Vertebrocarotid collateral in extracranial carotid artery occlusions: digital subtraction angiography findings

Levent Oguzkurt a,∗, Osman Kizilkilic a, Fahri Tercan a, Riza Türköz b, Tülin Yıldırım a

a Department of Radiology, Adana Teaching and Medical Research Center, Baskent University, Adana, Turkey
b Department of Thoracic and Cardiovascular Surgery, Adana Teaching and Medical Research Center, Baskent University, Adana, Turkey

Received 16 February 2004; received in revised form 26 March 2004; accepted 30 March 2004

Abstract

The internal and external carotid arteries are usually considered occluded distal to a common carotid artery occlusion but some collateral vessels may provide blood keeping the internal and external carotid arteries patent distal to the occlusion. Most common communication in such a case is diversion of blood from muscular branches of the vertebral artery to occipital branch of the external carotid artery which in turn could maintain blood flow into the internal carotid artery, a condition called carotid steal.

We encountered vertebrocarotid anastomoses maintaining the patency of carotid circulation in six patients. Patients were four females and two males, ages ranging from 40 to 67 (mean age: 56) years. Five of the patients had ischemic cerebral symptoms. The origin of the external carotid artery was occluded in two and the whole common carotid artery in the remaining four patients. Two patients had double steal, carotid and subclavian at the same time. There was also severe stenosis or occlusion of at least one other major extracranial cerebral artery in all the cases. This concomitant involvement of the second extracranial cerebral artery was thought to be the main reason for the development of vertebrocarotid collateral. In contrast to most of the previously published reports claiming the inadequacy of angiography when compared with colour Doppler ultrasonography, angiography finely depicted the distal patency of the carotid circulation and all the collaterals in detail in every case. Selective injection of the vertebral artery ipsilateral to the occlusion, is the key to demonstrate distal patency of the carotid circulation in cases of proximal carotid occlusion. Demonstration of patency of the distal circulation is very important because some of the patients might get benefit from a reconstructive surgery.

© 2004 Elsevier Ireland Ltd. All rights reserved.

Keywords: Carotid arteries; Cerebrovascular occlusion; Collateral circulation; Subclavian-carotid artery steal syndrome; Angiography, digital subtraction

1. Introduction

It is well known that occlusion of an artery is often accompanied by the development of collateral circulation through the dilatation of existing anastomosis. With occlusion of the common carotid artery (CCA) or origin of the external carotid artery (ECA), flow in the ipsilateral ECA and sometimes in the ipsilateral internal carotid artery (ICA) can be maintained by collateral vessels. This can occur mainly from the ipsilateral vertebral artery (VA) to the ECA through its occipital branch, a condition called carotid steal or external carotid steal [1,2]. Until the 1980s carotid steal was mostly reported in patients who had undergone therapeutic ligation of the CCA [3,4]. Thereafter, spontaneously occurring cases have been reported more frequently.

We present six vertebrocarotid collaterals in patients with CCA or ECA occlusions diagnosed by CDUS and confirmed by digital subtraction angiography (DSA). All the cerebral vessels were examined by DSA in detail with particular attention to the collateral blood flow.

2. Materials and methods

Between September 1999 and November 2003, vertebrocarotid collateral vessels were seen in four patients with CCA and two patients with ECA occlusions with preservation of the patency of the ECA and/or the ICA distal. Patients were four females and two males, ages ranging from 40 to 67 (mean age: 56) years. Four patients had patent ICA and ECA distal to CCA occlusion, whereas two patients had patent ECA distal to occlusion at its origin. We have searched angiographic findings in these six patients with
emphasis given on the collateral circulation. Five patients were symptomatic and all patients were referred for angiography after a CDUS examination. The angiography studies were performed with a digital subtraction angiography unit (Multistar, Siemens, Erlangen, Germany). The patients had a preliminary arch aortography. Selective injection of both common carotid and vertebral arteries were performed in all patients. Selective injection of the subclavian artery was also performed in patients with complex multiple stenoses or occlusions.

3. Results

Demographic data and presenting symptoms of the patients and surgical treatment, if applicable, were presented in Table 1. CDUS diagnosed the occlusion of the major arteries in all but could not demonstrate the collateral circulation in four of the patients. Angiography confirmed the diagnosis and finely depicted all the collateral blood flow. Table 2 demonstrates the distribution of occluded and stenosed arteries. Arch aortography revealed occlusion or stenosis of the origin of the main arteries but could show the patency of the carotid arteries distal to the occlusion in only two patients. Selective injection of the VA ipsilateral to the occluded CCA with delayed images revealed retrograde contrast filling of the occipital branch of the ECA through vertebrocarotid collateral in all patients. Contrast in the ECA in turn, opacified the ICA in four patients excluding two patients with occlusion of the origin of the ECA. Angiography also showed severe stenosis (>50%) or occlusion of at least one of the remaining extracranial cerebral arteries in each patient. Some DSA features of the patients not displayed on the tables are shown below:

Patient 1 had additional occlusion of the right subclavian artery. There were many small collaterals around the occluded right subclavian artery and the right vertebral artery. Right ECA was also supplying blood to the left ECA through superior thyroid and lingual arteries (Fig. 1).

Patient 2 had severe stenosis of the right (contralateral) CCA bifurcation. This patient had the mildest accompanying lesions in the other extracranial cerebral arteries (Fig. 2). Patient 3 had collaterals from the left ECA supplying the contralateral ECA through the superior thyroid and thyrocervical trunks.

Table 1

<table>
<thead>
<tr>
<th>Patient</th>
<th>Right CCA</th>
<th>Right ICA</th>
<th>Right ECA</th>
<th>Left VA</th>
<th>Left CCA</th>
<th>Left ICA</th>
<th>Left ECA</th>
<th>Left VA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>N</td>
<td>N</td>
<td>Occl</td>
<td>P</td>
<td>P</td>
<td>Occl</td>
<td>P</td>
<td>Occl</td>
</tr>
<tr>
<td>2</td>
<td>St</td>
<td>N</td>
<td>N</td>
<td>Occl</td>
<td>P</td>
<td>P</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>N</td>
<td>St</td>
<td>St</td>
<td>N</td>
<td>Occl</td>
<td>P</td>
<td>P</td>
<td>N</td>
</tr>
<tr>
<td>4</td>
<td>St</td>
<td>N</td>
<td>Occl</td>
<td>St</td>
<td>Occl</td>
<td>P</td>
<td>Occl</td>
<td>P</td>
</tr>
<tr>
<td>5</td>
<td>Occl</td>
<td>P</td>
<td>P</td>
<td>N</td>
<td>St</td>
<td>St</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>6</td>
<td>St</td>
<td>St</td>
<td>Occl</td>
<td>St</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
</tbody>
</table>


Patient 5 was a young lady who had the diagnosis of acute type 1 dissection of the aorta. CDUS showed dissecting flap in both common carotid arteries which were totally occluding the right CCA and left subclavian artery, partially occluding the left CCA and ICA. Angiography showed the right VA was supplying blood to the right ECA and left VA creating retrograde flow in both arteries, a condition called "double steal" (Fig. 3).

Table 2

<table>
<thead>
<tr>
<th>Patient</th>
<th>Sex</th>
<th>Age</th>
<th>Diagnosis</th>
<th>Symptoms</th>
<th>Surgery</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F</td>
<td>67</td>
<td>Atherosclerosis</td>
<td>Left hemiparesis</td>
<td>Left subclavian to left carotid artery bypass</td>
<td>Improved</td>
</tr>
<tr>
<td>2</td>
<td>F</td>
<td>52</td>
<td>Takayasu arteritis</td>
<td>Right hemiparesis</td>
<td>Right subclavian to left carotid artery bypass</td>
<td>No change of symptoms, no recurrence</td>
</tr>
<tr>
<td>3</td>
<td>F</td>
<td>60</td>
<td>Atherosclerosis</td>
<td>Deterioration of previously existing dysartria and right hemiparesis due to previous stroke</td>
<td>None</td>
<td>Ex 6 months after the angiography due to chronic renal failure</td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>53</td>
<td>Atherosclerosis</td>
<td>Vertigo and right hemiparesis, right upper extremity weakness</td>
<td>Left to right subclavian artery bypass (right vertebral artery stenting)</td>
<td>Right upper extremity weakness and vertigo improved</td>
</tr>
<tr>
<td>5</td>
<td>F</td>
<td>40</td>
<td>Type 1 aortic dissection</td>
<td>Sudden loss of consciousness</td>
<td>Resection and repair of dissecting aneurysm</td>
<td>Asymptomatic</td>
</tr>
<tr>
<td>6</td>
<td>M</td>
<td>63</td>
<td>Atherosclerosis</td>
<td>Asymptomatic</td>
<td>None</td>
<td>Asymptomatic</td>
</tr>
</tbody>
</table>
Fig. 1. Arch-aortography (a) shows occlusion of the left common carotid and right subclavian arteries. Note that the left vertebral artery also has a short-segment occlusion (arrow) distal to its origin. Left vertebral artery injection (b) demonstrates filling of the external (ECA) and then the internal carotid arteries (ICA) through vertebrocarotid collateral (arrow). Right common carotid artery (CCA) injection (c) shows faint opacification of the contralateral external and internal carotid arteries (shaded arrow) by superior thyroid and lingual arteries (arrows).
Fig. 2. Arch aortography (a) shows occlusion of the left common carotid artery (arrow) and stenosis of the right common carotid artery at its bifurcation (shaded arrow). Angiography with left vertebral artery (VA) injection shows filling of the occipital branch (arrow) of the left external carotid artery (shaded arrow) (b) and internal carotid artery (ICA) at late arterial phase (c).
Fig. 3. Patient with acute type 1 aortic dissection. Right vertebral artery (VA) injection shows filling of contralateral vertebral artery (subclavian steal) and external carotid artery (ECA) by vertebrocarotid collateral (carotid steal) creating a double steal (shaded arrow).

All the patients except patient 5 had the diagnosis of chronic occlusion by clinical and radiological findings. Four of the patients had surgical reconstruction, and outcome of the operations was presented in Table 2.

4. Discussion

Occlusion of the common carotid or external carotid artery is less frequent than occlusion of the internal carotid artery. Atherosclerosis is the most common cause while collagen tissue diseases with arteritis, fibromuscular dysplasia, post radiation fibrosis and trauma are rare causes [5,6]. The internal and external carotid arteries are usually considered to be occluded by distal propagation of clot after occlusion of the CCA. However, preservation of the patency of the ICA and ECA through collateral vessels is possible. It has been shown that therapeutic ligation of the CCA for cerebral aneurysms failed in some of the patients due to the formation of collaterals keeping the ECA and ICA patent [8]. The main collateral keeping the distal circulation patent in the presence of CCA occlusion is between muscular branch of the VA and occipital branch of the ECA. There are also anastomoses between occipital, lingual, ascending pharyngeal and superior thyroid branches of the ECA with the vertebral, thyrocervical and costocervical branches of the subclavian artery [4]. The ECA can also get collateral from the contralateral ECA mostly through the maxillary artery [2], and ipsilateral ICA through the ophthalmic artery or circle of Willis [8]. These collaterals can also be seen in patients without associated stenosis or occlusion [9,10]. In a patient with occlusion of the ECA and severe stenosis of the ICA, the ascending pharyngeal artery that had its origin at the ICA distal to the stenosis maintained patency of the ICA by getting blood supply from muscular branches of ipsilateral superior thyroid artery arising from the CCA and from the vertebral artery [11]. There are also some embryonic anastomoses that connect the fetal carotid arteries to the dorsal neural arteries which are the precursors of the vertebrobasilar system. The most common embryonic anastomoses are the persistent trigeminal artery and the persistent hypoglossal artery [12]. The former usually arises from the cervical ICA and joins to the basilar artery, and the latter arises from the cavernous ICA and joins to the basilar artery. Proatlantal intersegmental arteries is a less common anastomosis and can arise from the ICA or ECA and anastomoses to the vertebral artery [13]. Magnetic resonance angiography has been shown to have a high sensitivity in the demonstration of intracranial collateral pathways between the carotid and the vertebrobasilar arteries [14].

Some of the studies demonstrating the collateral circulation between extracranial cerebral arteries in the presence...
of CCA occlusion claimed inadequacy of angiography in the demonstration of patent distal circulation [15–20]. They concluded that CDUS is superior to angiography but did not refer to whether or not all the cerebral arteries were examined selectively. In his detailed study, Ozbek [21] reported 10 CCA occlusions with patent ICA and ECA out of 3463 CDUS. Six of the patients had had angiography which had confirmed the patency of the ICA and ECA. Eight of the 10 CCA occlusions shown by CDUS had had severe contralateral cerebral vessel disease. Barnett et al. [22] reported external carotid steal in nine cases. Two of the patients had “double steal” with innominate artery occlusion where contralateral vertebral artery supplied the subclavian and the external carotid arteries.

Angiography without selective injection of the vertebral arteries may not reveal the patency of the ICA or ECA distal to a CCA occlusion. Distal patency of the ICA and ECA was mostly maintained through proximal branches of the subclavian artery. In all of our patients, distal patency was easily demonstrated in the mid or late arterial phase of the ipsilateral vertebral artery injections which disclosed retrograde flow in the ECA in all patients and weak antegrade flow in the ICA in four patients. If angiographies of the VA ipsilateral to the occlusion were not obtained, demonstration of the collateral circulation and patency of the carotid arteries distal to an occlusion could not be possible.

Another finding common to all of our patients was presence of severe stenosis or occlusion of at least one other major extracranial cerebral artery. Although additional stenoses of the extracranial arteries were frequently referred to in other studies, this alone was not thought to be the reason for the development of vertebral collateral. Extracranial collateral circulation was suggested to occur when the cross circulation via the anterior circle of Willis is inadequate [2,3,18]. It is known that anterior communicating artery is absent in only 5% of the population [12]. The incidence of aplasia of the anterior communicating artery is too small to explain the formation of collaterals in most of these cases. We suggest that external carotid steal is mostly, if not invariably, seen when there are at least two severe stenoses or occlusions in the main extracranial cerebral arteries. This should be related to the total amount of blood flow the brain needs to keep vital functions normal.

Vertebrobasilar collateral can dilate and begin to supply distal circulation even in very acute circumstances, as shown in our patient with acute aortic dissection, probably saving the patient’s life. The dissecting flap, originating at the ascending aorta, was completely occluding the right CCA, left subclavian artery and partially occluding the left CCA. Angiography demonstrated that patent right VA supplied the ipsilateral ECA (carotid steal) and the left subclavian artery through the left VA (subclavian steal) creating a double steal. Acute occlusion and rapid collateral formation reflect the rapidity of body’s defence against impaired cerebral perfusion. It is known that dissection of the aorta may extend into the carotid artery partially or completely occluding it, but to the best of our knowledge there is no other case in the literature presenting with immediate formation of a vertebral collateral causing double steal [23]. Takayasu arteritis causing CCA occlusion is not infrequent, but vertebral steal collateral is rarely reported in Takayasu arteritis as is one of the patients presented here [19,21].

A correct diagnosis of the patency of the ICA is important because it helps decide whether a reconstructive surgery would be helpful for the patient, especially in the presence of cerebral symptoms. Surgical correction of a totally occluded CCA is controversial. Prevention of stroke and relief of symptoms from occlusion of the CCA is the principle indication for operative reconstruction. Fear of dislodging clot distally causing a thromboembolic event in the cerebral circulation is the main limiting factor. But if the patency of the ECA or ICA was maintained by collaterals in the face of an occluded CCA, a subclavian to carotid or carotid to carotid by-pass surgery may relieve symptoms of cerebral hemispheric ischemia. Symptoms of two of four patients who had had a reconstructive surgery in our study group improved and the other two patients were free of a new cerebrovascular accident 6 and 8 months after the surgery.

5. Conclusion

Vertebrobasilar collateral supplying blood into the ECA and ICA is a rare communication seen in patients with ipsilateral CCA or ECA occlusion. This collateral is mostly, if not invariably, seen in patients with multiple severe stenoses or occlusions of the extracranial cerebral arteries. Although CDUS usually diagnoses occlusion of the CCA and patency of the distal arteries, selective bilateral VA injection with delayed arterial images is the key to demonstrate the collateral flow and the patency of the ICA and ECA distal to the occlusion. Demonstration of the patency of the distal vessels is very important because some of the patients might get benefit from a reconstructive surgery.

References