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## Compensatory collateral circles in vertebral and carotid artery occlusion.

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*Keywords:* carotid artery occlusion; vertebral artery occlusion; collateral circulation.

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### SUMMARY

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The obstructive disease of the supraaortic trunks has considerable clinical importance.

Patients with the same grade of obstruction can display a wide spectrum of symptoms. Apart from the grade, etiology and localization of the obstruction, the presence of collateral circles plays an essential role in the determination of the symptoms.

We selected all asymptomatic patients, undergoing a diagnostic investigation with EchoColorDoppler in a period of 13 years, in whom an occlusion of the common carotid artery, of the internal carotid artery or of the vertebral artery was present, and we studied the compensatory collateral circles. We considered 8 subjects affected by common carotid occlusion, 66 subjects with internal carotid occlusion and 24 subjects with vertebral artery occlusion.

In the 8 subjects affected by common carotid occlusion, before the bifurcation, the collateral circle was realized by the superior thyroid arteries through the supraisthmus thyroid artery.

All of the 66 subjects with internal carotid disease showed collateral circles through the ophthalmic branches and through the communicating arteries.

In the 24 subjects with vertebral artery occlusion, the compensatory collateral circle was realized by the cervical, costocervical and occipital branches.

In conclusion, the presence of an adequate hemodynamic compensation through a collateral circle represents an important positive prognostic factor and can avoid invasive procedures, thus avoiding possible complications.

## INTRODUCTION

The obstructive disease of the supraaortic trunks has considerable clinical importance.

Patients with the same grade of obstruction can display a wide spectrum of symptoms (Macchi and Catini, 1993; Bisschops et al, 2003), and it is not unusual to find high grade obstructions in completely asymptomatic patients. Apart from the grade, etiology and localization of the obstruction, the presence of collateral circles plays an essential role in the determination of the symptoms (Macchi and Catini, 1993; Telman et al, 2006).

As for other body districts, their presence renders possible a suitable perfusion in the distribution territory of the arteries with total or partial obstruction.

With regard to the obstructive disease of the internal carotid, some studies have focused their attention on the collateral circle through the ophthalmic branches (Macchi and Catini, 1993; Liu et al, 2007), which represent a communication passage between the internal and external carotid arteries, independently from the opening of many other circles to compensate the flow reduction (Liu et al, 2007).

Another collateral circle of great interest is represented by the superior thyroid arteries; this circle creates a connection between the external carotid arteries (Macchi and Catini, 1995). In the case of a total obstruction of the common carotid artery, it permits an anterograde cerebral flow which originates from the other external carotid artery (Reinhard et al, 2003).

Finally, relevant collateral circles have been described in the vertebral region, through the cervical, costocervical and occipital arteries (Macchi and Catini, 1993).

The aim of this study is to detect, in patients affected by supraaortic trunk occlusion, collateral circles, and to evaluate their effectiveness in preserving an adequate cerebral flow.

## SUBJECTS AND METHODS

For this study we considered all the subjects examined in a period of 13 years, from 1982 to 1995, who came under our observation by undergoing a diagnostic investigation with EchoColorDoppler (ECD), independently from symptomatology. There were 10244 subjects, aged  $66 \pm 2$  years, of which 6020 males and 4224 females.

We selected all asymptomatic patients in whom there was an occlusion of the common carotid artery, of the internal carotid artery or of the vertebral artery, and we studied the compensatory collateral circles.

For this study we used the ECD Acuson 128 XP model, with 5 and 7 MHz probe and a digitalized angiography with a Philips DVI 2 instrument.

We considered 8 subjects affected by common carotid artery occlusion, 66 subjects with internal carotid artery occlusion and 24 subjects with vertebral artery occlusion.

## RESULTS

In the 8 subjects affected by common carotid occlusion, before the bifurcation, the collateral circle was realized by the superior thyroid arteries through the supraisthmic thyroid artery.

All of the 66 subjects with internal carotid occlusion showed collateral circles through the ophthalmic branches and through the communicating arteries.

In the 24 subjects with vertebral artery occlusion, the compensatory collateral circle was realized by the cervical, costocervical and occipital branches. (Table 1)

*Internal carotid artery occlusion*

In all of 66 subjects (30 males, mean age  $73 \pm 2$  years, and 36 females, mean age  $76 \pm 3$  years), the occlusion of the internal carotid artery was localized at the origin; in 32 patients the occlusion involved the right internal carotid artery, in 34 patients the left one. The compensatory circle was realized through the external carotid artery: in 31 subjects through a collateral circle that involved the facial, angular and ophthalmic arteries, while in 19 through the ophthalmic branches of the superficial temporal artery, anastomized with the supratroclear or, more frequently, supraorbital artery.

In 9 subjects the compensatory circle was guaranteed by the circle of Willis. In 3 patients we detected a collateral circle across the maxillary arteries and the infraorbital arteries, through the angular artery.

In only 1 case the collateral circle was realized by the contralateral external carotid through an anastomosis between the contralateral supratroclear arteries and the dorsal nasal arteries. In 3 cases the compensatory circle included the maxillary and infraorbital arteries and the medial and lateral branches of the palpebral arteries.

*Vertebral artery occlusion*

The group of 24 subjects with occlusion of the vertebral artery was composed of 10 males (mean age  $49 \pm 4$  years) and 14 females (mean age  $51 \pm 3$  years).

In 11 subjects the collateral circle involved the cervical branches. In 10 subjects the circle was the result of a combination of the cervical branches and the occipital artery. In 3 cases the hemodynamic compensation was realized only through the occipital artery.

In the 11 patients in whom the compensation was effected by the cervical branches, the occlusion was located near the origin of the vertebral artery. In 7 of these patients it involved the right vertebral artery, and in 4 the left one.

In 8 of the 10 cases, where the collateral circles occurred through both the cervical arteries and the occipital artery, the occlusion of the vertebral artery was situated at the origin. In 2 cases the occlusion was at the level of the C6 vertebra. The occlusion in 4 cases involved the left vertebral artery and in 6 cases the right one.

The 3 cases in which there was a compensatory circle only through the occipital artery (because of the occlusion of the right vertebral artery) were similar in dynamics to the previous collateral circles, with the exception of the lack of the opening of the cervical circles.

#### *Common carotid artery occlusion*

The group of 8 subjects with occlusion of the common carotid artery (5 right and 3 left), at the origin, was composed by 3 females (mean age  $45 \pm 1$  year) and 5 males (mean age  $49 \pm 3$  years). All the 8 subjects presented a hemodynamic compensation through the contralateral external carotid artery, across the superior thyroid arteries, and through the supraisthmus artery.

### DISCUSSION

The results of this study confirm that arteries of small calibre, apparently of little significance from the anatomical point of view, play an essential role in the maintenance of the perfusion of the cerebral tissue in the presence of cerebroafferent vessel occlusion. Despite the small calibre of many arteries composing these circles, the flow frequently results sufficient for blood supply.

In the case of an occlusion of the common carotid artery, of the internal carotid artery, or of the vertebral arteries, the possibility of realizing a hemodynamic compensation through the collateral circles is the main element determining the absence of symptoms. With regard to the occlusions of the internal carotid artery, it is not surprising that the relevant collateral circles, guaranteed by the circle of Willis, are significantly inferior compared to the circles supplied by the external carotid artery, which have already been described by many authors (Franceschi, 1981; Fearn et al, 2000). This can be explained by the wide variability of the circle of Willis, frequently showing hypoplastic or absent communicating arteries (Macchi et al, 1996; Urbansky et al, 2008), as also by the variability in the calibre of the vessels (Macchi and Catini, 1994), and by the autoregulation of the flow (Macchi and Catini, 1994). Moreover, a relationship has also been demonstrated between the carotid artery calibre and the configuration of the circle of Willis (Macchi et al, 2003). Finally, the vessel calibre is of fundamental importance because the variability of the calibre of cerebroafferent vessels explains why the same percentage of stenosis has different hemodynamic effects, depending on the entity of the residual lumen (Macchi et al, 2002).

The most impressive results, even if in a small survey, come from patients with common carotid artery occlusion, already described in a small number of subjects in a study of our group (Macchi and Catini, 1995), patients in whom the flow is surprisingly preserved by the superior thyroid artery arch.

This study also underlines that the presence of collateral circles in patients with occlusion of the internal carotid artery is more frequent than in patients with occlusion of the vertebral artery.

TABLE 1— summarizes the totality of the cases described and the collateral circles.

Occluded vessel	N° Cases	M	Mean Age	F	Mean Age	Right side	Left side	Side of occlusion	Coll.Circ.	through	Coll.Circ.	through	Coll.Circ.
<b>Internal carotid artery</b>	66	30	73±2	36	76±3	32	34	Origin	ECA	FA+AA+OB N° 31 C	ECA	TSA+SOA +STA N° 19 C	
<b>Vertebral artery</b>	24	10	49±4	14	51±3	13	11	Origin N° 21 C6 L N° 2	Cer B N° 11 C		Cer B + OA N° 10 C		OA N° 3 C
<b>Common carotid artery</b>	8	5	49±3	3	45±1	5	3	Origin All C	ECA	STrA			

Key: C= cases, C6L= Level of the C6 vertebra; Cer B= cervical branches; Coll.Circ= collateral circle; M= males; F= females; ECA = external carotid artery; FA= facial artery; AA= angular artery; OA= occipital artery; OB= ophthalmic branches; SOA= supraorbital artery; STA= supratroclear artery; StrA=supraisthmic artery; TSA=temporal superficial artery

This can be partially explained by the fact that frequently the compensation through the contralateral vertebral artery is sufficient for the maintenance of an adequate cerebral perfusion, and by the fact that the development of collateral circles between the cervical branches, the occipital artery and the vertebral arteries is anatomically more difficult. We also found a higher prevalence of occlusion of the right vertebral artery, compared to the left, and in women more than men. Furthermore the vertebral artery occlusions more frequently affected patients aged between 27 and 35, suggesting a predisposition caused by the presence of congenital vascular abnormalities.

In conclusion, the presence of an adequate hemodynamic compensation through collateral circles represents an important positive prognostic factor and can avoid invasive procedures, such as revascularization, thus avoiding possible complications.

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