Endovascular Recanalization of Subclavian Artery Occlusions

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Abstract

Percutaneous balloon angioplasty for subclavian stenosis achieves satisfactory procedural success rates except for total occlusion. Seven lesions in six consecutive patients who underwent stenting for subclavian total occlusion were reviewed to evaluate the feasibility and efficacy of endovascular stenting. Six lesions were treated using Palmaz stents, and one with the combination of a Palmaz and a SMART stent. Procedural success (residual stenosis ≤ 30%) was achieved for all lesions. The only neurological complication was an embolism in a branch of the posterior cerebral artery, which resulted in homonymous hemianopsia. Follow-up angiography over 6 months after the stenting for five lesions found one in-stent re-occlusion and one ostial restenosis due to elastic recoil. No patient had any new or recurrent symptoms except for recurrent upper limb ischemia due to the case of in-stent re-occlusion during the clinical follow-up period of 1 to 52 months (mean 16.6 months). This complication was resolved by a second treatment. Our limited experience suggests that stenting can redilate even cases of angiographical total occlusion of the proximal segment of the subclavian artery.

Key words: stenting, subclavian artery, total occlusion

Introduction

Percutaneous transluminal balloon angioplasty (PTA) had been a treatment of choice for cervicocerebral arterial occlusive diseases since the 1980s and is an accepted treatment for stenosis of the subclavian and innominate arteries.1–3,5,7,11,12) However, PTA is not as effective for total occlusion as for stenosis,5,7,12) resulting in a lower overall success rate. Endovascular stent placement, which was started in the 1990s, has increased the effectiveness and safety of PTA, and results have improved for subclavian artery total occlusions.4,8,13) Endovascular stenting has become the first choice of treatment for steno-occlusive lesions of the subclavian and innominate arteries in our institution.

The present study evaluated the technical feasibility and effectiveness of this method for treating total occlusions by retrospective review of a series of seven lesions in six consecutive patients with total occlusion of the subclavian artery.

Materials and Methods

I. Patient population

Eight patients, five males and three females, with steno-occlusive disease of the subclavian and innominate arteries totaling 11 lesions underwent endovascular stent placement between 1998 and 2002. The 11 lesions included seven subclavian artery total occlusions in six patients, one of whom had bilateral occlusions, and four high-grade stenoses of the subclavian and innominate arteries. This study retrospectively reviewed the seven subclavian artery total occlusions (3 right and 4 left) in six patients, three males and three females aged 17 to 72 years (mean age 49.5 years).

The underlying diseases included hyperlipidemia (2 patients, 2 lesions), hypertension (1 lesion), smoking (4 patients, 5 lesions), ischemic heart disease (3 patients, 4 lesions), and Takayasu arteritis (3 patients, 4 lesions). All lesions were associated with occlusive lesions in other cervicocerebral trunks. The clinical manifestations were upper limb ischemia in five patients with five lesions, and the combination of vertebrobasilar insufficiency and upper limb ischemia in one patient. Two patients (2 lesions) were asymptomatic; but both showed
subclavian steal phenomenon, and both had carotid steno-occlusive disease.

Subclavian stenting was performed prior to reconstructive treatment for the carotid diseases. The duration from angiographic diagnosis to endovascular treatment was within 1 year for five lesion, 17 months after diagnosis of subclavian artery occlusion for one lesion, and 4 years after diagnosis of subclavian steal phenomenon for one lesion.

II. Endovascular technique

All procedures were performed under local anesthesia. The patient with bilateral occlusion was treated bilaterally at one session. The transfemoral approach was used for all cases, in conjunction with the transbrachial approach for six lesions. An 8 or 9 Fr introducer was placed into the femoral artery and a 5 or 6 Fr introducer into the ipsilateral brachial artery. Systemic heparinization was performed to increase the activated coagulation time to around 300 seconds. A guide wire was passed through the lesion by either the transfemoral or transbrachial route. The transbrachial approach was tried first for most occlusions, because the catheter and the guide wire were unstable in the aortic arch, especially in the case of an ostial occlusion. In the case of bilateral occlusions, to avoid bilateral brachial punctures, only the transbrachial approach was used for the right occlusion which was a short lesion and was easily passed via the transfemoral approach. For tight occlusions that were not easily passed, stiff wires with a short soft tip (SV wire or Miracle; Johnson & Johnson, New Brunswick, N.J., U.S.A.) had to be used via the transbrachial route. Once a wire was passed through the lesion, predilation was performed with an undersized angioplasty balloon. Intravascular ultrasonography was performed to see if the catheter was in the true lumen and to measure the vessel diameter.

After the lesion had been predilated, stenting and postdilation were performed through the transfemoral route. If transfemoral catheterization into the true lumen was difficult even after predilation, the guide wire from the brachial artery was advanced down into the iliac artery and pulled out of the femoral introducer using a Goose-Neck snare (ev3 Inc., North Plymouth, Minn., U.S.A.). An 8 or 9 Fr guiding catheter was advanced over this wire from the femoral artery up into the subclavian or innominate artery beyond the lesion. If the ipsilateral vertebral artery (VA) was patent distal to the lesion, a balloon catheter (Multilumen balloon catheter; Clinical Supply Co., Hajima, Gifu) was advanced from the brachial route into the ipsilateral VA to prevent debris from entering the vessel. This protection balloon for the VA was employed for three lesions after experience with an embolism of the posterior cerebral artery.

A balloon-expandable stent was chosen for lesions proximal to the VA, and a self-expanding stent for lesions distal to the VA. The stent was positioned via the transfemoral route at the lesion, the guiding catheter was withdrawn proximal to the lesion, and the stent was deployed. Postdilation was performed if necessary. Heparin was reversed to remove the introducers. After hemostasis at the puncture sites had been completed, anticoagulation was resumed with heparin and continued for 3 days (15000, 10000, and 5000 U/day, over each 24-hour period). Antiplatelet medication (aspirin or ticlopidine) was started at least 1 week prior to the procedure and continued postoperatively.

Results

I. Immediate results

Procedural success with residual stenosis of less than 30% was achieved for all lesions (7/7, 100%). All five cases of upper limb ischemia and one case of vertebrobasilar insufficiency were resolved. Five lesions were passed via the transbrachial approach, and two lesions via the transfemoral route. Six lesions were treated using balloon-expandable Palmaz stents (Johnson & Johnson), and one with the combination of a Palmaz and a self-expanding SMART stent (Johnson & Johnson) (Case 2).

One patient without balloon protection of the VA developed homonymous hemianopsia due to an embolism in a tributary of the posterior cerebral artery. One patient suffered brachial hematoma causing transient local pain. One case of acute in-stent thrombosis occurred at the final stage of the procedure, which was successfully treated by angioplasty and thrombolysis with no subsequent sequelae.

II. Follow-up results

Angiography was performed over 6 months after the stenting for five lesions. One case of in-stent re-occlusion and one case of ostial restenosis due to elastic recoil were encountered, which were treated by recanalization by angioplasty (Case 1), and followed up without treatment as the patient was asymptomatic, respectively.

The clinical observation period was 1 to 52 months (mean 16.6 ± 18.0 months). No neurological event occurred during this period. One case of upper limb ischemia recurred due to in-stent re-occlusion which was resolved by repeat treatment.
Representative Cases

Case 1: A 45-year-old male presented with chilly sensation and easy fatigue of the left upper limb. Angiography showed left subclavian artery occlusion at the ostium and supply of the distal subclavian artery from the deep cervical artery (Fig. 1). Chest computed tomography (CT) with contrast medium showed a tiny enhanced spot in the angiographically unfilled part of the left subclavian artery, indicating the remaining tiny vascular lumen (Fig. 2). The total occlusion was around 10 mm in length, inconsistent with the angiographical findings.

A 0.035-inch guide wire was rather easily passed through the occluded vessel through the transbrachial approach. Transbrachial predilation and transfemoral stenting with a 3.9-cm Palmaz stent successfully recanalized the lesion and his symptoms were resolved (Fig. 3). Follow-up angiography 1 year after the procedure showed in-stent restenosis of approxi-
Fig. 5 Case 1. Final aortogram after angioplasty with a 7-mm balloon showing successful redilation of the lesion.

Fig. 6 Case 2. Aortogram showing total occlusion of the left subclavian artery, with no filling even at the latest phase of the angiography.

Fig. 7 Case 2. Angiogram via the left brachial artery revealing the distal end of the occlusion. The lesion was estimated to be 8–9 cm long.

mately 50%, which progressed to re-occlusion by the following year (Fig. 4). His symptoms then recurred. A guide wire was again passed through the occlusion and balloon angioplasty successfully performed (Fig. 5). His symptoms were thus resolved again.

Case 2: A 17-year-old female experienced pain and numbness in the left upper limb 2.5 years prior to presentation. One year later, a diagnosis of Takayasu arteritis was established. Angiography showed total occlusion of the left subclavian artery. She was referred to us 17 months after the angiographic diagnosis, as her symptoms had deteriorated to easy fatigue of the upper limb. The left radial and brachial pulsations were not palpable, and no blood pressure was detected in the left upper limb. Angiography showed total obliteration of the left subclavian artery. The distal part was not visualized even at the latest phase of angiography (Fig. 6). The findings were the same as those of the aortography taken 17 months previously.

Under local anesthesia, introducers were placed in the right femoral and left brachial arteries. Ultrasonography monitoring of the brachial artery facilitated puncture although the artery was not palpable. Angiography via the transbrachial route demonstrated a patent axillary artery, and the occluded part of the subclavian artery was 8–9 cm in length (Fig. 7). The occlusion was extremely tight, and a 0.035-inch wire could not be passed via the femoral or brachial route. However, a smaller guide wire (0.014-inch Miracle; Johnson & Johnson) could be passed through the occluded portion via the transbrachial route. Predilation was performed with a 3.5-mm angioplasty balloon via the transbrachial route. Intravascular ultrasonography showed no intimal flap, no medial dissection, and no additional lumen other than the recanalized lumen (Fig. 8). As these findings were true throughout the recanalized lumen, this was judged to be the true lumen. Transfemoral catheterization of the lesion was still difficult even after predilation, so a 300-cm-long guide wire was advanced from the brachial artery to the right iliac artery, and a Goose-Neck snare was used to trap and pull out the wire via a femoral introducer. An 8 Fr guiding catheter was advanced
Fig. 8 Case 2. Intravascular ultrasonogram performed after the predilation showing that the recanalized lumen was true, because of the absence of intimal or medial dissection, and no additional lumen throughout the lesion.

Fig. 9 Case 2. Aortogram after stenting with a 3.9-cm Palmaz stent at the proximal part of the lesion and a 6-cm SMART stent at the distal part.

postdilations were performed with a 6-mm balloon and the lesion was completely dilated (Fig. 9). The radial artery pulsation became palpable, and the blood pressure difference between the upper limbs disappeared.

Discussion

I. Procedural success rate

The success rate for percutaneous balloon angioplasty is between 80% and 100% for stenosis1,5,7,11,12 but around 50% or as low as 15% for total occlusions5,7,12) An 88% procedural success rate for total occlusions was followed by re-occlusion in 57% of these cases. These unfavorable results were due to the difficulty in passing the guide wire through total occlusions and to strong elastic recoil. The availability of stents increased the overall procedural success rate to 90–100%,4,6,8,13,15,16 and that for total occlusion to 70–100%.4,8,13) Stents are especially effective to resist strong elastic recoil and to resolve dissection caused by balloon dilation. Improvements of other endovascular devices such as guide wires and balloon catheters have also contributed to the penetration of tightly occluded lesions.

In our series, most occlusions were tight and not easy to penetrate. As shown in Case 1, angiographical total occlusion does not necessarily indicate actual total closure of the vascular lumen, which may be unvisualized by the digital subtraction angiography. However, CT with contrast medium could detect such a residual lumen. CT angiography might be more helpful in assessing such a pseudo-occlusion. Careful handling of the guide wire can detect an unvisualized true lumen. Once the guide wire has been passed through, the dilation process with stenting presents no problems. Even a very long and old lesion may be dilated, as in Case 2.

II. Technical considerations

Limitations still remain in the treatment of totally occluded lesions, even with better guide wires and stents. Our experience and reported cases suggest the following technical considerations are important to achieve success and to avoid complications in such difficult cases.

The transbrachial approach is mandatory for the crossing of a tight lesion, if the lesion is located at the ostial or proximal part of the artery. Otherwise, the catheters and wires would be too unstable in the aortic arch to allow the propulsive force to be conducted up to the tip of the devices. Puncture of a severely hypotensive brachial artery may be difficult, so ultrasonography of the brachial artery is
useful to place the introducer. Vessel exploration and cut-down procedures were not necessary in our patients. A stiff guide wire should be handled carefully to advance the soft tip but not to cause subintimal dissection due to the stiffer part of the wire. If dissection occurs, the wire tends to go exclusively into the pseudo-lumen. Extremely careful manipulation of the wire and avoiding forceful movement is essential to find the true lumen in such a case.

The transfemoral approach is preferable to perform stenting after the lesion is crossed and predilated, as this avoids the placing of a large introducer into the brachial artery and allows advance of the protection balloon from the brachial artery to the VA. Advance of the guiding catheter up to an irregularly dilated lesion is not always feasible via the transfemoral artery, so advance of the guide wire from the brachial artery, followed by dragging through the femoral introducer using a Goose-Neck snare is a useful and safe technique. The wire remained in the true lumen facilitates transfemoral catheterization and stenting.

III. Indications and complications

Endovascular treatment is now indicated for symptomatic lesions such as upper limb ischemia, vertebrobasilar insufficiency, and myocardial ischemia attributed to subclavian-coronary steal in patients in whom the internal mammary artery has been used for coronary bypass.4–6,12,15) Preservation of cerebral perfusion in asymptomatic patients with other brachiocephalic lesions, especially in the carotid vessels, is another indication.5) Embolism of the VA does not occur often, in 0.9–1.4% of recent large series,6,15,16) but did occur in one of our patients. VA embolism occurred in patients with normograde flow of the VA but not in patients with the subclavian steal phenomenon.17) Reversal of the subclavian steal phenomenon is delayed for at least 20 seconds after the stenosis is dilated and this delayed flow reversal explains the rarity of embolism to the VA in patients with subclavian steal phenomenon.14) However, dilation is now achieved stepwise by predilation and stenting, with or without postdilation. The retrograde flow of the VA will be reversed during these steps, so the VA should be protected as far as possible.

Stent dislocation, thrombosis of the axillary and brachial arteries,6,15) arterial disruption,9) and infection10) are all rare complications not seen in our series. Undersized stenting and self-expanding stents are contraindicated for treating an ostial lesion, as these devices may slip down into the aorta. Thrombosis of the axillary and brachial arteries may be provoked by poor run-off of the arteries even with full heparinization. Avoiding the use of a large introducer in the brachial artery may help to prevent such a serious complication.

IV. Long-term restenosis rate

The long-term patency rate of subclavian stenting remains unclear, but 73% primary and 90% secondary patency rates were reported in 70 cases of subclavian stenting for 53 stenoses and 17 total occlusions.15) No relationship between restenosis and initial total occlusion was found.

In our cases, one case of restenosis occurred because of elastic recoil of the calcified hard plaque located at the ostium of the artery. As the radial force of the Palmaz stent is weak at its ends, very hard plaque at the arterial ostium may be a problem. One case of in-stent re-occlusion was due to intimal hyperplasia. Long-term patency in relation to intimal hyperplasia should be studied further, but successful retreatment was feasible in our experience. Subclavian stenting for Takayasu disease showed a higher restenosis rate than that for atherosclerotic stenosis, as restenosis occurred in 21.7% of cases of Takayasu disease but only in 10% of cases of atherosclerotic disease.18) Although our three patients (4 lesions) with Takayasu disease showed no restenosis at 6 months (3 lesions) and 3 months (1 lesion) after stenting, they will be carefully followed up.

V. Conclusion

Subclavian artery stent placement is an feasible and effective treatment even for total occlusions. A tiny residual lumen is likely to remain and is expandable in almost all angiographic total occlusions. The long-term results remain unclear, but retreatment of a restenosed lesion was successful in our experience. Stenting should be considered as the first choice of treatment for subclavian artery total occlusions.

References


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Commentary on this paper appears on the next page.
Commentary

The authors have described their experience in the endovascular treatment of seven subclavian artery occlusions in six consecutive patients. With recent advances in technology including improved microcatheter construction and the use of endovascular stents, endovascular therapy has become an attractive alternative to open surgical treatment of subclavian stenosis. Endovascular treatment of complete subclavian occlusion, however, is more challenging for the endovascular therapist. This article not only demonstrates outstanding results in a small series of patients but also demonstrates the benefit of utilizing complementary technology such as contrast CT to detect pseudo-occlusion and intraluminal ultrasonography of the brachial artery to assist with placement of the introducer. As the authors have noted, the long-term outcome and incidence of restenosis following endovascular treatment of subclavian stenosis and occlusion remains to be seen.

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The authors report a series of 6 patients (7 lesions) with total occlusion of the subclavian artery, successfully treated by percutaneous transluminal angioplasty (PTA) and stenting. One restenosis was observed and retreated, and one cerebral embolism in PCA was demonstrated but did not cause significant clinical problems.

Surgical bypass grafting has long been considered the treatment of choice for complete occlusion of supraaortic vessels, particularly the subclavian artery. However, since the early 80s, PTA has been introduced in clinical practice, with a number of technical variants. Since then, several reports of PTA for subclavian occlusion have appeared in the literature. The percentage of success in cases of complete occlusion can vary substantially, and it is very significant that the authors obtained success in all their cases.

The technique was further improved with the introduction of stents, that were supposed to reduce the degree of restenosis affecting a sizeable number of patients months after treatment. Although the percentage of patency in the short term (<1 year) is higher for patients treated with PTA and stent as compared to those who received PTA only, it has recently been demonstrated that in the long run the opposite holds true. Schillinger et al.,1 among 115 patients with subclavian obstruction treated using PTA with or without stent, found a 59% patency in stented vessels at 4 years, as opposed to 68% in nonstented arteries. Therefore, I would expect that at follow up restenosis will appear also in other patients, not just the one reported by our authors.

Another critical point is whether the catheter for dilation can really be passed through the true lumen or if it goes through a subintimal dissection. In complete but not recent occlusion of the artery, the endothelium is hardly visible even at histological examination. In fact, most of the literature agrees that during dilation of a completely occluded vessel, it is virtually impossible to stay in the true lumen, and that a subintimal path is both probable and acceptable (see for instance Spinosa et al.2).

These criticisms notwithstanding, this is an excellent paper with a clear iconography, easy to read and useful.

References


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Dr. Sadato and colleagues have reported a wonderful experience of stent placement for angiographical total occlusion of the proximal segment of the subclavian artery. In this series, 7 arteries in 6 patients, including 3 patients with Takayasu arteries, were treated and procedural success was achieved for all lesions. The authors also give the detailed information about the procedure and operative results, and experience of neurological complication due to embolism after procedure without distal artery protection.

Endovascular treatment has developed and become the new option for the revascularization of total occlusion of the cervical cerebral arteries. Thrombolysis and angioplasty/stent for angiographical total occlusion of the cervical internal carotid artery has been observed, and more excellent results compared to endarterectomy have been reported. The pathological features of angiographical occlusion of the arteries should include pseudo-occlusion associated with fresh focal thrombus or chronic-thick occlusion. We think that pseudo-occlusion cases are more common in the
acute or subacute stages after ischemic events, and these lesions should be a good target for endovascular treatment. Especially, the technical risk of embolism may be lower in the subclavian artery than the carotid artery, and the effectiveness and significance of endovascular approach should be considered in subclavian artery occlusion.

Although the series is relatively small, their excellent study and thoughtful discussion assist in determining the role of endovascular treatment in selected patients in this clinical category.

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For neurosurgeons who are concerned with the endovascular procedure, this paper provides quite important technical and practical detail of the endovascular treatment for the occlusion of the subclavian artery. In this paper, the authors report six cases with occlusion of the subclavian artery who underwent endovascular treatment using the Palmaz and SMART stents.

The fact that the occluded subclavian artery can be reopened by the endovascular technique is the most important message of this paper. The authors honestly describe their outcome including the morbidity of cerebral infarction and re-occlusion of the artery. Except for this complication of cerebral infarction, the other 5 cases were treated successfully without any complication. Their limited and not well controlled experience suggests that the occluded subclavian artery can be empirically reopened without major morbidity. In addition, three of their six cases are Takayasu disease that is still difficult to properly treat. The follow up of this paper is not long enough to evaluate its long-term outcome of the intravascular stent for this chronic inflammatory disease. It is obvious that longer observation is required for the evaluation of the true benefit for patients with Takayasu disease.

As discussed in this paper, the indication of angioplasty for occluded subclavian artery is quite controversial. Most patients with peripheral artery occlusion are asymptomatic and other medical treatments such as the antiplatelet agent sarpogrelate hydrochloride and prostaglandin seems to be effective. As is well known, similar conditions such as arteriosclerosis obliterans (ASO) disease of the lower limbs can be medically controlled in most cases. As for the management of the peripheral arterial disease (PAD), in particular for the lower limbs, an enormous number of studies have established the guidelines.\(^1\) We need firm evidence that in some cases reopening of the occluded subclavian artery is recommended.

Finally, we should recognize that neurosurgeons are requested to actively commit to the management of the ASO of the ascending aorta and its branches. As revealed in this paper, the peripheral artery of the upper limbs and neck cannot be properly managed without understanding of the cerebral circulation.\(^2\)

\section*{References}
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