RENOVASCULAR HYPERTENSION: CAUSES AND TREATMENT

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Hipertensi Renovaskuler: Penyebab dan Terapi

ABSTRACT

Renovascular hypertension is now a curable disease in most cases by interventional radiological techniques. The authors reviewed diagnostic and therapeutic aspects of renovascular hypertension, focusing on practical points, and introduced several cases of renovascular hypertension, treated by surgery or interventional radiological techniques.

Keywords: Renal artery stenosis, Renovascular hypertension, Renal artery stent placement, Arteriosclerosis, Fibromuscular dysplasia.

ABSTRAK

Hipertensi renovaskuler saat ini merupakan suatu penyakit yang dapat disembuhkan pada sebagian besar kasus menggunakan teknik radiologi intervensi. Penulis mengkaji aspek-aspek diagnostik dan terapeutik dari hipertensi renovaskuler, berfokus pada poin-poin praktis, dan menunjukkan beberapa kasus hipertensi renovaskuler, yang ditangani dengan pembedahan maupun teknik radiologi intervensi.

Kata kunci: Stenosis arteri renalis, Hipertensi renovaskluer, Pemasangan *stent* arteri renalis, Arteriosklerosis, Displasia fibromuskuler

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INTRODUCTION

Most cases of renovascular hypertension are now curable by interventional radiological procedures. The purpose of this article to review causes and treatment of renovascular hypertension, introduce cases of renovascular hypertension treated by surgery or interventional radiological procedures and discuss the method of treatment of renovascular hypertension.

Currently, cases of fibromuscular dysplasia (or hyperplasia) (FMD hereafter) are identified with more frequency than a few decades ago. It is desirable, and expected, that such patients will be treated in the earlier stages of FMD since it is amenable to balloon angioplasty alone.

CAUSES

There are many causes of renovascular hypertension, including arteriosclerotic stenoses of the renal arteries, fibromuscular dysplasia of the renal arteries, neurofibromatosis, extrinsic compression of the renal arteries, aftereffects of renal transplantation and Takayasu's arteritis (Table 1).[1,2,3,4,5,6]

Causes
Arteriosclerosis
Fibromuscular dysplasia
Aortitis syndrome, arteritis (including Takayasu's arteritis)
Renal arteriovenous fistula
Extrinsic compression of renal arteries (from tumor, etc.)
Trauma
Ptosis of the kidney
Congenital stenosis, post-operative stenosis of anastomosis
Neurofibromatosis
Thrombosis, Infarction

Table 1. Causes of Renovascular Hypertension according to Narimatsu and Hiramatsu[1]

Hachiya[6] reported angiographic findings in 50 cases of "pulseless disease" (Takayasu's arteritis, aortitis syndrome) in Japan. He found renal artery stenosis in 32% of cases (16 out of 50 cases). Renovascular hypertension was more frequent in cases of renal artery stenosis when compared with other cases without renal artery stenosis.

Hachiya quoted Nasu's pathological conclusion that pulseless disease was essentially mesarteritis of the aortic arch and major arteries arising from the aorta. It is characterized by a granulomatous or diffuse productive inflammation of the media and adventitia by way of vasa vasorum with secondary juvenile arteriosclerosis. The changes in this disease are not necessarily limited to the aortic arch but spread to the thoracic aorta, abdominal aorta and even to the main pulmonary arteries. The etiology is unknown.

Hiramatsu and his associates[2] analyzed 31 cases of percutaneous transluminal renal angioplasty (PTRA) for renovascular hypertension (RVHT). They categorized RVHT into three groups, which will be described below.

1. Group 1: RVHT with Takayasu's arteritis (5 cases)
2. Group 2: RVHT with atherosclerosis (ASO), (12 cases)
3. Group 3: RVHT with fibromuscular dysplasia (14 cases)

The results of PTRA for RVHT in their cases will be described in the section titled "DISCUSSION".

Liu[7] reviewed aortoarteritis in 244 patients in China. He advocated the term of "aortoarteritis" instead of pulseless disease, Takayasu's arteritis or aortitis syndrome, probably from the pathological nature.

He stated that, in more than three-fourths of 231 cases in their previously reported series, it was the renal arteries that were involved in patients with aortoarteritis. He also stated that aortoarteritis is one of the most common vascular diseases in Asia, including China and Japan.

Among such cases about two-thirds had bilateral renal artery stenosis. In the majority of cases, the orifice and proximal segment were involved. In some cases, the lesion affected the entire length and middle to distal segment of the artery.

Liu commented that the renal artery lesion of aortoarteritis was one of the most important causative processes of renovascular hypertension in China, particularly in female adolescents and young adults. He and his associates performed PTA for renal artery lesions in ten patients. In their preliminary experience in China, the initial dilatation rate of PTA was good, and its long-term result is promising, although he further commented that further evaluation of PTA in the management of RVHT caused by aortoarteritis was needed.

DIAGNOSIS

Arteriosclerosis causes stenosis or occlusion in many arteries in the body. There are many sites of arteriosclerotic lesions from the head to the foot. Those arteries are cerebral, coronary, renal, celiac, superior mesenteric, limb arteries and even the abdominal aorta itself.

The majority of renal artery stenoses due to arteriosclerosis (atheroma) occur at the proximal portions of the renal arteries.

Fibromuscular dysplasia occurs in the middle portions of renal arteries. The details of angiographic findings of intimal, medial and adventitial FMD are

described by Kincaid[3].

According to Kincaid, medial fibromuscular stenosis is by far the most common type, the other two types being comparatively rare. Only two cases of each type (intimal fibrous stenosis and periarterial stenosis) were encountered in their series of 125 cases of fibrous and fibromuscular disease studied angiographically. The angiographic appearance of medial fibromuscular stenosis is usually characteristic, showing a "string of beads" or "sausage chain" image.

Occasionally FMD shows a short-segment stenosis at the middle or distal portions of the renal artery. FMD occasionally involves only a primary or segmental branch. In Kincaid's experience at Mayo Clinic the findings in intimal and periarterial fibrous stenosis are similar to medial fibromuscular stenosis, but consisted of fairly elongated, smooth and concentric stenoses with no suggestion of beading.

Other causes of renovascular hypertension are rare. References to renovascular hypertension due to neurofibroma[4,5] will be briefly introduced.

Neurofibroma is a common benign tumor originating in the peripheral nervous system. It usually appears in subcutaneous tissues, along peripheral nerves and at the neuromedullary junctions.

Cornell and Kirkendall[4] reported a case of neurofibromatosis of the renal artery as an unusual cause of hypertension. A girl with café-au-lait spots had been hypertensive since the age of four. At the age of sixteen, a radioactive renogram showed an abnormal curve on the right. Abdominal aortography and selective right renal arteriography identified two areas of stenosis of the renal artery with striking areas of aneurysmal dilatation. The appearance of the angiogram was somewhat suggestive of FMD. Surgery was performed with resection of the dilated portion and reconstruction by knitted Dacron graft. Pathological examination revealed disorganized fibrous overgrowth of the nerve sheaths of several small nerve trunks in the adventitia of the resected portion of the renal artery, in addition to atheromatous thickening of the intima with areas of calcification. The findings were consistent with plexiform neurofibroma. The surgery did not result in a return to normal blood pressure. Three months after the surgery the right kidney was not functioning. Six months after the initial operation, surgery was again performed and the grafted right renal artery was found to be not patent. Nephrectomy of the right kidney was carried out, which returned the blood pressure to a normal range.

In 1971, Fleming and Miller[5] reported only the 17th case of renovascular hypertension due to neurofibromatosis. Radioisotope renograms and renal schintigram suggested stenosis of the left renal artery in this case of a seven-year-old boy.

Aortography showed proximal stenosis of renal arteries on both sides. Biopsy revealed nerve tissue and ganglia consistent with neurofibroma in the renal artery wall. In their review of the literature they found the involvement of neurofibromas in the celiac axis, superior mesenteric artery and common iliac artery.

The authors surmised that neurofibroma could affect the intima, media or adventitia of the wall of the renal artery.

METHOD OF DIAGNOSIS

Direct proof of renal artery stenosis depends on contrast angiography. Recently direct angiography has been replaced by CT angiography (CTA) in most cases. MR angiography is another method of diagnosis. Although resolution is slightly inferior to CT angiography, it is useful. A high level of plasma rennin activity is a clue to a diagnosis of renovascular hypertension.

In order to correctly diagnose the responsible side of renal artery stenosis causing hypertension, venous sampling from the renal veins on both sides and the inferior vena cava to determine the renin activity is corroboratory.

Renal function is generally assessed by checking the serum BUN and creatinine values. Renogram or scintigraphy of the kidneys are noninvasive techniques for the examination of renal function. It is useful to assess the renal function by renogram or scintigram of the kidney. Severe renal artery stenosis or occlusion may cause atrophy of the kidney on the affected side due to ischemia of the kidney. Such a case will be introduced in the following section.

METHODS OF TREATMENT OF RENOVASCULAR HYPERTENSION

Before the era of interventional radiology, surgical treatment of renal artery stenosis such as surgical repair (grafting) or nephrectomy had been prevalent. Since the development of balloon angioplasty or stenting, renal artery stenosis has been treated by such angioplasty to control hypertension.

Treatment of renal artery stenosis by percutaneous transluminal balloon angioplasty is called percutaneous transluminal renal angioplasty (PTRA). PTRA was started as early as 1978 by Gruentzig *et al.,* [8] and Katzen *et al.,* [9] and others.

Techniques of renal angioplasty were extensively explained by Sos and his associates[10], Tegtmeyer *et al.,*[11,12] and Baert *et al.,*[13]. These articles are good references for balloon PTA of renal artery stenosis.

The use of stents in the treatment of renal artery stenosis, especially for atheromatous stenosis, improved the success rate and outcome of angioplasty for renal artery stenosis. In the preliminary study of Palmaz stent placement, Rees and his associates[14] reported that renal stents were beneficial in many patients with poor results from conventional angioplasty for ostial atheroma. They described construction of the balloon expandable metallic stents and the technique of stent placement.

Leertouwer *et al*.,[15] reported in their meta-analysis of stent placement for renal artery stenosis that most investigators used Palmaz stents and renal artery stent placement appeared to be superior, regarding initial success and restenosis rates, and clinically comparable to renal PTA.

Many investigators used predilatation of the artery. For ostial lesions, a slight protrusion of the stent into the aorta was recommended in five studies. Occlusive procedures of renal artery or branch arteries in cases associated with renovascular hypertension may be indicated when renal function is lost after assessment by renogram or renal scintigraphy.

Selection of the embolic materials depends on the medical and local situation. For example, embolic materials are gelatin sponge, metallic coils, absolute ethanol and so forth. Ethanol is said to be the most effective embolic material. However, ethanol embolization causes severe pain. Therefore, strong analgesics (pain killers) must be prepared. We have seen a patient's severe pain after ethanol injection, which required even intravenous injection of a narcotic like morphine hydrochloride (10 mg).

Ethanol may be effective when injected through the main renal artery, but partial ethanol renal ablation may be only partially effective in controlling hypertension. In such cases continued antihypertensive medication is necessary.

CASE PRESENTATION

Case 1. Bilateral renal artery stenoses due to fibromuscular dysplasia before the era of percutaneous transluminal angioplasty (PTA)

A 25-year-old woman presented with very high blood pressure. She had been known to have hypertension since the age of 17. Her highest blood pressure measured 230/110 mmHg. She was referred to the Department of Radiology, Hirosaki University Hospital for angiographic study of the renal arteries, because renovascular hypertension was suspected. Pheochoromocytoma or coarctation had been excluded in a previous admission elsewhere. Her plasma renin activity was 45 µg/L. (Normal value is 0.3 – 2.9 ngAl/ml/hr supine or 0.3 – 5.4 ngAl/ml/hr upright, both using the RIA2 Antibody method.)

Excretory urogram showed poor visualization of the left kidney. (Fig. 1)

Aortorenal angiography showed marked stenosis of the middle portion of the left main renal artery and moderate stenosis of the right middle portion of the right renal artery (Fig.2). The "string-of-beads" appearance is seen in the right main renal artery, which is consistent with FMD. The severe stenosis of the left main renal artery seemed to be caused by the same pathology.

There is a "string-of-beads" appearance in the right main renal artery, consistent with fibromuscular dysplasia. The severe stenosis of the left main renal artery seems to be caused by the same pathological process.

The patient was treated surgically. The attempted reconstruction of the left renal artery was difficult and the procedure resulted in nephrectomy. The right renal artery was reconstructed, and the prognosis has been favorable.

Fig. 1. Intravenous pyelography. The calyces and renal pelvis in the left kidney were very poorly opacified.

Fig. 2. Aortorenal angiography.

Case 2. Fibromuscular dysplasia treated by PTA

A 43-year-old woman was admitted to Tokyo Metropolitan Komagome Hospital with blood pressure of 280-250/170-190 mmHg. She had been hypertensive since a young age. Her occular fundi showed changes of Keith-Wagener-Barker classification grade-4. Aortorenal angiography showed stenosis at the middle portion of the right renal artery (Fig. 3).

There are no atheromatous changes in the aorta and renal arteries, though there is moderate-to-marked stenosis in the right main renal artery, suggesting FMD.

There was no evidence of atheromatous plaque in the abdominal aorta or at the ostium of the renal artery. The most likely diagnosis was FMD. The right renal artery stenosis was treated by balloon PTA. (Fig. 4A, B)

The stenosed right renal artery was dilated to 5 mm in diameter from 3 mm in diameter. It was easy to dilate without severe resistance or recoil. The patient's systolic blood pressure decreased to 170 mmHg, and hypertension was well-controlled by medication.

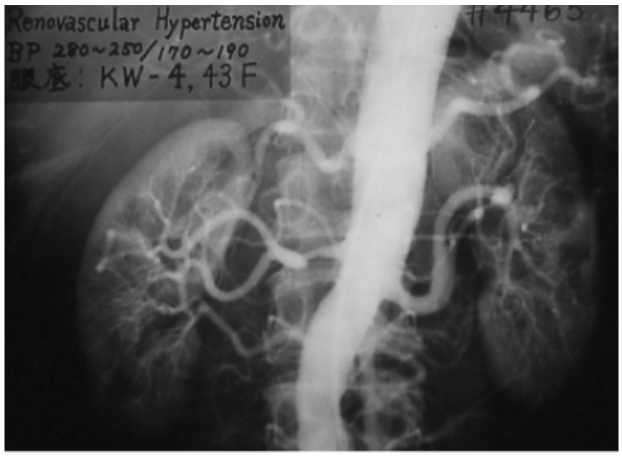

Fig. 3. Aortorenal angiography. (Case 2)

Case 3. FMD treated by PTA

A 35-year-old woman presented with hypertension. She was referred to Dokkyo University Koshigaya Hospital from a City Hospital for treatment of renal artery stenosis. She had experienced headaches and had been hypertensive since age 24. Renovascular hypertension due to FMD had been diagnosed since a high level of renin activity was present.

Selective right renal arteriography showed marked stenosis (over 90%) of the artery. (Fig. 5A)

Insertion of a guide wire was somewhat difficult, and a stiff guide wire had to be used for the passage of

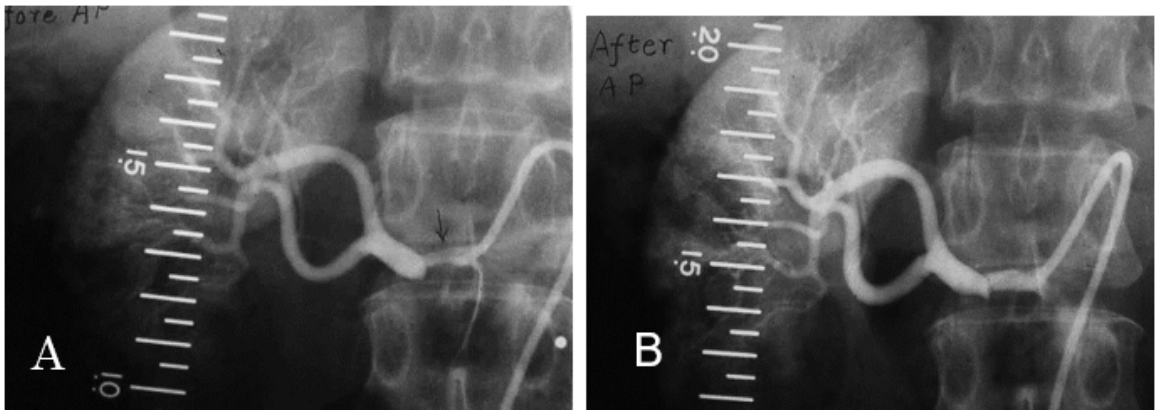

Fig. 4. Balloon angioplasty of the right renal artery stenosis. **A:** Before angioplasty. The stenosed segment of the renal artery measured 3 mm in diameter. **B:** After angioplasty. The stenosed segment of the renal artery was dilated and it measured 5 mm in diameter.

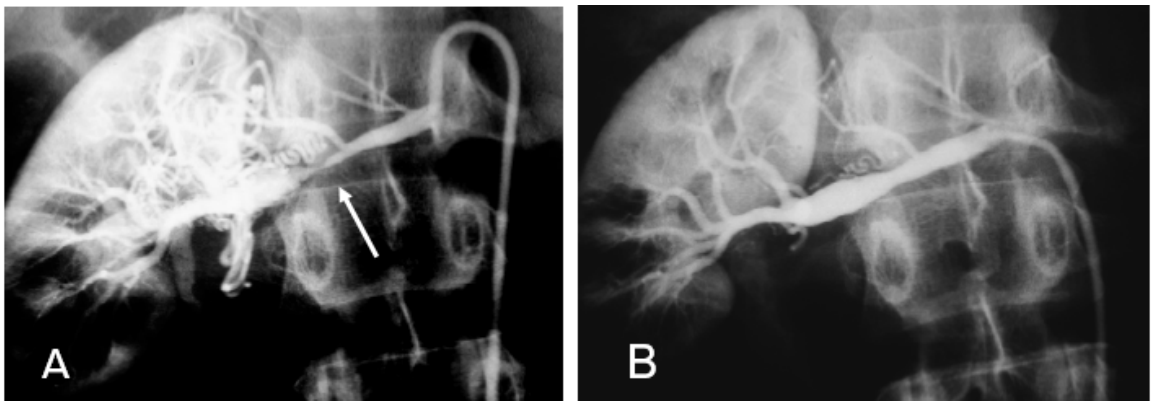

Fig. 5. Balloon angioplasty of the right main renal artery. **A:** Before angioplasty. Severe stenosis of the right main renal artery is seen. Note the collateral small arteries to the kidney from the renal artery proximal to the stenosis. **B:** After angioplasty. The stenosed segment was well dilated. Note marked diminution of the collateral circulation across the stenosis of the renal artery.

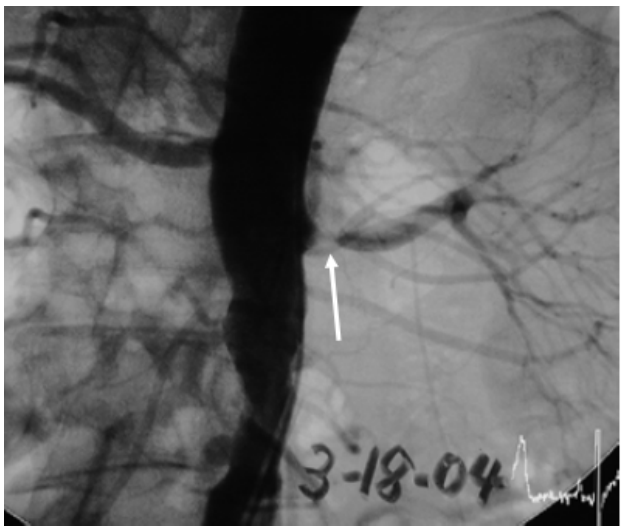

Fig. 6. Aortorenal angiography (Case 4). The aorta shows arteriosclerotic irregularity of the wall. The proximal portion of the left main renal artery is markedly stenosed.

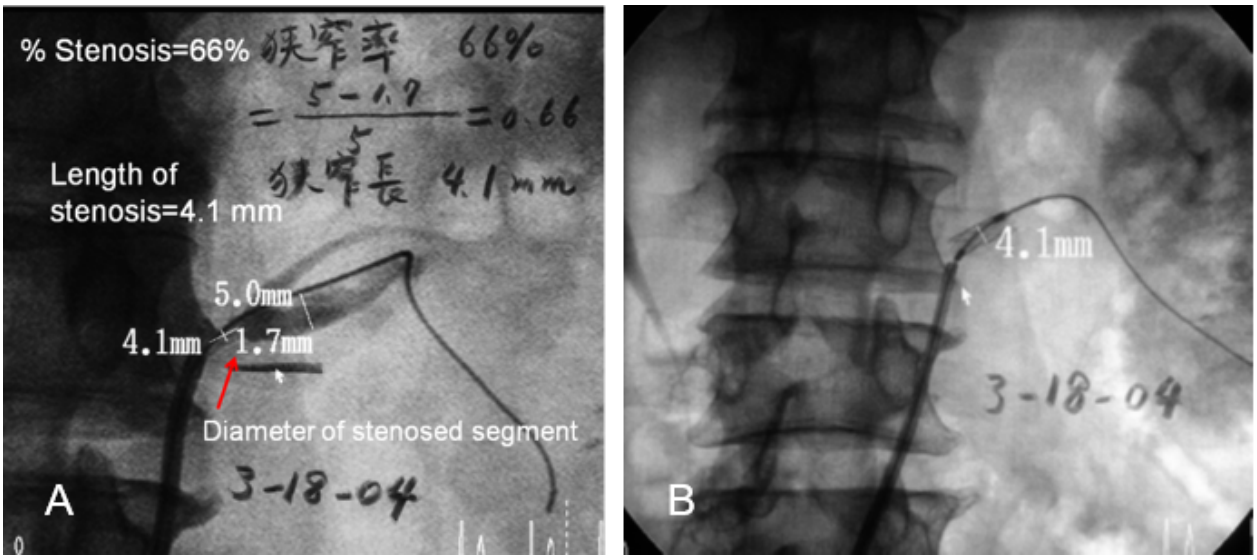

Fig. 7. Arteriosclerotic stenosis of the left renal artery treated by stenting. **A:** Before stenting of renal artery stenosis. The stenosed segment measured 1.7 mm in diameter and 4.12 mm in length. Predilatation was carried out. **B:** Stent in place.

the wire through the stenosis. It was easy to dilate the stenosis by balloon, and no recoil of the artery after dilatation was encountered (Fig. 5B).

The patient's blood pressure dropped to 130-110/80-60mmHg from 160-130/100-80mmHg. Blood pressure immediately following treatment was 100 mmHg systolic.

Blood pressure returned to normal without medication, and the patient experienced no recurrent hypertension in the following six years. Her last blood pressure measured 133/78 mmHg.

Case 4. Renovascular hypertension due to arteriosclerosis of the renal artery.

The patient was a 70-year-old man with hypertension and intermittent claudication over four months. His blood pressure was 220 mmHg systolic. Plasma renin activity was 20ngAl/ml/hr. BUN= 22.2. Creatinine= 1.48.

Aortorenal angiography showed marked stenosis of the proximal left main renal artery and atheromatous changes of the abdominal aorta. The left renal artery stenosis was evaluated as arteriosclerotic stenosis. (Fig. 6)

Selective left renal arteriography revealed the stenosed segment to be 1.7 mm in diameter and 4.1 mm in length. (Fig. 7A). The degree of stenosis of the left renal artery was estimated at 66%.

Stenting of the left renal artery with a Palmaz stent was carried out after preliminary balloon dilatation. The left main renal artery was sufficiently dilated. (Fig. 7 and 8). Selective left renal arteriography after stenting showed a dilated left main renal artery measuring 4.3 mm in diameter, whereas the distal renal artery measured 4.9 mm in diameter.

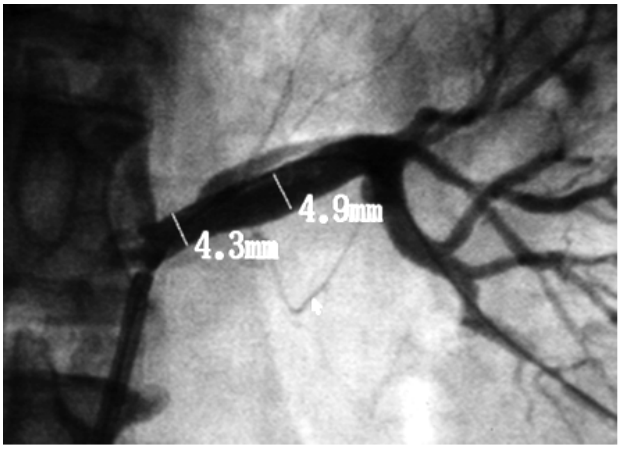

Fig. 8. Selective left renal arteriography after stenting to stenotic segment. The stenosed segment was dilated to 4.3 mm in diameter.

Aortorenal angiography revealed a well-dilated left main renal artery and atheromatous changes in the wall of the abdominal aorta. Some narrowing of the left proximal common iliac artery is faintly seen (Fig. 9).

Fig. 9. Aortorenal angiography after stenting in the left renal artery. (Case 4). The proximal left renal artery is well dilated. Note some remaining post-stenotic dilatation of the artery. Marked atheromatous changes in the wall of the abdominal aorta are observable.

The patient's blood pressure immediately after stenting measured 172/80 mmHg, but it measured 140/80 mmHg on discharge from the hospital. His plasma renin activity dropped to 1.6 ngAl/ml/hr. from 20ngAl/ml/hr.

The patient was placed on a reduced dose of antihypertensive medication and his blood pressure was well controlled. His intermittent claudication was due to stenosis of the left common iliac artery, which was treated by stenting also. His intermittent claudication was cured.

Case 5. Arteriosclerotic stenosis of the right renal artery

A 64-year-old man presented with hypertension. Blood pressure measured 210/108 mmHg and plasma renin activity was 20ngAl/ml/hr. Aortorenal angiography showed marked stenosis of the proximal right main renal artery (Fig. 10).

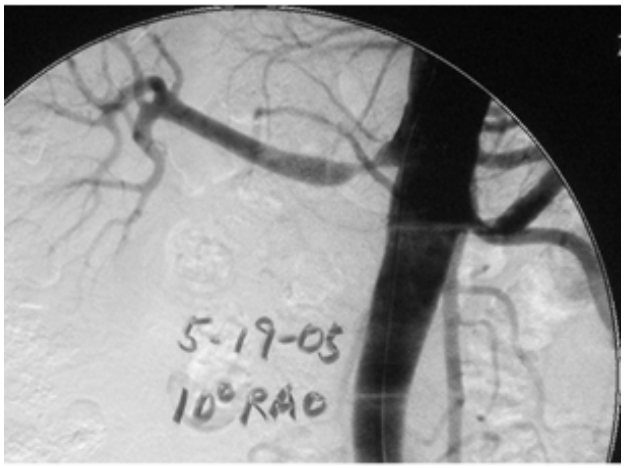

Fig. 10. Aortorenal angiography showing marked stenosis of the right main renal artery. (Case 5)

The selective right renal arteriography showed the stenosed segment of the renal artery, measuring 1.2 mm in diameter, whereas the distal portion of the right renal artery measured 3.6 mm in diameter. (Fig. 11) There is post-stenotic dilatation distal to the stenosis.

Stenting of the right renal artery stenosis with a Palmaz stent was carried out after predilatation with a balloon, and the stenosed segment was dilated to 3.1 mm in diameter

Following the procedure, the patient's blood pressure dropped to 160/80 mmHg. He was placed on medication at a much lower level than before treatment. Plasma renin activity after the treatment was not measured.

Case 6. Renovascular hypertension due to occlusion of the left main renal artery and development of collateral circulation to the left kidney. Treatment with renal ablation on the left

A 51-year-old man was referred to our hospital for the treatment of renovascular hypertension. He had severe stenosis of the left renal artery and some stenosis of the right renal artery. The referring hospital reported plasma renin activity was 44.1 ngAl/ml/hr and a renogram revealing an almost non-functioning left kidney.

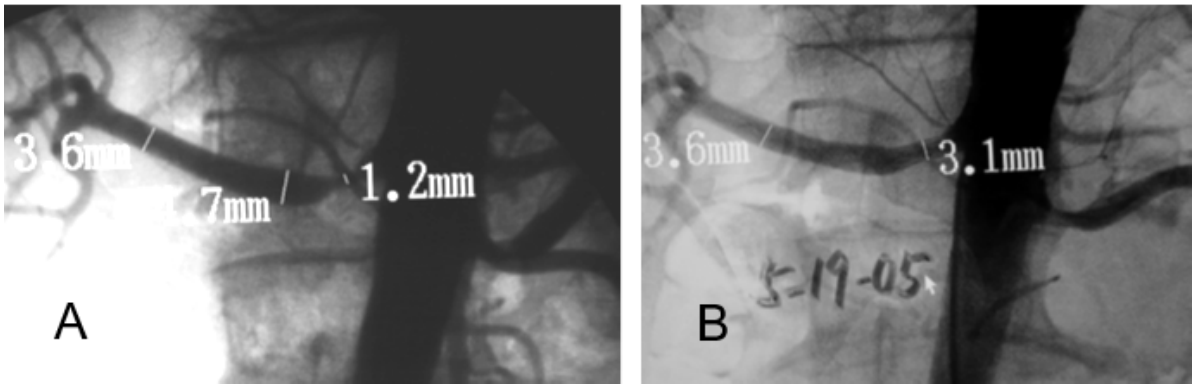

Fig. 11. Measurement of size of renal artery before and after stenting of the artery. **A:** Before stenting. Diameter of stenosed right renal artery, being 1.2 mm in diameter. There is post-stenotic dilatation. The distal renal artery measures 3.6 mm in diameter. **B:** After stenting. The stenosed segment of the right renal artery is dilated and measures 3.1 mm in diameter.

Fig. 12. Left Renal Venography. The venography shows the position of the tip of the catheter in the left renal vein.

Fig. 13. Aortorenal angiography showing occlusion of the left main renal artery.

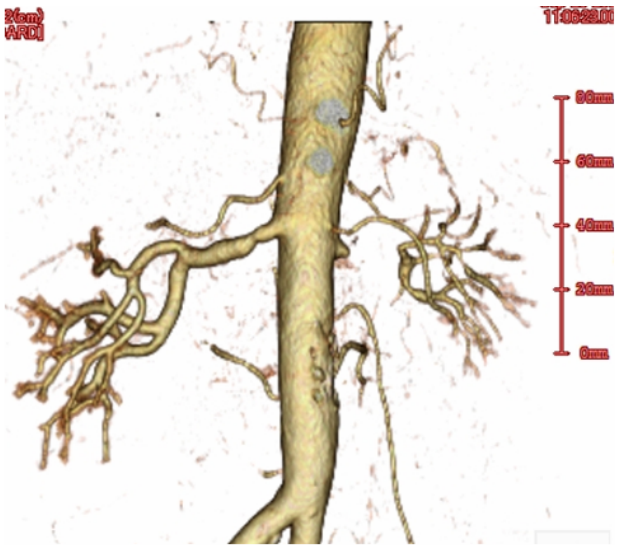

Fig. 14. CTA of the renal arteries before occlusion of a lower polar artery on the left.

Fig. 15. Before and after embolization of left lower polar artery with occluding coils. **A:** Before embolization. A portion of the left lower pole of the kidney is opacified. **B:** After embolization of the left lower polar artery with metallic coils. The portion of the left lower pole of the kidney is completely embolized.

Laboratory findings on admission to our hospital: BUN=13.3 mg/dL, Creatinine=0.85 mg/dL, RBC=438x104/µl, Hb=13.6 g/dL, WBC=7,060/µL. PLT=30.6 x104/µL, Glucose=195 mg/dL, HbA1c=5.9 %, HDL-C=48.4 mg/dL, LDL-C=134.5 mg/dL, Plasma renin activity=32.5 ngAl/ml/hr.

Past History: He was admitted to a hospital for cerebral infarction three months prior to the visit to our hospital. He had been treated for hypertension and diabetes mellitus and was a smoker of cigarettes per day for 31 years. Alcohol intake: whisky 10 cups/day for 10 years.

To begin with, venous sampling for plasma renin activity was carried out to determine the responsible side for hypertension. The renin activity in the left renal vein was over twice as high as on the right side (26.9 ngAl/ml/hr in the upper IVC, 56 ngAl/ml/hr in the left renal vein, and 23.6 ngAl/ml/hr in the right vein) (Fig. 12).

Aortorenal angiography revealed occlusion of the left main renal artery with development of collateral circulation, mild stenosis of the right renal artery and stenosis of the proximal superior mesenteric artery (Fig. 13). The angiographic findings and impossibility of crossing the occlusion with a guide wire precluded percutaneous transluminal renal angioplasty (PTRA) of the left main renal artery. The follow-up CTA in the next month showed again occlusion of the left main renal artery, some distal branches of the left renal artery and some stenosis of the right renal artery (Fig. 14).

Stenosis of the proximal superior mesenteric artery was present, but it is not shown in Fig. 14. The findings will be shown later.

Because of a higher level of renin activity in the left renal vein than in the right, renal ablation on the left was contemplated.

As there would appear to be several routes through collateral arteries to the left kidney, we started to occlude a collateral artery to the lower pole of the left kidney (Fig. 15).

The patient was placed on antihypertensive medication and drugs for diabetes mellitus after embolization of the lower polar artery. His plasma renin activity decreased gradually to about 18 to 20 ngAl/ml/hr, although it once rose to 84.9 ngAl/ml/hr four days post embolization of the lower pole renal artery. His blood pressure fluctuated between 155/111 and 198/138 mmHg.

About one year and three months later another embolization of the superior capsular artery was carried out. This time ethanol was chosen to embolize the artery. After injection of 1.5 ml of ethanol into the left superior capsular artery the patient experienced severe pain, requiring strong analgesics, including intravenous

injection of 10 mg of morphine hydrochloride (Fig. 16, 17). The faint staining of the left upper pole of the kidney disappeared after embolization of the upper capsular artery.

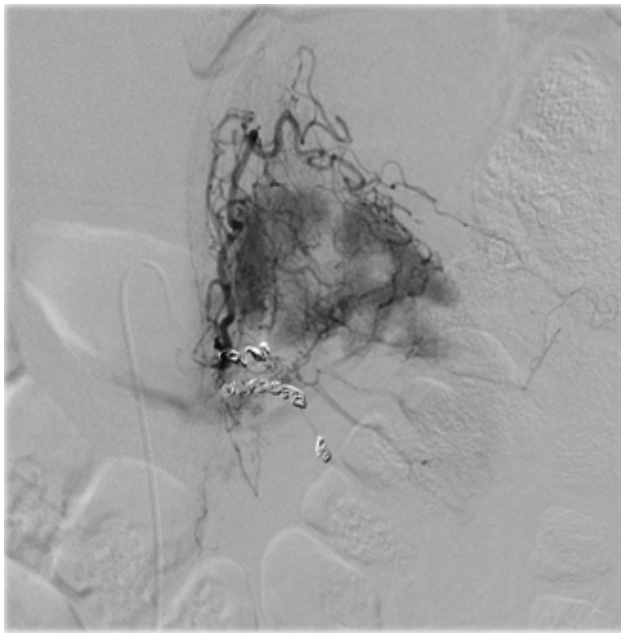

Fig 16. Left upper capsular arteriography, showing blood supply to the upper pole.

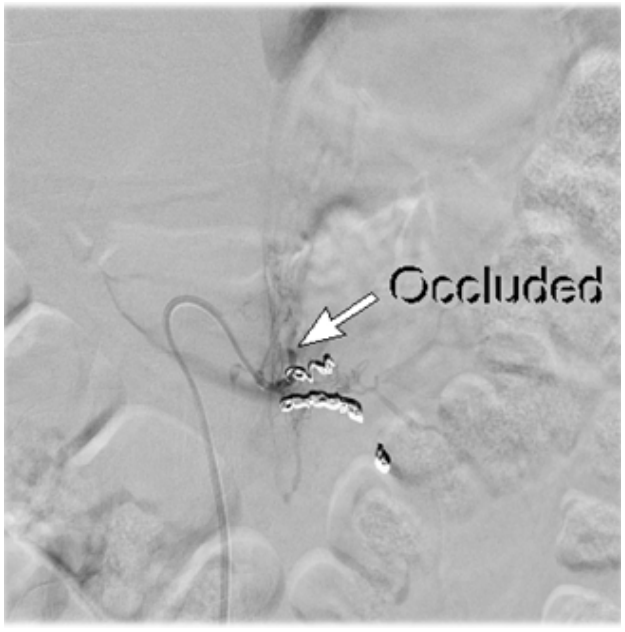

Fig. 17. Left upper capsular arteriography after embolization with Ethanol (1.5 ml).

In search of other collateral circulation to the left kidney we found the left spermatic (gonadal) artery supplying numerous narrow arteries to the lower pole of the kidney. We had to forgo occlusion of those narrow arteries (Fig. 18).

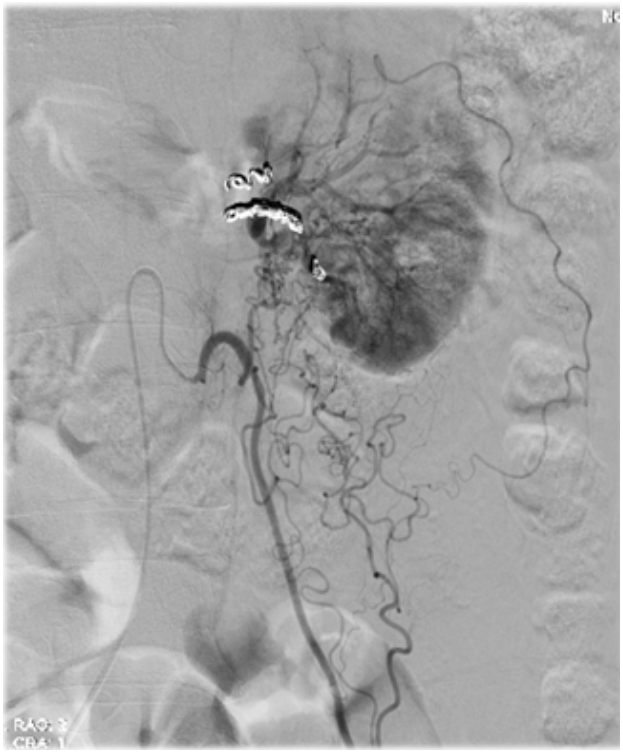

Fig. 18. Left spermatic arteriography showing collateral circulation to the lower pole of the left kidney.

The patient was then placed on medication, including 100 mg tablets of Pletaal (Cilostazol) b.i.d., 5 mg of Renivace (enalapril maleate) b.i.d., 15 mg of Altos (pioglitazone hydrochloride) once a day, and 200 mg of Bezatol (bezalifibrate) b.i.d.

Thereafter his blood pressure gradually decreased from 161/91 mmHg to 130-144/83-89 mmHg. In spite of fluctuation of plasma renin activity (22.1-40.2 ngAl/ml/hr), his blood pressure further decreased to around 130-112/90-73 mmHg when the antihypertensive drug was changed to 160 mg of Diovan OD (Angiotensin II receptor blocker) once a day. The patient has been doing well on the same medication for eight years and has returned to his former place of work.

Follow-up CTA five years after the second embolization for this patient revealed only faint opacification of the atrophied left kidney. The right main renal artery showed mild stenosis. There is stenosis

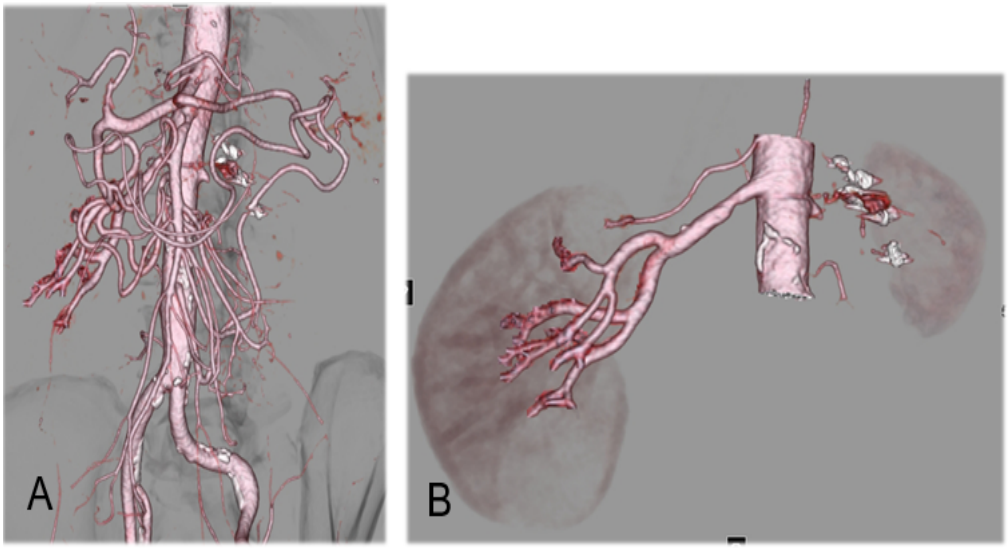

Fig. 19. Follow-up study with 3D CT angiography of the abdominal aorta and its branches five years after the second embolization of the left upper capsular artery. **A:** Abdominal aortogram shows occlusion of the left main renal artery and stenosis of the proximal superior mesenteric artery. Stenosis of the right renal artery is obscured by superimposed vessels. **B:** Renal arteries and shapes of kidneys. Occlusion of the left renal artery and atrophy of the left kidney. There is mild stenosis of the right main renal artery.

at the proximal portion of the superior mesenteric artery as seen before (Fig. 19). He has no complaint of postprandial abdominal pain, however. The patient's condition will continue to be followed at suitable intervals.

DISCUSSION

The details of the techniques of renal balloon angioplasty were thoroughly described by Tegtmeyer and Sos.[12] They described how to cross the stenosis, how to choose a guide wire, catheter, balloon catheter, how to control the spasm of the vessels and so forth. These techniques are very important to successful treatment with balloon angioplasty.

They also stated that FMD responded best to balloon angioplasty. They commented that they needed more pressure to dilate the lesions of Takayasu's arteritis. We also experienced the best results in treatment of FMD with balloon angioplasty, as illustrated in Cases 2 and 3.

Hiramatsu and his associates[2] reported the results of PTRA for RVHT as follows:

The initial success rates in each group are 86% (FMD), 92% (ASO) and 100% (Takayasu's arteritis). However, the six-month success rates are 87% (FMD), 71% (ASO) and 40% (Takayasu's arteritis).

The results would indicate that the low success rate of PTRA for Takayasu's arteritis may reflect the granulomatous change and secondary juvenile arteriosclerosis, which resist balloon dilatation due to rigidity.

Treatment of arteriosclerotic stenosis of the renal arteries became much easier after the advent of metallic stents. When the guide wire passes through arteriosclerotic stenosis it is relatively easy to deploy a stent after predilatation by a balloon.

Gill *et al.,*[16] studied 95 patients with renal artery stenosis treated with stent placement. There were 126 lesions and technical success was obtained in 95.2%. Hypertension was cured in 4.2%, had improved in 79.1%, and failed to respond to treatment in 16.7%.

In their conclusion they stated that stent placement for renovascular hypertension is the treatment of choice on the basis of reported superior technical success and clinical response rates when compared with PTA.

Sometimes a guide wire passes across the occluded segment of the renal artery only with meticulous tries and with precaution. In such cases stent placement will be successful, as reported by Takase *et al.,*[17]

In our case of renal artery occlusion the passage of the guide wire through the occlusion was not successful. Therefore, we had to try to ablate the kidney by embolization of the collateral circulation to the ischemic kidney. We succeeded in only partial decrease of blood supply to the left kidney, but the patient's blood pressure gradually decreased to near normal range with additional medication.

The collateral circulation to the kidney in the case with occlusion of the main renal artery through the left spermatic artery in Case 6 was dramatic. The collateral arteries from the spermatic artery were very narrow and numerous, and we hesitated to try to occlude these arteries. This is one cause of the continued elevation of plasma renin activity, because only partial embolization of collateral circulation could be achieved. However, our efforts resulted in a gradual suppression of his hypertension. Nephrectomy may be the last treatment method for renovascular hypertension if interventional radiological procedures fail.

Reuter and his associates[18] encountered recanalization of an embolized renal artery branch, but they succeeded in completely occluding the renal artery branch causing hypertension on the second treatment, using sterile USP barium on the first occasion and then Gelfoam on the second. Gelfoam tends to dissolve after a certain period, but they succeeded in occluding the renal artery branch, probably due to the small caliber of the branch artery, in which permanent coagulation and occlusion of the artery took place. Reuter used available embolic materials at that time, but suggested that a permanent occluding agent such as isobutyl-2-cyanoacrylate probably would have been better.

Matsuo[19] recommends absolute ethanol for renal ablation, because incomplete occlusion can cause increased secretion of renin. We used absolute ethanol for the second embolization, but ethanol was a very stimulating and painful embolic material. It is very important to prepare analgesics before injection of ethanol into the artery of a patient as previously described.

Nanni and his associates[20] reported that their patients experienced minimal to mild discomfort at the time of alcohol injection, when 2 ml of lidocaine was injected immediately prior to ablation. However, they also reported severe pain in an exceptional case.

Atherosclerotic renal artery stenosis at the ostia is usually hard to dilate. This problem seems to have been solved by the use of a stent, which prevents recoil of the artery. Complications of renal artery stent placement (RASP) for atherosclerotic renal artery stenosis were extensively studied and reported by Ivanovic and his associates.[21]

They reviewed 179 consecutive procedures of RASP in 171 patients. Technical success was achieved in 98% of the procedures. Overall, major complications occurred in 8.4% of procedures. Death within 30 days after RASP occurred in two patients (1.1%), but the cause of death was not related to the procedures.

Ivanovic divided all the complications into major and minor categories according to Society of Cardiovascular Interventional Radiology reporting standards. Major complications are blood transfusion, deep vein thrombosis, renal infarction, acute persistent post-procedural serum creatinine elevation of more than 20% from baseline level, requirement of hemodialysis, and any complication that required surgical intervention or prolonged hospital stay.

All other complications such as puncture-site pseudo-aneurysm treated non-surgically, aortic dissection at the renal artery level, transiently elevated serum creatinine level, arteriovenous fistula, and self-limited renal artery rupture that did not require further intervention, transfusion, or extended hospital stay were considered as minor complications.

Renal artery rupture was seen in three procedures (1.7%), aortic dissection at renal artery level in four procedures (2.2%), flow-limiting renal artery dissection in two procedures (1.1%), renal artery thrombus/ embolus in two procedures (1.1%), transient creatinine elevation lasting less than 30 days in five procedures (2.8%), and transient creatinine level elevation lasting more than 30 days in ten procedures (5.6%).

They recommended having good references and employing good judgement in offering RASP to only those patients who have the greatest chance of benefit.

CONCLUSION

Although the incidence of renovascular hypertension is not very high, it is a curable disease in most patients and it is hoped that attention will be paid to its identification.

The causes should be clarified and clinical status should be carefully reviewed before designing a strategy to treat the renal arteries. FMD is the best indicated disease to be treated by balloon angioplasty alone.

Many cases of arteriosclerotic stenosis could be treated with the aid of metallic stents, although careful judgement of indication is required in offering this treatment method to patients.

It is recommended the merits and demerits for each individual patient be carefully reviewed before carrying out any RASP procedure.

Occasionally renal ablation or nephrectomy may be required to control renovascular hypertension.

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CONFLIC OF INTEREST

The authors declare that they have no conflict of interest.

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