angiographically evident distal embolization in 1.2%, wire perforation in 0.2%, and vessel rupture in 0.2%; cases with a postoperative decrease in estimated glomerular filtration rate (eGFR) ≤ 30% were not statistically different from a medical therapy group, but 14.8% reportedly had procedure-related complications.

Postoperative renal function can also be adversely affected by procedural factors such as contrast medium-induced nephropathy (CMN) or distal embolization, both of which are complications of PTRS. Methods for preventing these factors that adversely affect renal function include using distal protection devices [3,4] or reducing the amount of contrast agent used by also using carbon dioxide enhancement [5], but these approaches have not been proven to be useful.

Minimally-invasive PTRS (MIPTRS), which we propose in the present study, is a method for preventing complications that can arise because of the PTRS procedure, such as distal embolization, cholesterol crystal embolism, and CMN. In this technique, carbon dioxide enhancement [5] and intravascular ultrasound (IVUS) [6] are used to reduce the amount of contrast agent used, and an attempt is made to prevent complications by downsizing catheter size and using a distal protection device.

The purpose of the present study is to perform MIPTRS on RAS cases with eGFR at 45 mL/min/1.73 m^2 or lower, and to investigate its safety and efficacy.

2. Methods

2.1. Subjects

Patients who underwent MIPTRS for the treatment of atherosclerotic renal artery stenosis (ARAS) at our hospital between December 2010 and June 2015 were subjects of

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this retrospective survey. Among a total of 50 PTRS cases, 27 had an eGFR <45 mL/min/1.73 m^2; 22 of these cases underwent MIPTRS. Clinical indications for PTRS are drug-resistant hypertension, renal preservation due to renal dysfunction, and/or a history of heart failure. Duplex ultrasonography was performed before MIPTRS. Stenosis with a peak systolic velocity (PSV) ≥ 200 cm/s or that is ≥50% on magnetic resonance angiography (MRA) was considered a target lesion. Written consent was obtained from all patients prior to MIPTRS. The present study was certified by the Bioethics Committee of St. Marianna University School of Medicine.

2.2. Duplex ultrasonography

All subjects underwent duplex ultrasonography of the renal arteries before and 6 months after MIPTRS. Pulse doppler waveforms of the aorta near the renal arteries, renal artery stenosis area, and inside the renal parenchyma were displayed, and the fastest flow rate during the systolic phase was measured as the PSV, while the flow rate in the end-diastole was measured as the end-diastolic velocity (EDV). The renal/aortic ratio was calculated by renal artery stenosis area PSV/aorta PSV, while the resistance index (RI) was calculated as PSV – EDV / PSV in the renal parenchyma.

2.3. Magnetic resonance angiography or computed tomography angiography

The patients with suspected RAS identified by duplex ultrasonography underwent magnetic resonance angiography (MRA) or computed tomography angiography (CTA) to assess the severity of the stenosis in the renal arteries and atherosclerosis in the renal arterial branches. All MRA examinations were performed using a 1.5 T superconducting magnetic resonance imaging scanner (Achieva 3.0 T Nova Dual; Philips, Tokyo, Japan) under the following settings: sense body coil; field of view, 300; matrix, 256 × 256; 78.54 scan percent; and 90 slices. Stenosis >50% was visually confirmed as significant stenosis. Multidetector CTA was performed by a 64-slice CT scanner (Aquilion 64; Toshiba Medical Systems, Odawara, Japan), while 600 mg I/kg of nonionic iodinated contrast material containing iohexol 300 mg I/mL (OMNIPAQUE 300; Daiichi-Sankyo, Tokyo, Japan) was injected at a rate of 2.5–5.0 mL/s using a power injector (Dualshot, Nemoto, Tokyo, Japan). Stenosis >50% was visually confirmed as significant stenosis.

2.4. MIPTRS technique

2.4.1. Trans-radial 4Fr Sheathless guiding catheter approach

A 4Fr sheath is inserted into the left radial artery. After a 0.035-inch guide wire is inserted as far as the ascending aorta, an IMA catheter is inserted up to the aortic arch and a 0.035-inch guide wire is guided to the descending aorta and advanced to near the branching of the common iliac artery. The IMA catheter is removed, leaving the guide wire. The 4Fr sheath is also removed and replaced with a 4Fr sheathless guiding catheter (Sheathless PV®; ASAHI INTECC J-sales, INC, Tokyo, Japan). Carefully passing over the aortic arch, it is inserted up to the central side of one to two vertebrae from the renal arteries.

The Sheathless PV® has an outer diameter of 2.16 mm (6.5 Fr) and inner lumen of 1.78 mm with a hydrophilic coating that enables smooth insertion even from the radial arteries. Using a lower-profile system is thought to make the procedure less invasive for the blood vessel walls and reduce the risk of atherothrombosis.

2.4.2. Guiding catheter non-touch technique

With the 0.035-inch nitinol hydrophilic guidewire (Radifocus® Guidewire M Standard type; Terumo Medical, NJ, USA) remaining in place, the inner tube of the Sheathless PV® is pulled out and a Y-connector is connected to the catheter end. At this point in time, there is no direct contact between the tip of the guiding catheter and the wall of the aorta to minimize injury. A 0.014-inch polymer jacketed guide wire (Cruse®; ASAHI INTECC J-sales) is inserted into the catheter and insertion into the renal artery is also attempted.

Consulting the pre-procedural MRA makes it easy to ascertain the positional relationships between the branches of the renal arteries and the vertebral bodies. The guiding catheter is brought close to the renal artery where the 0.014-inch guide wire passes through the transit of the renal arteries, and guide wire position is confirmed by carbon dioxide angiography.

2.4.3. Carbon dioxide enhancement

A three-way stopcock is connected to a carbon dioxide gas injector (Gaster®; Gadelius Medical K.K., Tokyo, Japan). A 30-mL syringe is connected to one of the stopcocks of this three-way stopcock and the remaining one is released. CO_2 is fed in until the inside of the syringe is filled with gas. However, air is being mixed inside the syringe, so the three-way stopcock is opened on the released side to discard the gas. It is completely pushed out, and CO_2 is again fed into the syringe. This work is repeated several times to avoid mixing air. Once the inside of the syringe is finally filled with CO_2, the syringe is removed from the three-way stopcock and guided up to the guiding catheter while the tip of the syringe is being pressed with the finger to connect to a three-way stopcock connected to the Y connector. To remove air that is mixed in during this time, 10 mL of gas is passed from the syringe through the three-way stopcock and discarded to the exterior. This concludes the CO_2 preparation; the procedure now transitions to contrast enhancement. Digital subtraction angiography is started with breathing stopped on an exhale; CO_2 is injected, and the injection is stopped once the contrast enhancement reaches the peripheral renal arteries, thus concluding contrast enhancement. Because contrast enhancement is not very clear, a large amount of CO_2 must not be hastily injected. Approximately 10 mL of CO_2 is used in each injection for a maximum of 40 mL of CO_2 in cases of bilateral RAS.

Using contrast enhancement, the transit of the renal arteries is confirmed, as is the insertion of the 0.014-inch guide wire to the correct position. Once it can be confirmed, the guiding catheter is engaged into the renal artery and the 0.035-inch guide wire is pulled out.

2.4.4. IVUS-guided stenting

A Dragonfly® is used as an imaging catheter, and an s5 Imaging System (Volcano Corporation, San Diego, CA, USA) is used as an IVUS system. First, the entire lesion is observed by manual pull back. Next, images are captured on the distal side of the lesion and at the ostium of the renal artery while the imaging core is being confirmed with IVUS images. The Dragonfly® has radiopaque marks at 5-mm intervals, making it possible to measure the approximate lesion length. Lesion stenting and ballooning is performed, with the positional relationship between a marking and a vertebra. Lesions were predilatated with a 4.0-mm semi-compliant balloon catheter in all cases. Stenting is performed to completely cover the lesion, with one stent strut from the ostium being placed to send the stent out into the aorta. Using this technique, stenting is done with the greatest possible reduction, or even total elimination, of contrast agent use. However, if the patient ends up changing their body position, the positional relationship with the marking is also shifted; therefore, the patient must be prompted not to change body position, and it is important that the ballooning and stenting be performed quickly. Even the act of breathing alters the vertical position of the kidneys, so careful attention must be paid during the procedure. Stenting is followed by IVUS observation again to check for stent apposition and proper extension.

2.4.5. Distal protection device

In PTRS, a peripheral embolism is also a cause of worsened renal function. We have used a distal protection device (Filtrap®; Japan Lifeline Co., Ltd., Tokyo, Japan) to provide distal protection. The lumen diameter on the peripheral side of the lesion is measured by IVUS, and a filter that is 1–2 mm or larger is selected. A 0.014-inch guide wire that has already been inserted into the renal artery is used to guide insertion of the Filtrap®. It is not used for the type that has two or more branches immediately after the branching from the aorta. After stenting, the Filtrap® is retrieved by a retrieval catheter. The adhering blood is removed from the recovered filter with gauze, and only the filter part is cut with scissors and placed in formalin solution to fix the recovered debris. Several days later, the filter is deployed and a macrospecimen is prepared and observed macroscopically.

2.4.6. Final angiogram

Once favourable stent extension is confirmed by IVUS, angiography is performed for the first time with a contrast agent. Contrast enhancement is used to check for any complications such as distal embolization or perforation. Iodixanol, a non-ionic isosmotic contrast agent containing 270 mg I/mL (VISIPAQUE® 270; Daiichi-Sankyo), is used for contrast, 4 mL of the contrast agent is injected with an added 2 mL of saline for imaging. Following the entire procedure above makes it possible to finish using only a small amount of contrast agent (4 mL).

2.5. Follow-up observation

Blood pressure measured, blood is collected to measure creatinine, and eGFR is calculated before, 2 days after, 1 month after, and 6 months after MIPTRS. We also monitored for procedure-related complications such as intraoperative vascular injury, renal artery perforation, or distal embolism as well as postoperative acute renal dysfunction.

2.6. Statistical analysis

Continuous variables are presented as mean ± SD and discrete variables are shown as frequencies and percentages. The paired *t*-test was used to compare continuous data. Statistical significance was noted at $p < 0.05$. Statistical analysis was performed using JMP10 (SAS Institute Inc., Cary, NC, USA).

3. Results

MIPTRS was performed in 22 patients (mean age, 71 ± 11 years [range, 49–85 years]; 19 men) with 32 lesions. There were nine cases of bilateral RAS, five cases of RAS to solitary functional kidney, and eight cases of unilateral RAS. The GFR categories for CKD stage were one case of G3a (4.5%), 11 of G3b (50%), seven of G4 (31.8%), and three of G5 (13.6%). Table 1 shows the patient characteristics. In all cases, the eGFR was ≤45 mL/min/1.73 m^2 or lower. The clinical indication for PTRS was heart failure in five cases (22.7%), protecting kidney function in 16 cases (72.7%), and drug-resistant hypertension in one case (4.5%). All patients were administered dual antiplatelet therapy (DAPT) consisting of aspirin 100 mg and clopidogrel 75 mg; three patients (13.6%) also received warfarin for atrial fibrillation. A preoperative renal artery ultrasound was performed in all cases, with a stenotic PSV of 318.2 ± 135.1 cm/s, renal aortic ratio (RAR) of 5.1 ± 5.2, and RI of 0.70 ± 0.12 (Table 2). In three cases, measurement was not

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