The anatomy and clinical importance of the collateral circles between the vertebral arteries and the cervical, costo-cervical, and occipital

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The Anatomy and Clinical Importance of the Collateral Circles between the Vertebral Arteries and the Cervical, Costo-cervical, and Occipital branches in 52 Living Subjects

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Key words: vertebral arteries, cervical branches, collateral circles.

SUMMARY

In this study, 52 cases of vertebral artery obstruction, comprising 29 women and 23 men between the ages of 27 and 78 years, were taken into consideration. The relevant arterial territories of these patients, who had sought medical attention for a variety of symptoms, were studied by means of doppler ultrasound, duplex, and digital subtraction angiography. Of the original 52 patients, 38 were excluded because of the failure to demonstrate a functional collateral circle with the vertebral artery distal to the point of its obstruction. Of the 14 remaining patients (6 men, 8 women), a collateral circle through cervical branches arising from the thyrocervical and costo-cervical trunks was demonstrable in 7. Six others (3 men, 3 women) demonstrated a collateral circle through a combination of cervical and occipital artery branches. In one (female) case, a collateral circle was demonstrated through the sole occipital artery. With the exception of a single case (a 47-year-old woman), the occlusion was localized to the origin of the vertebral artery. Hemodynamically, the collateral circles were sufficient to maintain perfusion.

INTRODUCTION

The study of the vertebral arteries has always been the subject of much interest. Knowledge of the normal and abnormal anatomy of these arteries is necessary for an understanding of the variable clinical manifestations of disease of these vessels. On account of the variability of their clinical manifestations, pathology of these vessels presents a great diagnostic challenge. It is known that a statistically significant asymmetry of caliber exists between the 2 vertebral arteries

(Orlandini, 1970; Franceschi, 1980; Gulisano *et al.*, 1982; Dauzat *et al.*, 1986; von Reutern and Budingen, 1992). Furthermore, in 4 to about 6% of cases, the left vertebral artery directly from the aortic arch (von Lanz, 1955; Testut and Jacomb, 1974; Lang, 1979; Gray's, 1989), instead of the left subclavian artery. However, most relevant to our studies are the descriptions by several investigators of the formation of compensatory collateral circles as a consequence of the obstruction of a vertebral artery (Franceschi, 1980; Dauzat *et al.*, 1986; Hennerici and Neuebrurg, 1991; von Reutern and Budingen, 1992).

The aim of our study is to confirm the presence of compensatory collateral circles in cases of vertebral artery obstruction and their hemodynamica adequacy, to identify their origin as exaclty as possible, and to determine their significance and clinical implications.

MATERIALS AND METHODS

We have studied 52 cases of vertebral artery occlusion. The patients (23 men, 29 women; age range: 27 to 78 years), had sought medical attention for the following complaints: several «objective» episoders of vertigo ($n=5$; 2 men, 3 women), syncope ($n=3$; 2 men, 1 woman), intermittent episodes of «subjective» vertigo ($n=28$; 13 men, 15 women); a variety of visual complaints, such as «flames» or «scintillation» ($n=6$; 3 men, 7 women).

After the patients had undergone doppler ultrasonography and were found to have velocimetric abnormalities indicative of occlusion of a vertebral artery, a color doppler ultrasound and digital subtraction angiogram of the vertebral artery was performed in each patient.

A Meda Sonic D9 doppler ultrasonography unit, a 5-MHz Acuson 128 color doppler ultrasonography system, and Philips DVI 2 digital subtraction unit were used in our study.

RESULTS

Of the 52 patients examined, 38 failed to demonstrate a compensatory collateral circle, or at any rate a hemodynamically functional collateral circle. These 38 patients were excluded from our study. The remaining 14 patients (6 men, 8 women; age range: 27 to 67 years) who were enrolled in the study were found to have a functional compensatory collateral circle.

In 7 patients (3 men, 4 women), the collateral circle comprised the cervical branches; in 6 (3 men, 3 women), a combination of cervical branches and the occipital artery, and in a single case (female), only the occipital artery.

In the 7 cases in which the cervical branches constituted the compensatory circle, the vertebral artery occlusion was localized to its origin or close to it. In 5 of these cases, the right vertebral artery was involved; in the other 2, the left. *Figures 1*

to 4 summarize the doppler velocimetric tracings and the ultrasound tomographic and angiographic findings in one of the 7 cases in which the vertebral artery was obstructed at its origin, that of a 27-year-old woman with occlusion of the left vertebral artery.

Figure 1 represents the doppler velocimetric tracings in the regions examined. Note the presence of flow in the distal vertebral artery. It is reduced and irregular in comparison to the flow in the contralateral vertebral artery, but nonetheless present (frame A). *Figure 2* demonstrates the ultrasound tomographic findings in the vertebral artery. The lack of color enhancement indicates the absence of flow. *Figure 3* is a reproduction of the angiogram.

In the six cases in which the collateral circle was established through a combination of the cervical branches and the occipital artery, the occlusion of the vertebral artery was localized to the origin in 5 cases and at the level of C6 in one. In 3 cases, the right vertebral artery was occluded; in the other 3, the left.

Figures 4 and *5* illustrate the findings in the case of a 47-year-old woman with right vertebral artery obstruction at the level of the C6 vertebra. *Figure 4* demonstrates the findings of ultrasound tomography. The interruption of blood flow is evidenced by the abrupt curtailment of color enhancement above C6. *Figure 5* is the angiographic representation of the same finding.

Figure 6/1 illustrates the doppler velocimetry of various arteries, while figure 6/2 demonstrates the angiographic findings in a 56-year-old woman who had an obstruction of the right vertebral artery. Note the presence of blood flow in the right vertebral artery at the level of the ansa of the atlas. It is slightly reduced in comparison with the contralateral vertebral artery (frame B). Furthermore, there is evidence (frame C) of diastolic flow in the cervical branches that originate from the costo-cervical and thyro-cervical trunks, as well as in the occipital artery (frame D). These findings confirm that these vessels supply a compensatory circulation to a territory of lower resistance, such as the vertebral arteries. Manual compression of the cervical and occipital zone causes the cessation of flow in the vertebral artery at the level of the ansa of the atlas. This manoeuvre confirms the origin and functional importance of these collateral circles.

The case of obstruction of the right vertebral artery (in a 42-year-old woman) in which the collateral circle was supplied but the ipsilateral occipital artery was completely identical to the preceding case, with the exception that there was no compensatory circle through the cervical collaterals.

Figure 7 illustrates the collateral circles described up to this point.

Among the 14 patients examined, we noted that less severe symptoms corresponded with those who had developed a more extensive collateral circle. In fact, 10 of them (3 men, 7 women) had reported only non-specific complains that were not clearly referrable to insufficiency of the vertebral circulation. Three others (1man, 2 women) presented with visual disturbances that were mostly reported as «flames» or «scintillation». Only one woman complained of recurrent episodes of «objective» vertigo.

DISCUSSION AND CONCLUSIONS

It appears from our study that, in cases of vertebral artery obstruction, the frequency of functional compensatory circle is rare with respect to cases of internal carotid artery obstruction (Franceschi, 1986; Hennerici, 1987; von Reutern, 1992). In part, this may be explained by the frequent presence of adequate compensation through the contralateral vertebral artery; in part, it is explained by the anatomic difficulty of developing a collateral circle among the cervical branches, the occipital artery, and the vertebral artery.

Another finding is the higher prevalence of occlusions among women as compared to men and in the right vertebral artery as compared to the left, even though these data are not statistically significant. Furthermore, it must be emphasized that there is an inverse correlation between the severity of the symotomatology and the functional adequacy of the collateral circle. The finding of vertebral artery occlusions that we have reported does not correlate with age. As a matter of fact, occlusions were more frequent between the ages of 27 and 35. This suggests a high frequency of congenital abnormalities, which may predispose to occlusive events.

The possible establishment of a functional collateral circle confirms the importance of knowing the pathways through which such circles are formed, even if they are found in only a minority of cases. This is important, both for therapeutic and prognostic purposes. Since vascular surgery in this region is extremely delicate, it would be absurd to intervene in cases in which a sufficient collateral circle had been established. Problems associated with the vertebral arteries are always very controversial, since their clinical manifestations are extremely frequent between the ages of 20 and 80, and there is a great deal of confusion regarding this issue (Loeb and Meyer, 1965; Marshall, 1972; Hennerici, 1991). This increases the importance of understanding the anatomy of the collateral circles and justifies the great devotion of research to a filed that may otherwise appear to be of only slight interest.

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LEGENDS

Fig. 1. — Doppler velocimetry tracings; frame A: right and left vertebral arteries.

Fig. 2 — Ultrasound tomographic findings in the vertebral artery. The lack color enhancement indicates the absence of flow.

Fig. 3. — Digital subtraction angiography. The large arrow indicates the left vertebral artery (occluded at its origin) at the point at which the flow of blood is restored by means of the cervical collateral arteries (indicated by the small arrow with the round tip) that arise from the thyro-cervical and costo-cervical trunks.

Fig. 4. — Ultrasound tomographic findings in the right vertebral artery obstruction at the level of the C6 vertebra. The interruption of blood flow is evidenced by the abrupt curtailment of color enhancement above C6.

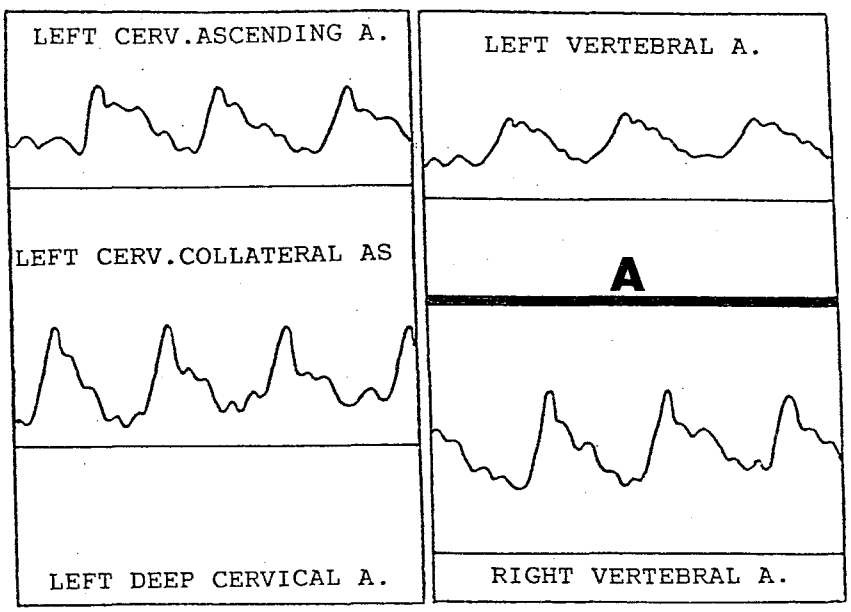
Fig. 5. — Digital subtraction angiography, right vertebral artery. The large arrow indicates the vertebral artery at the level of C6, the point at which it is obstructed. The small, curved arrows indicate the collateral cervical arteries that arise from the thyro-cervical trunk. The small arrow with a square base indicates a branch of the occipital artery. All these arteries contribute to the reperfusion of the vertebral artery at a point distal to the obstruction.

Fig. 6/1, frames B, C, and D. — Doppler velocimetry tracings.

Fig. 6/2. — Right vertebral artery. The clear arrows on the left indicate branches of the deep ascending cervical artery. The small arrow with a square base indicates a branch of the occipital artery. Together, they contribute to the reperfusion of the distal vertebral artery (large, black arrow).

Fig. 7. — Description of the cervical and occipital collateral circles.

. Fig. 1-2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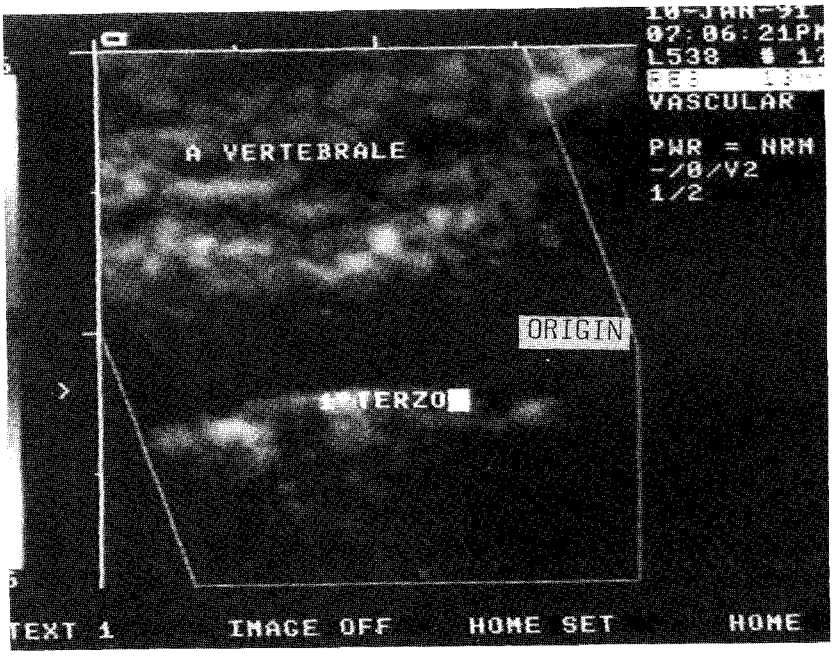
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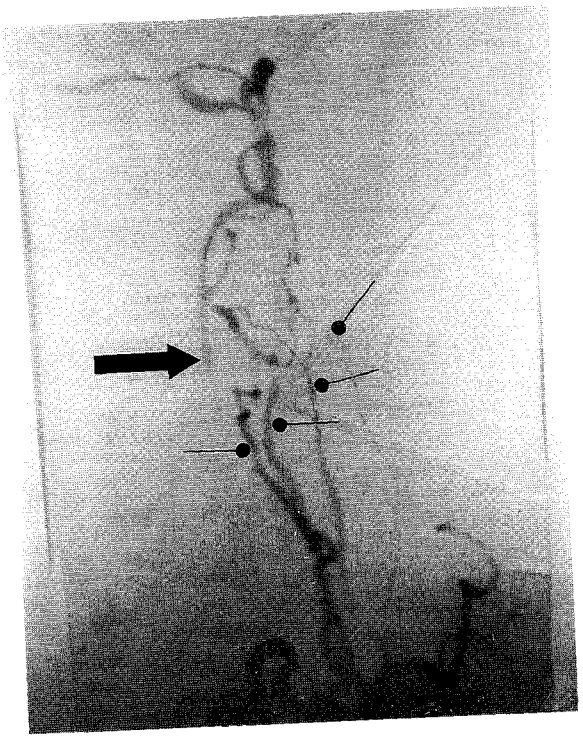
Fig. 3-4



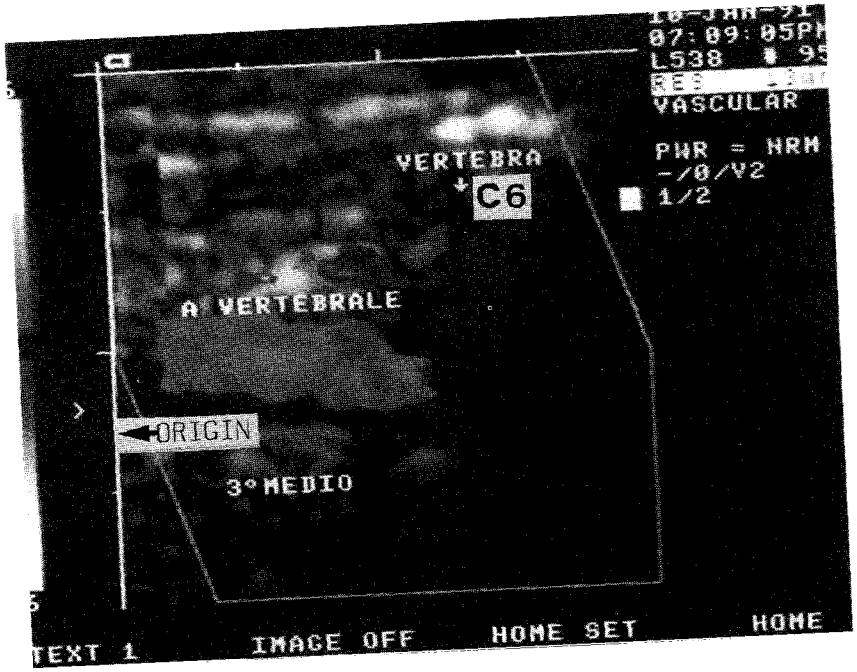

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Fig. 5

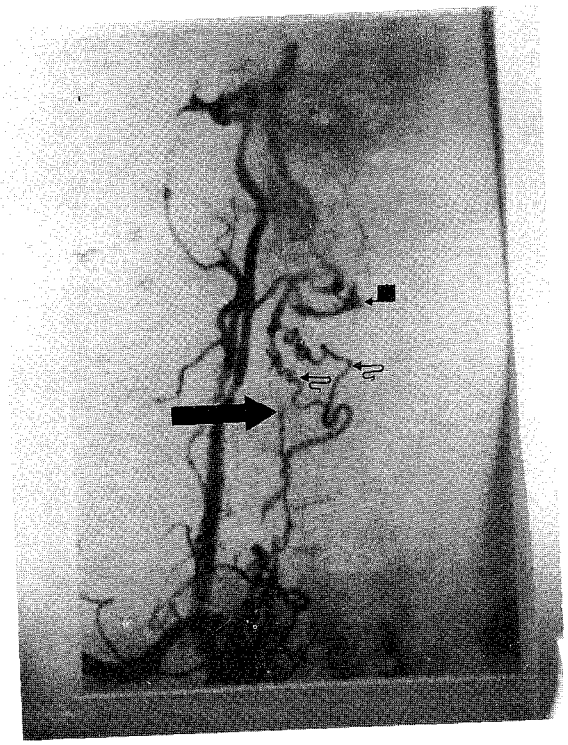


Fig. 6/1 - 6/2

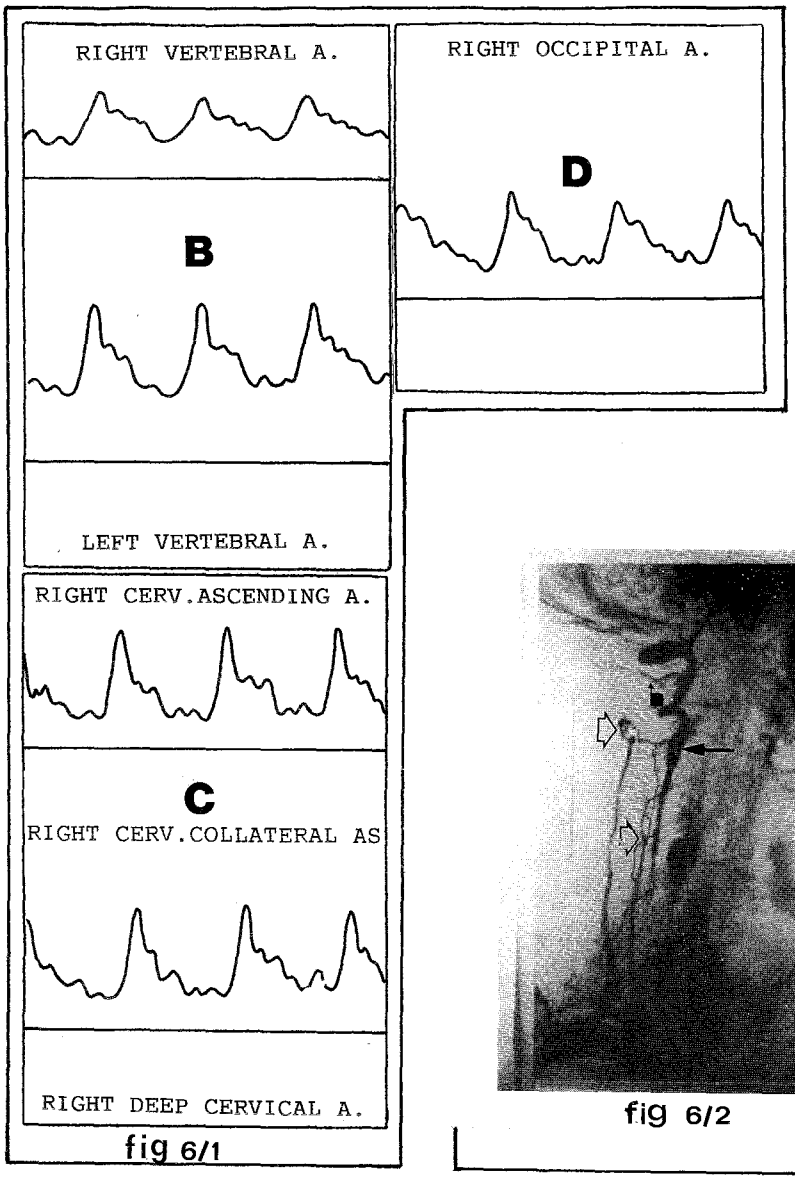
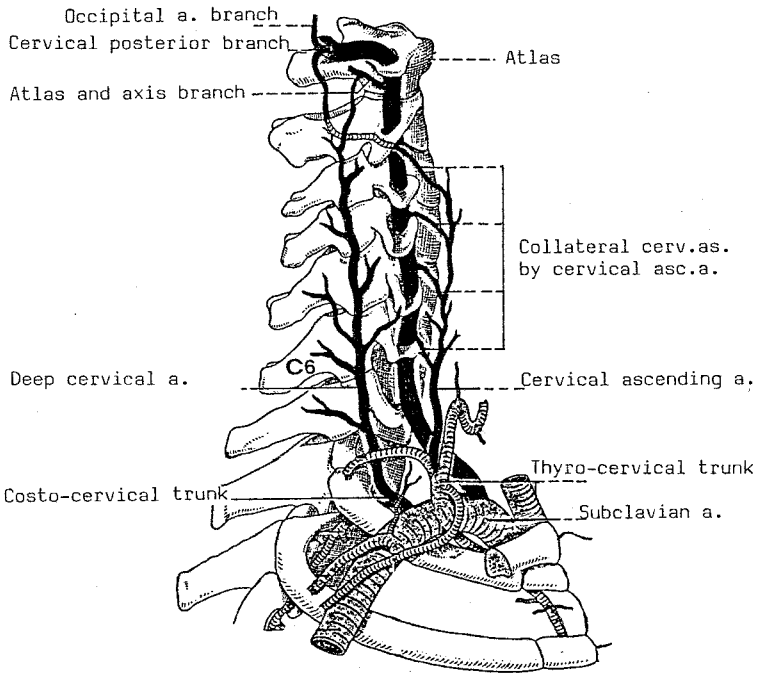


fig 6/1

fig 6/2

Fig. 7


Occipital a. branch
Cervical posterior branch
Atlas and axis branch
Atlas
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by cervical asc.a.
C6
Deep cervical a.
Cervical ascending a.
Thyro-cervical trunk
Costo-cervical trunk
Subclavian a.