Evaluation of the pattern of proximal and distal occlusion and collateral circulation of lower limb arteries using combined contrast arteriography and color doppler ecography.

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Key Words: Echo-color-doppler, contrast arteriography, lower limbs, PAOD, collateral circulation

SUMMARY

Lower limb peripheral arterial occlusive disease (PAOD) is highly prevalent and causes disability and poor quality of life. The purpose of our study was to evaluate the pattern of proximal and distal occlusion and collateral circulation of lower limb arteries using combined contrast arteriography and color doppler ecography.

The study concerned 140 subjects (88 men and 52 women, age range 65-88 years) with symptomatic lower limb arterial disease (Fontaine's stage II) subsequent to the occlusion of vessels downstream from the subrenal aorta. The assessment of lower-extremity PAOD was performed by using the FRASI study three step protocol.

The calculation of the Winsor index showed progressively lower haemodynamic compromission in distal occlusion. The more the site of occlusion was proximal, and the greater was its hemodynamic effect, although there was no statistically significance.

A combined use of contrast arteriography and color doppler ecography appeared very useful in studying the anatomy of the occlusions and their haemodynamic impact, as well as in analysing the presence and the effects of collateral circles. These findings may be fundamental for identifying the most correct indications for surgical therapy and for selecting optimal strategies and prostheses.

INTRODUCTION

Lower limb peripheral arterial occlusive disease (PAOD) is highly prevalent and causes disability and poor quality of life (Selvin, 2004). Vascular surgery is an ever expanding specialty, and nowadays new reconstructive techniques allow adequate perfusion of districts distal to stenotic or occluded arterial tracts by means of artificial or biological arterial prostheses (Becquemin et al., 2003; Kudo et al., 2006; Sabeti et al, 2007).

The study of the collateral circles is of major importance in pre-operative assessment, so as to plan the optimal surgical treatment. Contrast Arteriography (CA) represents the gold standard for the analysis of arterial anatomy; nevertheless its association with Color Doppler Ecography (CDE) has the potential of outlining the situation of the vessels and of the surrounding tissues in an even better way (Norgren et al, 2007; Rutherford, 2009).

Only a few studies (Macchi et al, 1996; Macchi et al, 1996) are available in the literature reporting clinical research experiences combining CA and CDE), and the most used techniques are still CA in living subjects and coloured resins in the cadaver. The purpose of our study was to evaluate the pattern of proximal and distal occlusion and collateral circulation of lower limb arteries combining CA and CDE.

MATERIAL AND METHODS

We studied 140 subjects (88 men and 52 women, age range 65-88 years) with symptomatic lower limb arterial disease (Fontaine's stage II) subsequent to the occlusion of vessels downstream from the subrenal aorta.

The assessment of lower-extremity PAOD was performed using the FRASI study three step protocol (Bandinelli, 2006):

1) Medical history and clinical examination:
we considered as suffering from PAOD those patients complaining of claudication (according to the key questions of the modified Rose Questionnaire) or showing clinical signs of peripheral hypoperfusion such as reduced or absent pulses, skin ulcers or gangrene. Then we classed subjects according to the modified Fontaine classification (Dormandy et al, 2000):
1: Asymptomatic
2a: Can walk for 300 m without pain.
2b: Pain appears while walking less than 300 m.
3: Pain present at rest.
4: Skin ulcers or gangrene.

2) Continuous Wave Doppler measurement of ankle pressure:
once we had assessed the presence of PAOD through clinical examination, selected patients underwent Ankle-Brachial Index (ABI) measurement (following the protocol

described by Newman for a further classification based upon an instrumental basis). An ABI between 0.90 and 0.50 was considered as single-level arterial occlusive disease, while an ABI below 0.50 was defined as multi-level arterial occlusive disease.

3) Duplex Scan:
after informed consent, each subject with an ABI diagnosis of PAOD underwent CA and CDE of the aorto-iliac and lower limb arteries. Blood flow velocity and pressure were measured by means of CDE.

The haemodynamic significance of the collateral circles was evaluated by calculating the Winsor Index (WI):

WI= (dP X 100)/hP
Where: dP = systolic arterial pressure at the anterior or posterior tibial artery or the average of the two measurements when both were possible; hP = humeral systolic arterial pressure.

For CA a Philips DVI 2 (Amsterdam, Holland) digital imaging subtraction was used. For CDE an Acuson Sequoia (Malvern, USA) Echo-Color-Doppler equipped by 7 MHz probe was used.

Radiologic, ultrasonographic and haemodynamic data were correlated with age, sex and body surface area using Student's "T" test.

RESULTS

The results are presented separately for each level of vascular occlusion. The collateral circle was established as indicated for each level.

- Occlusion of terminal abdominal aorta (2 cases): through the inferior mesenteric and ischial arteries and through the lumbar, iliolumbar and gluteal arteries.
- Occlusion of the iliac tract (5 cases) through the spermatic or ovarian artery followed by the funicular, external pudendal and middle sacral arteries.
- Occlusion of the ilio-femoral tract (8 cases): through the internal and external pudendal arteries and through the ilio-lumbar, obturator, gluteal and circumflex iliac arteries.
- Occlusion of the first tract of the superficial femoral artery (36 cases): through the deep femoral artery and the perforating arteries.
- Occlusion of the terminal tract of the superficial femoral artery (17 cases): through the articular branches of the same artery originating proximal to the occlusion and through the branches of the deep femoral artery.
- Occlusion of the superficial and deep femoral arteries at their origin (5 cases): through the ischial artery (directly and indirectly, through the perforating arteries) and through the tegumental arteries.

- Occlusion of the popliteal artery (9 cases): through the deep femoral artery and, with a possibly less important contribution, through the great anastomotic artery which is connected to the muscular small arterioles originating from the tibio-peroneal trunk, to the recurrent posterior tibial artery, to the articular supero-lateral artery, to the muscular branches originating from the quadricipital artery and the popliteal artery. In this case the blood flows from the superior articular arteries or, less often, from the inferior articular arteries and from the recurrent arteries originating from the tibio-peroneal trunk, to the anterior and posterior tibial arteries.
- Occlusion of the anterior tibial artery (22 cases): through the collateral posterior tibial arteries, and through the collateral peroneal arteries.
- Occlusion of the posterior tibial artery (28 cases): through the great anastomotic artery, through the branches of the arterial circles of the ankle and through the perforating plantar arteries (from the anterior tibial artery).
- Occlusion of the peroneal artery (8 cases): the collateral circle was only through branches of the arterial circle of the ankle.

The evaluation conducted by calculating WI showed progressively lower haemodynamic compromission in distal occlusion. The haemodynamic significance of the index was higher the more proximal the occlusion, though there was no statistical significance.

Table 1 shows the characteristics of the study sample

DISCUSSION AND CONCLUSION

The most important predictor of surgical revascularization outcome is the anatomical and haemodynamic state of the lower limb circulation, regardless of the time elapsed from the onset of symptoms. For these reasons an accurate preoperative assessment with both CA and CDE is of primary importance in the morphological and functional definition of collateral pathways, leading to the best choice of timing and type of intervention (Rutherford, 2001; Rutherford, 2009).

The WI (a pressure index) is also a valid measure of the haemodynamic significance of a stenosis, and can help to evaluate the adequacy of a compensatory circle. In fact, an arterial stenosis or occlusion increases blood flow through high resistance vessels, determining the reduction of the pulsatory wave and of the average arterial pressure downstream (Schumann, 2007). The differences between haemodynamic compromission at the various levels of occlusion are explainable by the analysis of vessels involved in the development of collateral circulation.

The lower haemodynamic significance of an occlusion involving the superficial femoral artery with respect to an iliac stenosis is due to the fact that the deep femoral artery and the circumflex femoral artery can often provide an adequate collateral circulation. On the other hand, the low calibre of the vessels involved in

TABLE 1 — Study sample

Site of Occlusion	N° cases	M	Range of Age	Mean Age	F	Range of Age	Mean Age	Right side	Left Side	Mean WI (%)	Range of WI(%)
TERMINAL ABDOMINAL AORTA	2	1	-	69	1	-	81	-	-	33,2	33,0 - 33,4
ILIAC TRACT	5	3	76-80	78	2	61-65	63	3	2	41	39,9- 42,1
ILIO-FEMORAL TRACT	8	2	58-68	63	6	61-71	66	5	3	38,1	36,2 - 40
1ST TRACT SUPERFICIAL OF FEMORAL ARTERY	36	27	66-84	75	9	72-78	75	16	20	50	47,7 -52,3
TERMINAL TRACT OF SUPERFICIAL FEMORAL ARTERY	17	12	58-72	65	5	64-78	71	8	6	39,3	37,4 - 41,2
SUPERFICIAL AND DEEP FEMORAL ARTERIES AT THEIR ORIGIN	5	2	61-69	65	3	55-63	59	1	4	36,7	35,5 -37,9
POPLITEAL ARTERY	9	3	72-88	80	6	77-81	79	5	4	35,8	33,7 - 37,9
ANTERIOR TIBIAL ARTERY	22	15	63-73	68	7	65-75	70	9	13	45,2	44,3 - 46,1
POSTERIOR TIBIAL ARTERY	28	19	76-82	79	9	80-86	83	13	15	55	52,5 - 57,5
PERONEAL ARTERY	8	4	66-74	70	4	76-80	78	2	6	67	65,8 - 68,2

the collateral circles in the case of a proximal occlusion determines a high haemodynamic compromission. In these cases the most important vessel in the collateral circulation is represented by the funicular artery which connects the external iliac artery both with the internal iliac artery, through the deferential artery, and with the abdominal aorta, through the internal spermatic artery. In some cases, the higher calibre of the vessels forming the collateral circles in the occlusion of the external iliac artery allows an adequate perfusion. This is also due to the high number of connections among the collateral vessels. The compensation is realized through large anastomoses between the obturator arteries and the retropubic branches, between the gluteal artery and the ischial artery, and between the internal pudendal artery and the middle haemorroidal artery.

Popliteal occlusion can only occasionally ensure an adequate perfusion of the leg, since it has a poor outcome when it develops acutely or subacutely. As for the iliac artery, collateral circulation is realized only through the small calibre vessels. Analogously, in the case of anterior tibial artery occlusion, collateral circulation is formed only by small vessels with an unfavourable location (transversal-perpendicular) originating from the posterior tibial and peroneal arteries. In other cases, circulation in the occlusion of the posterior tibial artery can be supplied thanks to large calibre vessels such as the great anastomotic artery, the anterior tibial artery, and the peroneal artery. The same is also true with reference to collateral circulation in the occlusion of the peroneal artery, that develops from both the anterior and posterior tibial artery.

In our study no significant difference between males and women was found, suggesting that aging determines a balancing effect in muscular development, vessel calibre and risk factors for atherosclerosis.

In conclusion, a combined use of CA and CDE appears very useful in studying the anatomy of occlusions and their haemodynamic impact, as well as in analysing the presence and the effects of collateral circles. These findings may be fundamental for the identification of the most appropriate indications for surgical therapy, for the selection of optimal strategies and prostheses.

Arrived 1/10/2009. Accepted 13/10/09

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