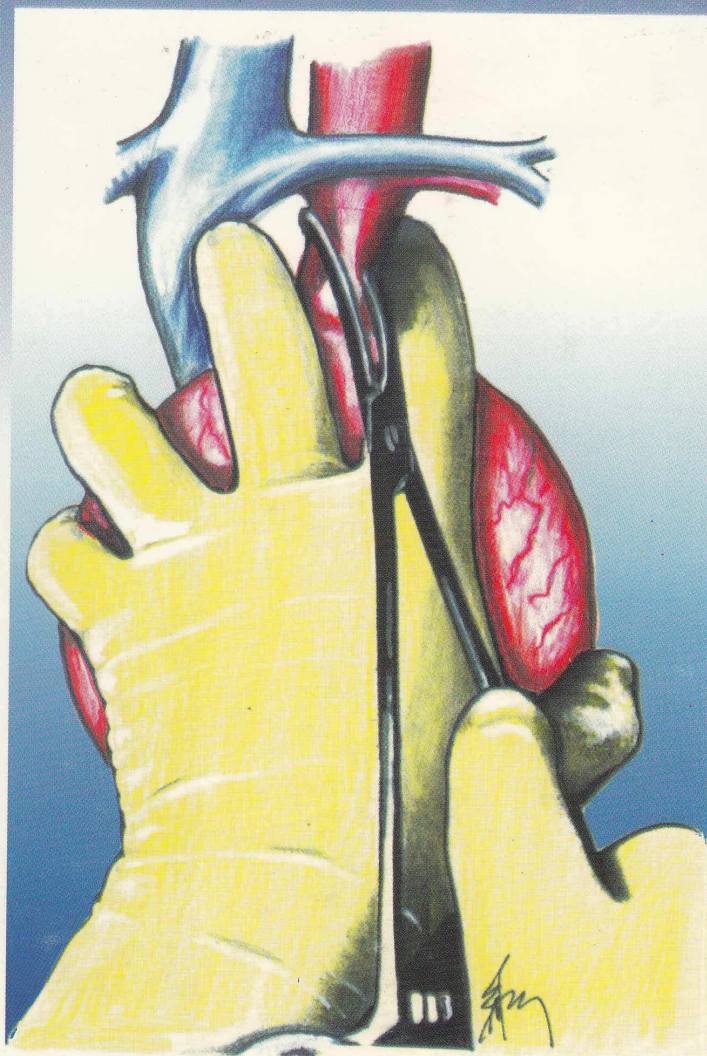


ΤΙΜΗΤΙΚΟΣ ΤΟΜΟΣ

ΚΑΘΗΓΗΤΟΥ Π. ΜΠΑΛΑ



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Analysis of Preoperative Diagnostic Procedures for Assessment of Patients Candidates for Thromboendarterectomy: Survey on 6,000 cases

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Thromboendarterectomy (TEA) of the carotid bifurcation is one of the most efficient means of prevention of cerebral ischemia. Since the first publication appeared in 1954¹ data on a wide series of operations from various Medical Schools referred the incidence of morbidity and postoperative mortality more and more encouraging.^{2,3}

In the United States in the 1980's over 100,000 carotid TEA's were carried out^{4,5} compared to 15,000 in 1971;⁵ Nevertheless, towards the end of the 1980's a series of scientific publications cast some doubts on the value of the TEA as a means of prevention of cerebral infarction.

The conservative treatment^{6,7} as well as the correction or elimination of risk factors^{8,9} have been reconsidered and a consequent reduction in the number of carotid TEA's performed.

The results of a study carried out by NASCET (North American Symptomatic Carotid Endoarterectomy) on a group of symptomatic patients suffering from significant carotid stenosis between 70-99%,¹⁰ seems to have cleared all doubts. It has, in fact, been demonstrated that surgery is more efficient than the best medical therapy in the prevention of cerebral infarction.

Data shows an incidence of ipsilateral cerebral infarction at two years from TEA in 9% of patients, compared to 26% of patients treated medically, whereas the mortality rate is 2.5 and 13.1% respectively.

Nevertheless a disturbing, unpredictable risk of mortality and postoperative cerebral infarction still

remains, despite constant preintra and postoperative methods of cerebral monitoring and protection.

It is therefore mandatory to make precise surgical indications based on a number of clinical and diagnostic considerations; in addition to this the patient must be carefully informed of the risks that may be encountered whenever conservative treatment is indicated. These are mostly due to:

1. Case history of previous symptomatology of transient cerebral ischemia.
2. Age and general physical and cardio-respiratory condition of the patient (coexistence of neoplastic or cardiovascular pathologies which require major surgery in other vascular territories).
3. Characteristics and composition of the carotid plaque.

The purpose of this study is to analyse the procedures of preoperative monitoring for patients undergoing carotid TEA's.

Preoperative Monitoring

The methods of preoperative investigation for a complete study of the carotid plaque in the intra and extra cranial cerebral circulation and of the brain are illustrated in Table 1.

The patients's brain examination and an accurate investigation of the clinical history, fundamental in determining symptoms of previous cerebral ischemia, are to be considered a first approach to be followed by further clinical assessments.¹¹

The data supplied by Doppler, B-mode and ocu-

Table 1. Preoperative investigations.

* History of the patient.
* Clinical examination.
* Doppler scanning.
* B-mode ultrasound.
* Oculoplethismography.
* Duplex scan.
* Color-flow imaging.
* Selective or digital angiography (mono or biplanar)
* CT Scan.

loplethismography is not sufficient for an accurate study of the carotid plaque. At present the majority of surgeons use non-invasive diagnostic procedures (Duplex scan and Color Flow Imaging) and invasive (angiography) prior to surgery, even though there is a tendency to abandon the invasive technique due to neurological complications and morbidity during preoperative angiography^{12,13} which now offer extremely high levels of sensibility, specificity and accuracy in favour of non-invasive diagnostic methods^{14,15,16,17,18} as illustrated by literature.

Some authors¹⁶ relate the significative importance of the Duplex scanner in identifying stenosing plaques, mild but ulcerated and therefore at a high risk of cerebral embolization. It seems always more essential to know not only the site, extension and grade of the plaque but also the composition: calcific, fibrotic, soft, haemorrhagic or ulcerated.

In spite of conflicting data recently appeared in literature^{19,20,21} we believe that the identification of the structure of the plaque is of extreme importance for surgical indication as the risk of embolization depends on the actual composition of the plaque.

At the Non-Invasive Vascular Laboratory of the Bassini Teaching Hospital of the University of Milan, from March 1988 to April 1992, a total of 11,565 Eco-Color-Doppler examinations were carried out, of which 6,041 (52%) of the supra-aortic trunks (Fig. 1) with an accuracy of 92% and a sensitivity of 96%.

Use of the CT scan in routine pre-operative investigations for prospective TEA patients, has recently been criticized by a number of Authors.²² Nevertheless in our Institute all TEA surgery candidates undergo pre-operative CT scan as this

	Total	TSA
Color flow imaging investigations	11,565	6,041 (52%)

Figure 1.

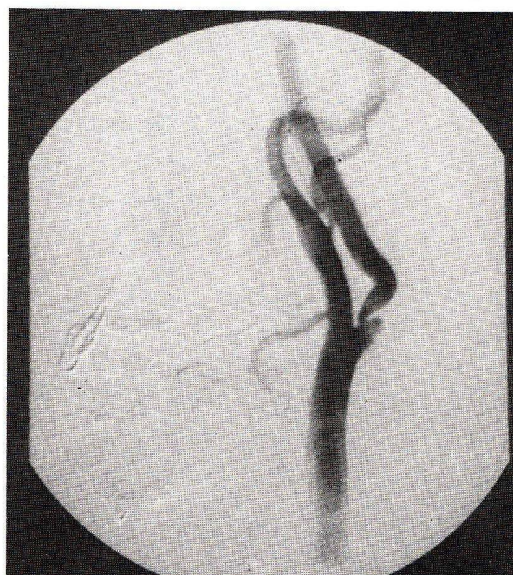
examination can emphasize or exclude other cerebral pathologies, which otherwise might not be recognized (tumours, aneurysms, FAV, etc.).²³

Apart from the conclusion reached from literature, an incidence of 14% asymptomatic cerebral infarction^{22,24} makes, in our opinion, essential the use of the CT scan as a routine preoperative procedure, in order to assess the risk of neurologic damage during clamping and to have indications on the application of a shunt.

A series of 107 consecutive patients operated upon, all except one, submitted to preoperative angiography was analyzed (Fig. 2,3). A confrontation between Color Duplex Scan and angiography, following examination of the surgical specimen, demonstrated the reliability of the non-invasive technique in defining accurately the extension, limits and grade of the stenosis (Fig. 4).

In the last 18 cases surgically treated, the pre-operative Eco-Color images were processed by a computerized programme, made by us,^{*} which gives a graphic analysis of the carotid plaque, extrapolating from the densometric B-mode image the various shades of grey.

The variation in the grey tone indicates the density of the plaque and the composition. The B-mode image of the plaque is formed on the basis of 256 shades of grey, which, divided into three

**Fig. 2.** Digital subtraction angiography: Tight stenosis at the origin of the internal carotid artery (ICA) with a large ulceration within the plaque.

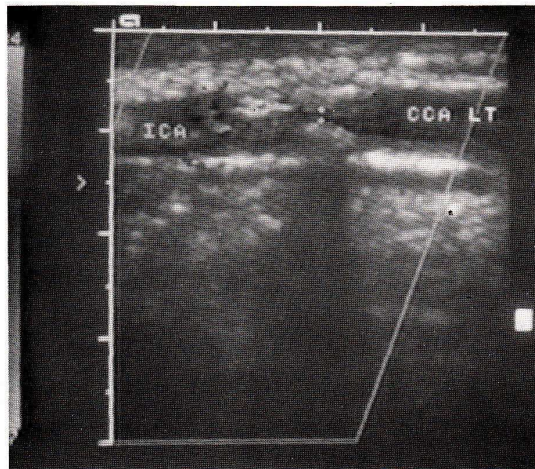


Fig. 3. Color duplex scan examination of a high grade stenosis at the origin of the ICA. Fibro-calcific annular plaque (well in evidence the underlying shadow cone). Ulceration of the distal part of the plaque. Grade of stenosis of 85% (as indicated on the left of the figure). The white color in the ejective tract of the plaque indicates a marked increase in the blood velocity.

	D.S.	Angio.	Surgical Specimen
Stenosis 40% - 70%	11 (100%)	8 (72%)	11
Stenosis > 70%	56 (100%)	49 (87.5%)	56
Ulcerated plaques	20 (80%)	17 (68%)	25
Vertebral steal s.	15 (100%)	15 (100%)	15
	102 (95.3%)	89 (83%)	107

Fig. 4. Accuracy of the different diagnostic procedures (color-flow-imaging and angiography) in defining grade of stenosis and morphological aspects of the plaque-personal observations.

parts, give the three fundamental structural compositions of the plaque (Fig. 5).

After having digitized the image and outlined the plaque, the grey scale is calibrated in the computer, thus giving a visualization of the plaque enlarged in three colours, in line with the main structural components (yellow-soft, green-fibrotic, blue-calcified). (Fig. 6, 7, 8, 9).

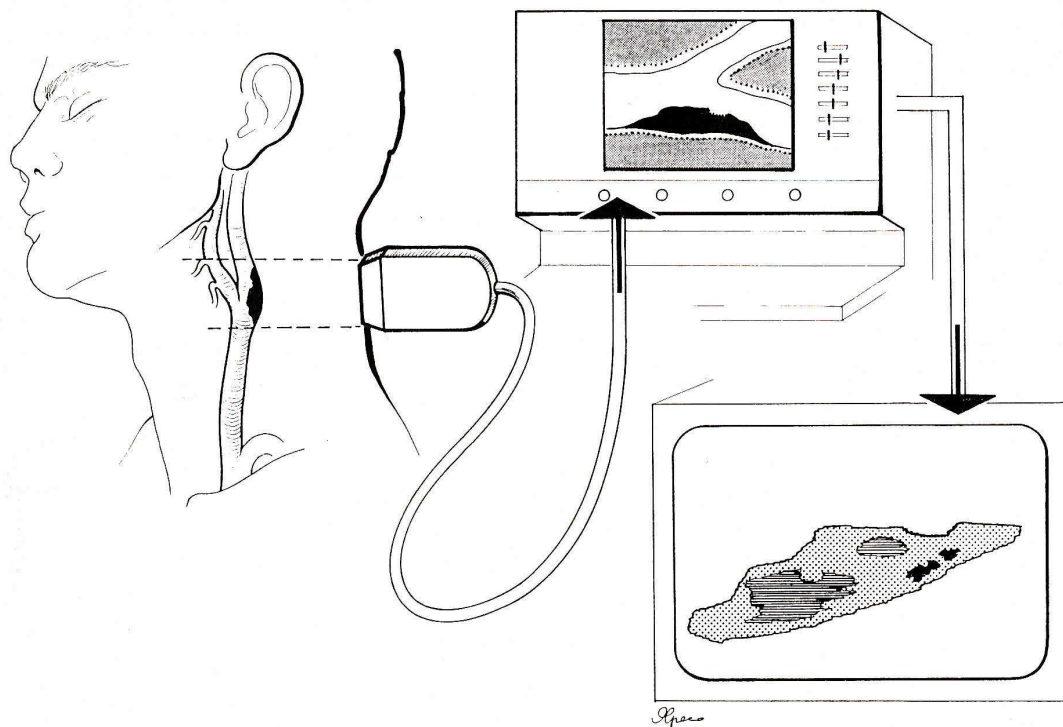


Fig. 5. Explanation in the text.

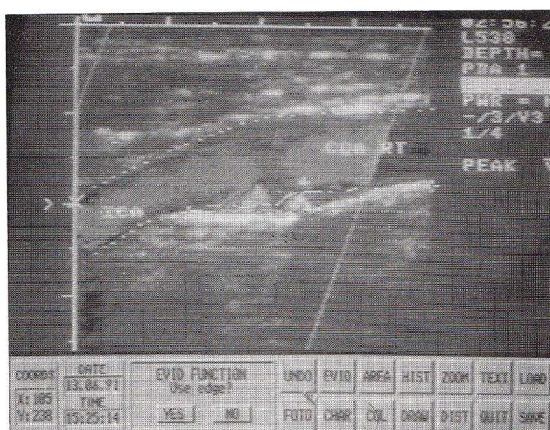


Fig. 6. Once the computerized echographic image has been memorized the plaque is outlined.

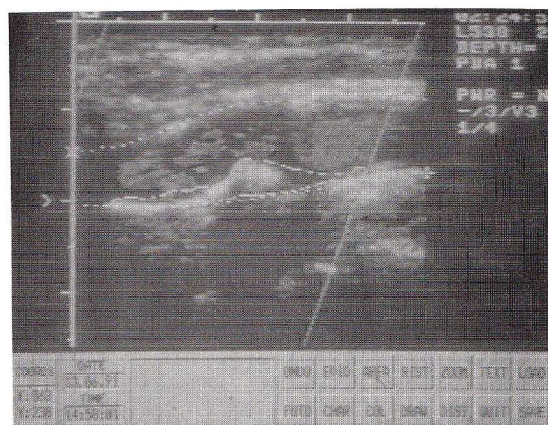


Fig. 8. Another example in which the plaque is outlined and evidenced.

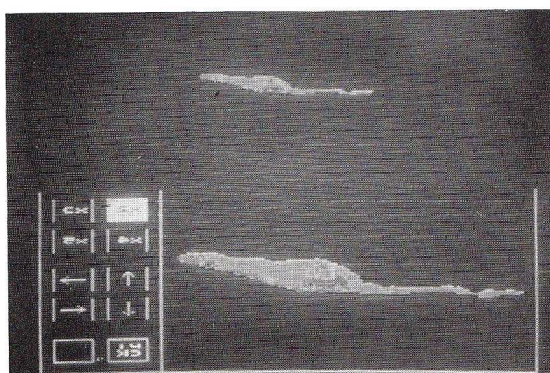


Fig. 7. The computer provides a coloured enlargement of the image of the plaque:
Yellow corresponds to soft tissue.
Green and blue respectively to fibrotic and calcific components.



Fig. 9. The various components of the plaque are visualized and individually analyzed by the computer and their incidence in the plaque is determined exactly and measured.

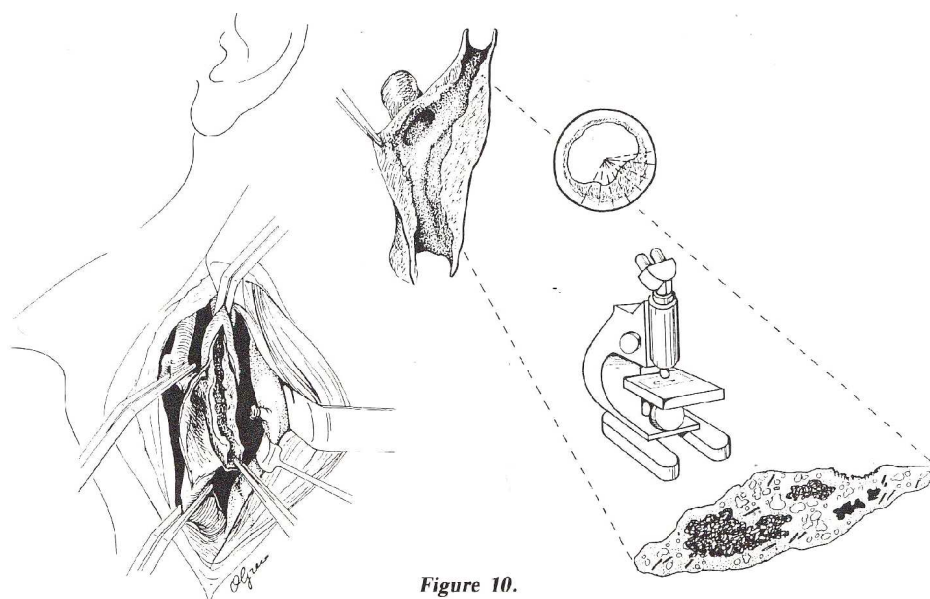


Figure 10.

The software is able to give information regarding the surface of the plaque, the percentage of each of the three components and also the medium echogenicity.

The limitation of this procedure is the dependence on the skill of the operator, and also on the difficulty in obtaining a standard in the shades of grey without being influenced by the anatomical variations of the neck of the patient (depth of artery, interposition of muscle layers, etc.).

The plaque is surgically removed, marked and examined by an histologist who prepares sections which reproduce as near as possible, the echographic image (Fig. 10, 11, 12).

The histological data obtained (with particular attention regarding the definition and site of the components which constitute the plaque (Fig. 13, 14, 15), are then confronted with the Duplex scan memorized data to update the tone in the scale of greys and the shades set up prior to surgery, in order to obtain information as near as possible to reality.

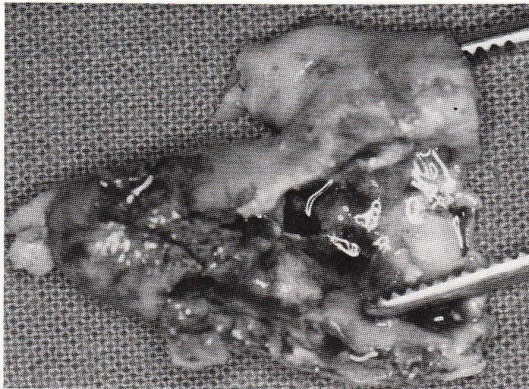


Fig. 11. Same case as figure 6. Macroscopic aspect of the postoperative specimen. Mostly soft and irregular plaque.

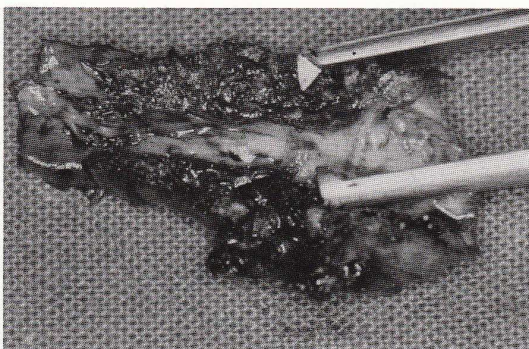


Fig. 12. Same case as figure 8. Postoperative specimen - calcified area in the central part of the plaque.



Fig. 13. Same case as figure 7. The carotid plaque surgically removed is processed and sectioned according to the corresponding preoperative scans.

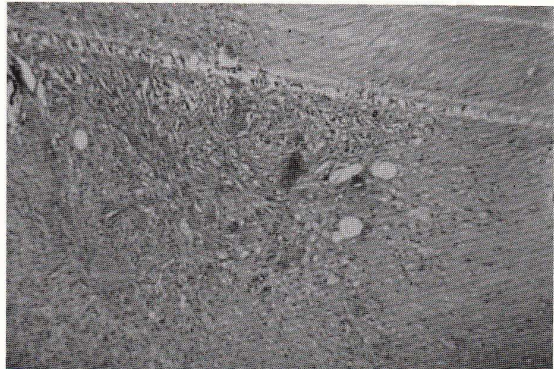


Fig. 14. Same case as figure 8. Histologic aspects of rearrangement of the atherosclerotic plaque. Presence of giant cells.

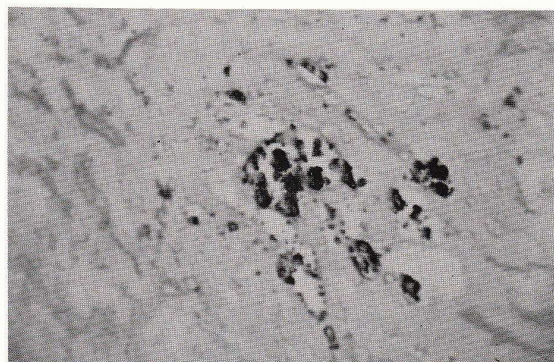


Fig. 15. Same case as figure 8. Fibrocalcific aspects.

References

1. Eastcott H.H.G., Pickering G.W., Rob C.G. Reconstruction of internal carotid artery in a patient with intermittent attacks of hemiplegia. *Lancet* 2:994-6, 1954.

2. Thompson J.A., Patman R.D., Talkington C.M. Asymptomatic carotid bruit: long-term outcome of patients having endarterectomy compared with unoperated controls. *Ann. Surg.* 188:308-16, 1978.
3. Herzer H.R., Arison R. Cumulative stroke and survival ten years after carotid endarterectomy. *J. Vasc. Surg.* 2:661-8, 1985.
4. Dyken M.L., Pokras R. The performance of endarterectomy for diseases of the extracranial arteries of the head. *Stroke* 19:1289-1290, 1988.
5. Pokras R., Dyken M.L. Dramatic changes in the performance of endarterectomy for diseases of the extracranial arteries of the head. *Stroke* 19:1289-1290, 1988.
6. Warlow C.P. Carotid endarterectomy: Does it work? *Stroke* 15:1068-76, 1984.
7. Antiplatelet Trialists' Collaboration. Secondary prevention of vascular disease by prolonged antiplatelet treatment. *Brit. Med. J.* 296:320-31, 1988.
8. Garraway W.M., Whismant J.P. The changing pattern of hypertension and the declining incidence of stroke. *Jama* 258:214-217, 1987.
9. Mayberg M.R. et al. for the Veterans' Affairs Cooperative Studies Program 390 Trialist Group. Carotid endarterectomy and prevention of cerebral ischemia in symptomatic carotid stenosis. *Jama* 266:3289-3294, 1991.
10. North American Symptomatic Carotid Endarterectomy Trial (NASCET) Collaboration. Beneficial effect of carotid endarterectomy in symptomatic patients with high-grade stenosis. *N. Engl. J. Med.* 325:445-53, 1991.
11. Goldman L., Koller R.L., Lebow S.S., Loewenson R.B., Anderson D.C. Cervical bruits: Clinical correlates of stenosis. *Angiology* 42:491-7, 1991.
12. Moore W.S., Ziomek S., Quinones-Baldrich W.J., Machleder H.I., Busuttill R.W., Baker J.D. Can clinical evaluation and non-invasive testing substitute for arteriography in the evaluation of carotid artery disease. *Ann. Surg.* 208:91-4, 1988.
13. Martin K.D., Patterson R.B., Fowl R.J., Kempczinski R.F. Is the continued use of ocular pneumoplethysmography necessary for the diagnosis of cerebro-vascular disease? *J. Vasc. Surg.* 11:235-43, 1990.
14. Polak J.F., Dobkin G.R., O'Leary D.H., Wang A., Cutler S.S. Internal carotid artery stenosis: accuracy and reproducibility of color-doppler assisted duplex imaging. *Radiology* 173:793-8, 1989.
15. Londrey G.L., Spadone D.P., Hodgson K.J., Ramsey D.E., Barkmeier L.D., Sumner D.S. Does color-flow imaging improve the accuracy of duplex carotid evaluation? *J. Vasc. Surg.* 13:659-62, 1991.
16. Comerota A.J., Katz M.L., White J.V., Grosh J.D. The preoperative diagnosis of the ulcerated carotid atheroma. *J. Vasc. Surg.* 11:505-10, 1990.
17. Hass W.K., Fields W.S., North R.R., Krichell I.I., Chase N.E., Bauer R.B. Joint study of extracranial arterial occlusion as a cause of stroke-II Arteriography, techniques, sites and complications. *Jama* 203:961-8, 1968.
18. De Amicis P., Mingazzini P., Bellucci D., Abbritti F., Albizzati M., Biasi G.M. La diagnostica eco-color-doppler nella chirurgia della carotide. *Atti 93° Congresso Soc. It. Chir.-Ott.* 1991, Ed. Minerva Medica 881-83.
19. Leen E.J., Feeley T.M., Colgan M.P., O'Malley M.K., Moore D.J., O'Brein Hourihane D., Shanik G.D. "Haemorrhagic" Carotid Plaque Does Not Contain Haemorrhage. *Eur. J. Vasc. Surg.* 4:123-28, 1990.
20. Sterpetti A.V., Hunter W.J., Schultz R.D. Importance of ulceration of carotid plaque in determining symptoms of cerebral ischemia. *J. Cardiovasc. Surg.* 32:154-58, 1991.
21. Shanik G.D., Moore D.J., Leahy A., Grouden M.C., Colgan M.P. Asymptomatic carotid stenosis: a benign lesion? *Eur. J. Vasc. Surg.* 6:10-15, 1992.
22. Martin J.D., Valentine R.J., Myers S.I., Rossi M.B., Patterson C.B., Clagett G.P. Is routine CT scanning necessary in the preoperative evaluation of patients undergoing carotid endarterectomy. *J. Vasc. Surg.* 14:267-70, 1991.
23. Vollman R.W., Eldrup-Jorgenson J., Hoffman M.A. The role of cranial computed tomography in carotid surgery. *Surg. Clin. North. Am.* 66:255-68, 1985.
24. Sise M.J., Sedwitz M.M., Rowley W.R., Shackford S.R. Prospective analysis of carotid endarterectomy and select cerebral infarction in 97 patients. *Stroke* 20:329-32, 1989.