Comparison of Doppler Sonography and Plate Thermography for Detection of Carotid Artery Stenosis

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SUMMARY Foils coated with specific cholesterol esters indicate differences in temperature by changes in color. When these foils are placed on the skin, the skin temperature measured is related to the perfusion provided by the vessels supplying this area of the skin. A group of 300 patients were examined simultaneously with plate thermography and directional Doppler sonography in order to detect obstruction or occlusions of the carotid artery. Abnormalities were found in 42 patients. In 31, the positive findings obtained by the 2 methods were in agreement. In 8 only plate thermography gave a positive result, and in 3 only Doppler sonography yielded a relevant finding. Plate thermography as a method for the detection of a stenosis or an occlusion of the carotid artery is suggested as useful for an initial screening method.

Method and Material

A total of 300 patients of both sexes were examined with plate thermography and with Doppler sonography (System Delalande). The patients were divided into 3 groups:

A. Normal Group. The first group, a normal control group, consisted of 100 patients (38 women, 62 men), over 50 years of age (average 62.6 years). None had history or clinical findings of cerebrovascular disease. The EEG and the results of Doppler sonography were unremarkable.

B. Stroke Group. The second group consisted of 100 patients (32 women, 68 men) (average age 68.7 year). All had had a stroke with neurological deficits indicating a supratentorial lesion. Plate thermography was performed within 24 hours after onset of symptoms.

C. Doppler Sonography Group. The third group consisted of 100 further patients (41 women, 59 men) (average age 54.3 years). All of these patients were referred for Doppler sonography because they presented with either transient ischemic attacks, which were thought to be of carotid artery origin, or they had an audible bruit in the neck at clinical examination.

While expensive and complex equipment, including radiation detectors, infrared cameras, and conversion from thermic radiation into an electrical signal for the reproduction of heat, was being developed, Ferguson, in 1964, discovered that certain specific cholesterol es-
FIGURE 1. The plate or foil (28 cm long and 5 cm wide) should be placed directly on the skin of the patient. After a few seconds the coloration appears. Normal result: both sides are equal in color.

Ters reacted to temperature oscillations with color changes. Only after a soft, pliable, synthetic material had been developed so that the cholesterol crystals could be applied as microcapsules to various parts of the body, was it possible to use this diagnostic method easily. The plates which are now available may be used repeatedly and show differences in temperature with adequate accuracy.

The method indicates differences in color shades ranging from brown-black to a rust color and to reddish, orange-yellow-green, green-blue, blue to marine and to violet tones. The method can differentiate differences in temperature of 0.1°C. For the examination of the forehead there are 3 different foils available, with temperature spans of 32–33°, 33–34°, and 34–35° (Bayer AG, Abteilung Biomedizinische Technik, D-5090 Leverkusen, Germany.)

The plate thermography tests were conducted with foils (28 cm long and 5 cm wide) that were narrow, very flexible and easy to apply to the patient’s forehead. Within a few seconds after application, color appeared on the plate and, after its removal, the color vanished and the plate returned to its original color so the foil may be used repeatedly. When handled with care, the foil may be used up to 200 times.

If no unequivocal difference in temperature could be found in spite of using several thermosensitive foils, the forehead of the patient was cooled for 2 minutes with a ventilator. The reactive hyperemia produced by this measure made it easier to recognize differences in skin temperature and, thus, perfusion, when the plate was again applied to the skin (so-called dynamic plate thermography).

A grading scheme for the color differences was introduced: 1) uncertain difference, 2) small but reproducible difference, 3) clear difference. Only the last grading was used in this work.

In all patients, the Doppler examinations were carried out in the following manner. The Doppler probe was applied to both carotid arteries in the neck and a differentiation was sought between the external and internal carotid arteries on both sides. Subsequently, the medial frontal artery was sounded with and without compression of the external carotid artery branches supplying the face. An increase in flow on compression of the branches of the external carotid artery or a reverse of the flow direction in the medial frontal artery were regarded as indications of a stenosis or an occlusion of the internal carotid below the junction of the ophthalmic artery.

In all three groups, plate thermography was per-
FIGURE 2. Stenosis of the internal carotid artery on the left side. On the left side of the forehead (right side of illustration) there is a color diminution in comparison to the other side.

formed first, then the subjective impression about a color difference on comparing the 2 sides was recorded and, finally, Doppler sonography was carried out.

Results

Technically, the best results were obtained by using plates sensitive in the range of 33°C. In doubtful cases, foils for 32° and 34°C were used as well.

A) Normal Group. In a group of 100 patients whose case history, clinical examination, EEG and Doppler examination gave no indication of cerebrovascular disease, a difference between the 2 sides of the forehead was observed on only 2 occasions. These must be considered as false positive results.

B) Stroke Group. Among the 100 patients who had suffered a stroke according to clinical examination, a positive result was seen with plate thermography in 6. Five of these 6 patients had unequivocal indications by Doppler sonography of a unilateral disturbance in the carotid artery blood flow. Plate thermography produced one false positive result when compared to Doppler sonography. There were no false negatives in this group.

C) Doppler Sonography Group. Among the 100 patients who were referred for Doppler sonography because of previous examinations, there were pathological findings at plate thermography in 31 and at Doppler sonography in 29. In 26 patients the results of plate thermography and Doppler sonography were in agreement. In 3 patients only Doppler sonography yielded an abnormal finding without a skin temperature difference on plate thermography. In 5 patients only plate thermography showed a difference between the 2 sides which could not be confirmed by Doppler sonography (table).

In comparing Doppler sonography to plate thermography there were 5 false positive and 3 false negative results as well as 26 findings in which both method results were similar. Among the 300 patient investigated, there was a positive finding on Doppler sonography in 34 and a positive finding using plate

| TABLE Pathological Findings with Plate Thermography, Doppler Sonography and the Coincidence of the 2 Methods. |
|---|---|---|---|
| n | Pathological results with Plate thermography | Doppler sonography | Plate thermography and Doppler sonography |
| Group a) | | | |
| Normal persons | 100 | 2 | 0 | 0 |
| Group b) Stroke-attack patients | 100 | 6 | 5 | 5 |
| Group c) TIA patients | 100 | 31 | 29 | 26 |
| | 300 | 39 | 34 | 31 |
thermography in 39. A comparison of the incidence of 2 occurrences was measured biometrically with the chi-square test. This test shows whether the basic similarities of the 2 groups from which samples are taken are significant or accidental. With the chi-square result of 0.32, there is no significant difference between results of the 2 methods of investigation.

Discussion

Screening diagnostic measures have been important in the early diagnosis of obstructive and occlusive disease of the cerebral arteries. Since the screening tests are reliable, they are a good aid in indicating the need for cerebral angiography. In recent years, Doppler sonography has attained a special importance for this purpose. A comparison between Doppler sonography and angiography shows a high degree of correlation (von Reutern 1976). However, Doppler sonography will probably not be used widely as a screening method for 2 reasons. First, the average amount of time necessary for the examination is 20 minutes and, secondly, the method requires practice and experience as well as thorough knowledge of cerebral vessel anatomy.

In comparison to Doppler sonography, plate thermography is a simple procedure, since it consists only of placing a foil on the forehead and observing it for several seconds for color change. Thus, it is a diagnostic aid which can be widely employed.

Both methods, thermography and Doppler sonography, have limitations. They are only sensitive in hemodynamically significant vascular lesions, including high grade stenosis or occlusion. They are likely insensitive to potentially important but nonstenotic occlusive lesions such as ulcerated plaque and they are only applicable to vascular disease in the carotid territory.

In our experience no final conclusion may be drawn from the color differences shown by plate thermography between the right and the left half of the forehead so far as localization of the cerebrovascular lesion is concerned. When one side of the forehead is cooler than the other, a stenosis or occlusion of the internal carotid artery may exist on this side. However, it is equally possible that there may be an occlusion of the external carotid artery on the other side which leads to an increased circulation of the internal carotid artery and thus to a greater warmth of this half of the forehead. The diagnostic information is thus limited to a difference in color between the 2 sides.

Although one subjective diagnostic method, namely plate thermography, was compared to another subjective method, Doppler sonography, there was a fairly good correlation in a series of 300 examinations of patients. Since plate thermography is a quick and easy method, it may be of value as a first diagnostic procedure in a general practitioner’s office. Should a positive result be found, the diagnosis should be followed up by a Doppler study. Further diagnostic examinations should be made when the history and clinical examination are suspicious of ischemia even though plate thermography yields a negative result.

References

Comparison of Doppler sonography and plate thermography for detection of carotid artery stenosis.
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