Vertebral artery transposition for revascularization of the posterior circulation: a critical assessment of temporary and permanent complications and outcomes

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OBJECT Despite advances in medical management and endovascular therapies, including the introduction of statins, antiplatelet agents, and drug-eluting stents, some patients experience medically refractory vertebrobasilar insufficiency and may benefit from robust surgical revascularization. The aim of this study was to evaluate such patients after surgical revascularization, emphasizing long-term outcomes and rates of complications.

METHODS The authors retrospectively identified 22 patients (5 women and 17 men) whose mean age was 69.1 years (range 48–81 years) who underwent revascularization of the posterior circulation via a proximal vertebral artery–carotid artery transposition between 2005 and 2013. The patients' conditions before surgery were clinically summarized, and long-term outcomes and complication rates after surgery were evaluated.

RESULTS All the patients were symptomatic before surgery although they received the best medical therapy as defined by their primary care physician. Presenting symptoms consisted of stroke, transient ischemic attacks (TIAs), and/or findings attributable to posterior circulation hypoperfusion. There were no deaths associated with revascularization surgery. The postoperative complication rate was 45.5%, which included 3 cases of recurrent laryngeal nerve palsy, 1 case of thoracic duct injury, 2 cases of TIA, and 4 cases of Horner's syndrome. The thoracic duct injury was identified intraoperatively and ligated without sequelae, all the TIAs resolved within 24 hours of surgery, all 4 sympathetic plexus injuries resolved, and all but 1 of the recurrent laryngeal nerve palsies resolved, resulting in a 4.5% complication rate in a mean follow-up period of 8.8 months. All the patients had resolution of their presenting symptoms, and a single patient had symptomatic restenosis that required stenting and angioplasty, resulting in a restenosis rate of 4.5%.

CONCLUSIONS Despite the optimization of medical therapies and lifestyle modifications, a select subset of patients with posterior vascular circulation insufficiency remains. In the authors' experience, vertebral artery–carotid artery transposition provides a surgical option with relatively low long-term complication and restenosis rates that are comparable or lower than those reported with endovascular treatment.

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KEY WORDS vertebral artery; stenosis; occlusion; revascularization; vertebrocarotid transposition; vertebral artery–carotid artery transposition; vascular disorders

POSTERIOR circulation infarction accounts for 25%–30% of all ischemic infarcts.³ After the carotid bifurcation, the proximal vertebral artery (VA) is the most common site of stenosis of the feeding vessels to the brain.¹⁵ Unlike the carotid bifurcation, stenosis of the proximal VA that exceeds 30% is significantly associated with infarction in the posterior circulation²¹ and large-vessel occlusive disease is implicated in 14%–32% of infarctions in the posterior circulation.^{3,4}

Unlike the carotid circulation, for which the natural history of stenosis is well understood, the natural his-

tory of vertebrobasilar insufficiency is less well known. Furthermore, the effect of novel agents, including antiplatelet agents and statins, on altering the natural history of these lesions is less well studied. Recent attempts at the use of stenting and/or angioplasty for these lesions has produced mixed results^{1,8,26,27} and significant rates of restenosis, ranging from 11% for drug-eluting stents to more than 30% for bare-metal stents.

Microsurgical revascularization of the proximal VA has been well described, but the majority of published series included small patient populations and short follow-up

ABBREVIATIONS CCA = common carotid artery; CTA = CT angiography; CVA = cerebrovascular accident; ICG = indocyanine green; TIA = transient ischemic attack; VA = vertebral artery.

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durations.^{2,9,10,14,25} Microsurgical revascularization can be performed by proximal VA endarterectomy,⁵ VA–common carotid artery (CCA) transposition,^{2,10,14} and graft interposition techniques.⁹ Indeed, most reports of VA revascularization have described a combination of the aforementioned techniques for augmenting flow to the posterior circulation. We sought to evaluate the outcomes of patients with medically refractory vertebrobasilar insufficiency treated with VA–CCA transposition, emphasizing the long-term outcomes and rates of complications in this group.

Methods

Patient Population

A retrospective analysis from the prospective vascular database of the Barrow Neurological Institute was performed on patients who had VA–CCA transposition.

Between 2005 and 2013, we treated 22 patients with medically refractory vertebrobasilar insufficiency using VA–CCA transposition at the Barrow Neurological Institute (Table 1). A medically refractory condition was indicated if the patients had persistent symptoms attributable to posterior circulation ischemia despite an adequate trial of best medical therapy. There were 17 men (77%) and 5 women (23%) with an average age of 69.1 years (range 48–81 years). Their medical records, neurological examinations, and radiographic studies were reviewed retrospectively. The patients' pre- and postoperative neurological function was evaluated using modified Rankin Scale scores.

Diagnostic Evaluation

All the patients underwent digital subtraction angiography, CT angiography (CTA), or MR angiography (Figs. 1 and 2).

Surgical Technique

We have previously described our VA–CCA transposition technique (Videos 1 and 2).¹⁴

VIDEO 1. A 52-year-old man had a history of symptomatic VA stenosis. Imaging was significant for severe stenosis of the left VA at its origin. The patient was advised to undergo a left VA–CCA transposition. A 4-cm incision along the anterior border of the sternocleidomastoid muscle, beginning at the superior edge of the clavicle, is used for access. After exposing the left CCA just superior to the clavicle, the thoracic duct is dissected out, ligated, and divided. The VA is identified and traced as inferiorly as possible. The proximal VA is ligated and divided after heparinization, and the CCA is occluded and rotated to allow anastomosis to the posterior lateral wall. A running 6-0 Prolene suture is used to perform the anastomosis, which is then back-bled, and patency is confirmed with an intraoperative ICG angiogram. Copyright Barrow Neurological Institute. Published with permission. Click here to view with Media Player. Click here to view with Quicktime.

VIDEO 2. A 64-year-old woman had symptomatic VA stenosis. Imaging was significant for severe stenosis of the left VA at its origin. The patient underwent a left VA–CCA transposition. A 4.5-cm incision along the anterior border of the sternocleidomastoid muscle, beginning at the superior edge of the clavicle, is used for access. After exposing the left CCA just superior to the clavicle, multiple thoracic ducts are dissected out, ligated, and divided. The VA is identified and traced as inferiorly as possible. Intraoperative ICG angiography demonstrated lack of blood flow to the VA. The proximal VA is cut without ligation to verify patency and blood flow.

The proximal portion of the VA is clamped. A Fogarty balloon is inserted into the distal VA, and a thrombectomy is performed until adequate backflow is obtained. Then the artery is irrigated and heparinized. The CCA is occluded and rotated to allow anastomosis to the posterior lateral wall. A running 6-0 Prolene suture is used to perform the anastomosis, which is then back-bled, and patency is confirmed with an intraoperative ICG angiogram. Copyright Barrow Neurological Institute. Published with permission. Click here to view with Media Player. Click here to view with Quicktime.

Surgery is performed under general anesthesia. Somatosensory evoked potential monitoring and electroencephalography are routinely used. Barbiturate-burst suppression is induced before vascular clamping and maintained during occlusion. The head is kept in a neutral position with no extension (to prevent stretching of the muscle). A 6- to 8-cm linear incision is made along the medial border of the sternocleidomastoid muscle. Both muscle heads are dissected and separated. (The clavicular head is no longer taken, as we used to do in the past.) Dissection is carried down until the CCA is identified and isolated. The jugular vein is identified and isolated. Special attention must be paid to the thoracic duct, especially on the left side. This pale vessel-like structure should be identified on the fat pad deep to the jugular vein; it is ligated and divided. It is not uncommon to encounter more than 1 thoracic duct (Video 2).

The VA is identified using anatomical landmarks. The thyrocervical trunk originates from the subclavian artery and is visualized first. Medial to this trunk, the VA can be identified. The VA can be distinguished from the thyrocervical and costocervical trunks by the lack of branches on its proximal segment. The C-6 transverse process can be palpated to guide identification and localization of this vessel. The CCA and VA are isolated and liberated from adhesions.

The CCA is the site most commonly used to implant the transposed VA. The initial step is to ligate the VA at its origin with hemoclips. The VA is divided, and the lumen is inspected. The VA is clamped with a temporary aneurysm clip at the level of the transverse foramen. The lumen is irrigated with heparinized saline. The CCA is clamped proximal and distal to the planned level of the arteriotomy. Using the vascular clamps, the CCA is rotated slightly to bring the back wall of the vessel up, facilitating the anastomosis and enabling it to be seated further posteriorly in a better anatomical position at the conclusion of the procedure.

Using a No. 11 blade followed by a 4-mm-diameter arteriotomy punch, the arteriotomy is performed. The vessel is fish-mouthed as needed to tailor it to the diameter of the CA arteriotomy. A 6-0 monofilament Prolene (Ethicon, Inc.) is used for the anastomosis. After one side is done, the lumen is inspected. The procedure is then performed on the second side.

Before the suture line is closed, the distal VA is temporarily unclamped and allowed to back-bleed. The lumen is irrigated with heparinized saline. All arterial clamps are released. Small bleeding points at the suture line are usually self-limited and can be controlled with the use of Surgifoam (Ethicon, Inc.). Videoangiography with indocyanine green (ICG) is performed intraoperatively to check patency. The sternocleidomastoid muscle is reapproximated, and the wound is closed.

TABLE 1. Demographic and clinical summary of patients who underwent VA transposition

Case No.	Age (yrs), Sex	Sm	AHTN	ACoag/ APTI	Previous MI/TIA	History of CEA	Presenting Symptom(s)	Side	% Stenosis	Status of Contralat VA	Transient Complication(s)
1	63, F	+	+	+/+	-/+	—	TIA	Lt	70–80	<50% stenosis	
2*	81, F	—	+	+/+	+/+	+ (bilat)	TIA	Rt	80–90	Occluded	
3	70, M	—	+	+/+	-/+	—	Gait imbalance	Lt	60	<50% stenosis	RLN injury (T)
4	70, M	+	—	-/-	-/+	—	PCA CVA	Rt	>90	>90% stenosis	Horner's syndrome
5†	62, F	+	+	-/+	-/+	—	SSS	Lt	NA	<50% stenosis	
6	77, M	+	—	-/-	-/+	—	TIA	Rt	NA	Occluded	
7*	64, M	+	+	+/+	-/+	—	Syncope	Lt	70–80	NA	Horner's syndrome
8	81, M	+	+	+/+	-/-	—	Syncope	Lt	60	NA	
9	75, M	+	+	-/+	-/+	—	TIA, vertigo	Lt	80–90	80–90% stenosis	Thoracic duct injury
10	78, M	—	+	-/-	-/-	—	Gait imbalance	Rt	60–70	Occluded	Horner's syndrome
11	75, F	—	—	-/+	-/-	—	TIA, gait imbalance	Lt	>90	Occluded	RLN injury (T)
12	73, M	—	+	+/+	-/-	—	TIA, vertigo	Lt	50	<50% stenosis	
13	60, M	+	—	+/+	-/-	—	Vertigo	Lt	80–90	<50% stenosis	TIA, slurred speech
14	66, M	+	+	+/+	-/+	+	CVA	Rt	80–90	<50% stenosis	
15	48, M	—	—	+/+	-/+	—	Dysmetria, slurred speech	Lt	>90	Occluded	TIA, lt leg weakness
16	73, M	—	—	-/-	-/-	—	TIA, vertigo	Lt	>90	Occluded	RLN injury
17	67, M	—	+	-/-	-/-	—	SAH	Rt	60–70	Occluded	
18	81, M	+	+	+/+	+/+	—	TIA, vertigo	Lt	70–80	Occluded	
19	57, M	+	+	+/+	-/-	—	TIA, vertigo	Lt	70–80	Occluded	Horner's syndrome
20	61, F	—	+	+/+	-/+	—	Vertigo	Rt	50	Occluded	
21	67, M	+	+	-/+	-/+	+ (stent)	CVA	Lt	>90	Occluded	
22	60, M	+	+	+/+	-/+	—	CVA	Lt	>90	Occluded	

ACoag = anticoagulation medication; AHTN = antihypertensive medication; APTI = antiplatelet medication; CEA = carotid endarterectomy; MI = myocardial infarction; NA = not applicable; PCA = posterior cerebral artery; RLN = recurrent laryngeal nerve; SAH = subarachnoid hemorrhage; Sm = history of smoking; SSS = subclavian steal syndrome; T = temporary; — = negative; + = positive.

* Patient received previous stenting/angioplasty treatment.

† Patient experienced restenosis 3 months after surgery and underwent stent placement and angioplasty.

All patients in this study were treated using this technique. The patients were all on aspirin therapy.

Results

Patient Characteristics

The clinical parameters of the patients included in this study can be found in Table 1. Of the 22 patients in the study, 12 had a significant history of tobacco use, 2 had no documentation of smoking history, and the remaining 8 were nonsmokers. Sixteen patients were hypertensive and were actively being treated with antihypertensive medications. Six patients had no documented history of hypertension. Eleven patients were actively treated for hyperlipidemia, and 17 patients were on antiplatelet or anticoagulation therapy (12 patients on antiplatelet and anticoagulation therapy, 4 on antiplatelet therapy only, and 1 on anticoagulation therapy only). Two patients had a history of myocardial infarction, and 3 patients had undergone carotid endarterectomy for anterior circulation ischemia. Thirteen patients presented with a history of cerebrovascular accident (CVA) or transient ischemic attack (TIA), 1 patient presented with subarachnoid hemorrhage, and the remainder presented with symptoms suggestive of

vertebrobasilar insufficiency. Two patients had previously undergone stenting and angioplasty procedures of the affected side without improvement of symptoms. The left side was more commonly involved (15 on the left vs 7 on the right). In a majority of the patients (n = 18), the contralateral VA was noted to exhibit mild to severe stenosis.

Morbidity and Mortality

There were no cases of perioperative death in this series. We identified 3 cases of recurrent laryngeal nerve palsy, 1 of which had not resolved at latest follow-up, 4 cases of temporary Horner's syndrome, 2 cases of postoperative TIA, and 1 case of thoracic duct injury associated with a left-sided approach (Table 2).

Follow-Up

Clinical follow-up information was available for 20 patients. At a mean clinical follow-up of 4.4 months (range postoperatively to 17 months), all patients had resolution or improvement of their presenting symptoms (Figs. 1 and 2). At a mean angiographic follow-up of 8.8 months, clinically significant restenosis was evident in a single case. This patient was treated with stenting 3 months after the microsurgical revascularization.

FIG. 1. A 67-year-old man with acute subarachnoid hemorrhage with negative results on 2 cerebral angiography studies was found to have moderate to severe stenosis (arrow) of the right VA (A) and complete occlusion of the left VA (B). The patient underwent a right VA-CCA transposition (C and D). At 6-month follow-up examination, CTA (C) demonstrated adequate patency and flow (arrow) of the VA-CCA anastomosis.

Discussion

Previous reports of microsurgical revascularization of the proximal VA consisted of small cohorts of patients treated with a diverse array of revascularization techniques.^{2,5,9,10,14,25} These techniques included endarterectomy of the proximal VA and subclavian artery,⁵ VA-CCA transposition,¹⁴ and placement of interposition grafts.⁹ These series consisted of relatively short-term follow-up and focused on immediate symptom improvement (Table

3). Still, there are no randomized data on the benefit of revascularization of the proximal VA for stroke prevention. However, cervical carotid trials^{11,12,23} and case series support microsurgical or endovascular treatment.^{1,2,9,10,17,25} The goal for either treatment is successful resolution of the patients' symptoms and an angiographic result (< 50% residual stenosis) without neurological or procedure-related complications.¹⁴ The success rates of both modalities are similar, ranging from 93% to 98%.^{1,2,6,9,16,25,26,28}

FIG. 2. A 58-year-old man presented with vertigo, dizziness, and brainstem stroke. Cerebral angiography demonstrated a complete occlusion of the right VA and severe stenosis of the left VA (A and B). The patient underwent a left VA-CCA transposition. One-month postoperative CTA of the neck (C and D) showed adequate patency and flow through the anastomosis.

TABLE 2. Procedure-related complications

Complication	No. of Cases	
	Temporary	Permanent
Wound hematoma	0	0
Recurrent laryngeal nerve injury	2	1
Intraop thoracic duct injury	1	0
Chylothorax	0	0
Horner's syndrome	4	0
Postop TIA	2	0

Here we have presented a series of 22 consecutively treated patients with medically refractory posterior circulation ischemia who underwent VA-CCA transposition. A majority of the patients in this series had an extensive history of tobacco use and hypertension. Seventy-five percent of the patients were treated aggressively with antiplatelet therapy, anticoagulation therapy, or both therapies. In 50% of the cases, the patients presented with a completely occluded contralateral VA, and a majority of the patients presented after suffering a CVA or TIA, in accordance with previous literature. For all the patients treated microsurgically, we identified resolution or improvement of their symptoms and adequate angiographic results. To our knowledge, this population represents the largest cohort of patients treated with this strategy to date.

When selecting the method of choice for revascularization of the proximal VA, the durability of the treatment becomes crucial. Albuquerque et al.¹ found restenosis in 43.3% of patients who underwent angioplasty and stenting for revascularization of the proximal VA. Similar results have consistently been reported in other studies.^{1,19,20,26} In the Stenting of Symptomatic Atherosclerotic Lesions in the Vertebral or Intracranial Arteries trial, 43% of the patients who received treatment for extracranial VA stenosis and had 6 months of follow-up had evidence of in-stent stenosis. Half of them had a complete vessel occlusion.²⁶ Recently, Li et al.¹⁸ demonstrated the efficacy of balloon-assisted angioplasty and self-expanding stents in 32 patients with symptomatic VA ostium stenosis. The mean extent of stenosis before and after stenting declined from 76.4% to 11.4%, and only 1 patient (3.1%) developed asymptomatic restenosis at a mean angiographic follow-up of 12.5 months. Drug-eluting stents can reduce restenosis rates by inhibiting neointimal hyperplasia, but the stent fracture rate is significantly high.⁷

The durability of microsurgical revascularization has been described extensively.^{9,10,14,16,17,19} Hanel et al.¹⁴ reported that 7% of patients developed new or recurrent vertebrobasilar symptoms after surgery (mean follow-up 29 months). Their angiographic results showed only 1 case of recurrent stenosis among those patients who underwent follow-up imaging. Berguer et al.² reported a 71% 5-year survival rate for patients with extracranial VA disease undergoing microsurgical revascularization. A majority of the patients who died did so as a result of cardiac disease. Of those patients with 5 years of follow-up after microsurgical intervention, 97% remained stroke free.² In the present series, in a mean follow-up period of 8.8 months,

1 patient had restenosis 3 months after the microvascular procedure and required endovascular stenting.

Temporary and Permanent Complications

Complications of endovascular treatment for VA stenosis are variable. Parkhutik et al.²⁴ reported a neurological complication rate of 3.4%, with 1 immediate vertebral TIA and 2 other strokes during a mean 32-month follow-up period. Fiorella et al.¹³ reported periprocedural neurological morbidity and mortality rates of 26.1%, including 10 clinically evident strokes, in patients with vertebrobasilar atheromatous disease undergoing endovascular treatment. Mohammadian et al.²² recently presented their experience in using angioplasty and stenting to treat symptomatic VA stenosis and found periprocedural and follow-up complication rates of 7.2% and 6.3%, respectively. Microsurgical revascularization of the VA has inherent risks of complication from soft-tissue manipulation, such as wound infection or hematoma, laryngeal nerve injury, thrombosis, lymphatic injury, Horner's syndrome, and stroke. In a large series that included 218 proximal VA transpositions, Berguer et al.² found a mortality rate of 0.6% and a perioperative stroke rate of 1.9%. Their patency rate at 5 years was 80%. Hanel et al.¹⁴ reported incidence rates of 48.3% for transient and 7.4% for permanent neurological deficits. Only 2 patients had new symptoms related to vertebrobasilar insufficiency, and 1 patient had a new distal vertebral stenosis 17 years after surgery.

In the current series, we did not identify any cases of perioperative death associated with this treatment strategy, but we did identify an array of temporary complications and 1 permanent complication. We noted recurrent laryngeal nerve palsies in 3 patients. This complication was temporary in all of them except for 1 at last follow-up. There was 1 case of a thoracic duct injury associated with a left-sided approach that was identified intraoperatively and treated without sequelae. We identified 4 cases of temporary Horner's syndrome and 2 cases of perioperative TIA. Postoperative CVAs have been reported in association with both microsurgical and endovascular treatment of the proximal VA and seem to be associated with manipulation of the atherosclerotic burden within the vessel. Anatomical knowledge and gentle tissue manipulation are the bases for avoiding complications.

Conclusions

Despite advancements in medical therapy, a subset of patients with vertebrobasilar insufficiency remain candidates for microsurgical revascularization of the posterior circulation. Although endovascular management has contributed to a decline in the surgical treatment of vertebrobasilar insufficiency, the long-term outcomes for patients subjected to this regimen remain limited, and the rates of restenosis, even with drug-eluting stents, remain high. In experienced hands, microsurgical revascularization of the proximal VA using VA-CCA transposition is a safe and effective treatment for medically refractory vertebrobasilar insufficiency.

TABLE 3. Summary of complications and restenosis on patients treated for proximal VA stenosis

Authors & Year	Overall	No. of Cases			
		Periop Complications	Permanent Complications	Deaths (cause)	Restenosis (timing)
Endovascular series					
Albuquerque et al., 2003	33	0	0	2 (1 stroke [4 mos later], 1 preexistent basilar thrombosis)	20 (43.3%) (7 mild, 8 moderate, 5 severe) (mean 16 mos)
SSYLVA, 2004	61 (14 VAs)	4 strokes	4 strokes	0	6/14 (42.9%)
Lin et al., 2004	58 (67 VAs)	3 strokes 1 GI hemorrhage 1 femoral pseudoaneurysm 1 thoracoacromial artery injury	3 strokes	1 (cardiac)	8/32 (25%) (2 complete in-stent occlusions) (mean 31 mos)
Lin et al., 2006*	80 (90 VAs)*	3 strokes* 1 GI hemorrhage* 1 femoral pseudoaneurysm* 1 thoracoacromial artery injury* 1 PC infarction	4 strokes*	1 (cardiac)*	11/40 (28%) VAs (mean 11.7 mos)
Surgical series					
Hanel et al., 2009	19	14 (48.3%) 5 RLN injuries 5 HS 1 wound hematoma 1 chylothorax	2 (7.4%) 1 RLN injury 1 HS	0	2 (7.4%) (1 & 17 yrs)
Berguer et al., 2000	65	1 TIA 3 strokes (RLN injury & HS not reported)	3 strokes	4 (3 cardiac, 1 stroke)	2 (0.03%) (3 & 24 mos)
Present study, 2014	22	2 TIAs 2 RLN injuries 4 HS 1 thoracic duct injury	1 RLN injury	0	1 (3 mos)
					1 angioplasty/stent

GI = gastrointestinal; HS = Horner's syndrome; PC = posterior circulation; SSYLVA = Stenting of Symptomatic Atherosclerotic Lesions in the Vertebral or Intracranial Arteries.

* Some of these results were published by Lin et al. in 2004.

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Conception and design: Rangel-Castilla, Kalani, Cronk, Russin. Acquisition of data: Rangel-Castilla, Kalani. Analysis and interpretation of data: Rangel-Castilla, Kalani, Russin. Drafting the article: Rangel-Castilla, Kalani, Cronk, Zabramski, Russin. Critically revising the article: Spetzler, Zabramski. Reviewed submitted version of manuscript: Spetzler, Zabramski. Statistical analysis: Rangel-Castilla, Kalani, Russin. Administrative/technical/material support: Cronk, Russin. Study supervision: Spetzler, Zabramski.

Supplemental Information

Videos

Video 1, Media Player. http://mfile.akamai.com/21490/wmv/digitalwbc.download.akamai.com/21492/wm.digitalsource-na-regional/jns14-194_video_1.asx.

Video 1, Quicktime. http://mfile.akamai.com/21488/mov/digitalwbc.download.akamai.com/21492/qt.digitalsource-global/jns14-194_video_1.mov.

Video 2, Media Player. http://mfile.akamai.com/21490/wmv/digitalwbc.download.akamai.com/21492/wm.digitalsource-na-regional/jns14-194_video_2.asx.

Video 2, Quicktime. http://mfile.akamai.com/21488/mov/digitalwbc.download.akamai.com/21492/qt.digitalsource-global/jns14-194_video_2.mov.

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