ECG-Gated Blood-Pool Study of Carotid Arterial Pulsation as a Sign of Stenosis: Concise Communication

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The large elastic arteries, such as the carotids, pulsate (expand and contract) in synchrony with the heart beat. These pulsations should be reduced by significant stenosis. This hypothesis was studied in 15 men by obtaining sequential ECG-gated labeled blood-pool images of these vessels in anterior and lateral oblique views. These were computer processed by a functional program that displays each pixel with an intensity proportional to its change in activity level during the cardiac cycle. Blank areas indicated lack of pulsation and were correlated with angiographic studies. The blank skip areas were present when there was 50% or greater narrowing in arterial diameter (94% sensitivity) but were not seen in patients with normal or minimally diseased vessels (25% or less narrowing). They were present inconsistently in the four vessels with 25 to 50% narrowing.

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Occlusive disease of the coronary and carotid arteries is quite likely to coexist (*1*). It would be useful and efficient if the same noninvasive screening tests used to detect one could also be used at the same session for the other. Of the tests commonly used, which include echography (imaging and Doppler), thallium-201 scanning, and dynamic wall-motion study, an analysis of ECG-gated dynamic activity seemed most likely to be applicable in both areas. This study is the result of an effort to adapt the conventional ECG-gated blood-pool study to a noncardiac site, and to verify its utility.

Twenty-four patients were referred for noninvasive imaging of the carotid arteries because of clinical suspicion of disease based on symptoms ranging from transient ischemic attacks to minor stroke or the physical finding of bruit. The patients were all male, aged 52 to 76 yr. This report considers only the 19 patients on whom carotid angiography was performed within the three months before or after this study.

METHODS

Red blood cells were labeled in vivo, by the method of Pavel et al. (*2*), using 3 mg Sn PPi and 20 mCi Tc-99m as pertechnetate. ECG leads were connected. For the anterior view, patients were positioned supine with the neck slightly hyperextended under a camera with standard field of view and a LEAP collimator. Acquisition of a 14-frame multiple gated study was performed using commercial software and computer. Frame duration was calculated so that the 14 frames should occupy the first 75% of the cardiac cycle.

Similar acquisitions were obtained in 45° LAO and RAO positions, with the head turned slightly away from the side undergoing study in order to allow closer approach of the collimator. Each study was then processed by a functional program in which each pixel was searched through each frame for change between its maximal and minimal count levels (ΔA); a parametric image was then displayed highlighting those pixels with greatest ΔA.

This has the effect of displaying only those areas where pulsatile flow is occurring, thus blanking nonarterial blood pools, as well as portions of the arteries where pulsation is damped by stenosis.

RESULTS

Individual patients are presented in tabular form in Table 1, where 38 vessels are available for analysis. Of 19 vessels with hemodynamically significant disease

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TABLE 1

Patient	Right carotid Nuclear	Right carotid Angio	Left carotid Nuclear	Left carotid Angio
1	Normal	Minimal	Mild reduction	50% stenosis
2	Normal	Normal	Normal	Minimal
3	Equivocal	25–50% sten	Reduced	50% stenosis
4	Reduced	>50% stern	Reduced	>50% sten
5	Normal	25–50% sten	Normal	>50% sten
6	Normal	Minimal	Reduced	Endarterectomy
7	Normal	Minimal	Reduced	>50% sten
8	Reduced	>50% sten	Reduced	>50% sten
9	Reduced	25–50% sten	Reduced	>50% sten
10	Reduced	>50% sten	Reduced	>50% sten
11	Normal	Minimal	Mild reduction	25–50% sten
12	Reduced	>50% sten	Reduced	>50% sten
13	Normal	Minimal	Normal	Minimal
14	Normal	Minimal	Normal	Minimal
15	Normal	Minimal	Normal	Minimal
16	Reduced	>50%	Reduced	>50%
17	Severely reduced	Occluded	Reduced	>50%
18	Reduced	>50%	Reduced	>50%
19	Normal	Minimal	Normal	Minimal

(defined angiographically as greater than 50% diameter shrinkage of an internal carotid artery), only one was missed. (Only an anterior view had been obtained in this individual.) The other 18 were correctly identified as positive on one or both views, yielding a sensitivity of 94%. All 14 vessels with angiographically determined minimal disease (under 25% occlusion) were considered normal (specificity 100%). Of four vessels with stenosis in the 25% to 50% range, two were felt to be abnormal (Figs. 1–4).

A defect was seen where one patient had undergone endarterectomy. This has also been seen in another patient, not included in this series, and is considered an endarterectomy artifact rather than false-positive result.

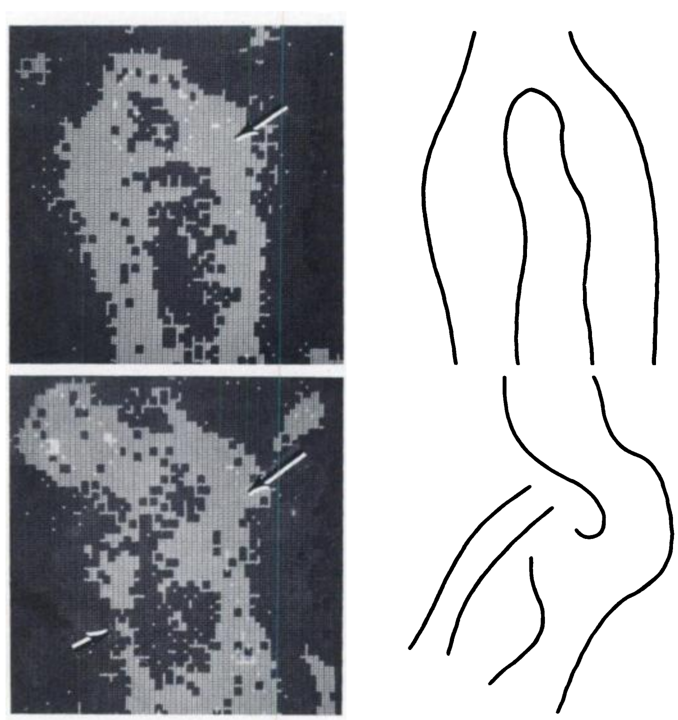

FIG. 1. Normal study. Anterior (upper, left) and LAO views (lower, left). Long arrows indicate approximate level of carotid bifurcation. Short arrow (lower left) indicates opposite vessel. Sketches are adjacent to corresponding functional images showing uniform pulsation along vascular channels.

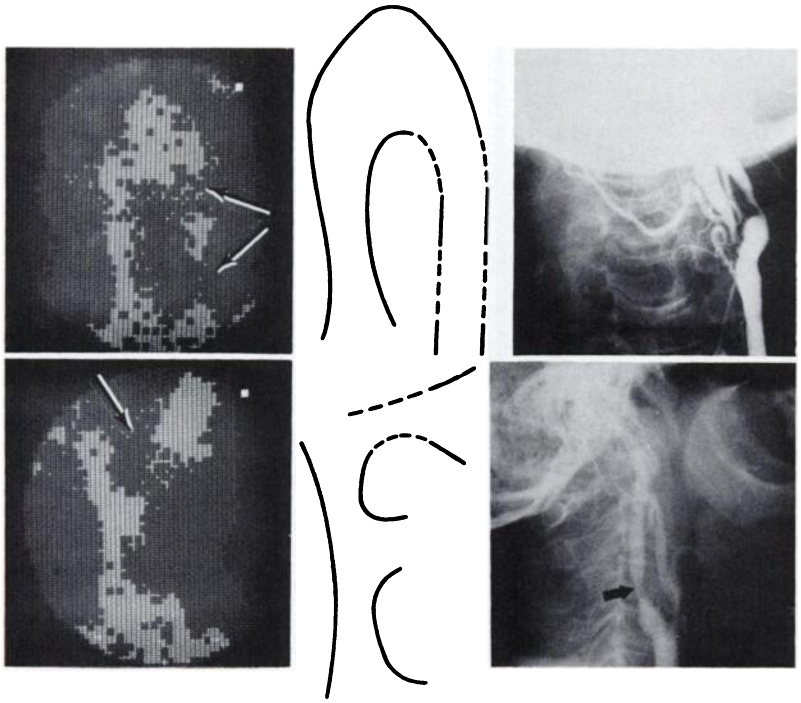

FIG. 2. Severe stenosis, anterior view (upper left), anterior projection, left carotid angiogram (upper right). Lower arrow indicates common carotid artery which, though not stenosed, appears to have reduced pulsation. RAO view (lower left), same patient, reveals moderate disease not apparent on anterior view but confirmed by right carotid angiogram, lateral view (lower right). In this and subsequent illustrations, dashed areas in sketch indicate foci of diminished pulsation shown in functional images as areas of decreased activity.

One patient has been studied on two occasions, three months apart, with identical results.

DISCUSSION

In this technique, a functional image of the carotid vessels is produced, based upon changing activity levels (pulsations) along the length of the vessel during the cardiac cycle. In order to relate this to anatomic patency or obstruction, several assumptions are made. First, that in a normal vessel, these pulsations will be relatively uniform throughout its extent, or that any nonuniformities will be reproducible from patient to patient. Second, that at and beyond a hemodynamically significant obstruction, pulsation will be diminished. Several mechanisms might account for this: loss of vessel distensibility owing to wall thickening at the stenosis; or pressure drop across an area of stenosis resulting in lower pulse pressure distally.

These assumptions appear largely to have been borne out. Functional images of normal or minimally diseased carotid vessels display uniform activity along their length, suggesting uniform pulsatility, whereas images of stenotic vessels reveal blank areas, suggesting loss of pulsatility. This is not surprising because the larger arteries, of predominantly elastic medial construction, normally distend and contract in response to the pulse wave, thus contributing to the propulsion of the blood.

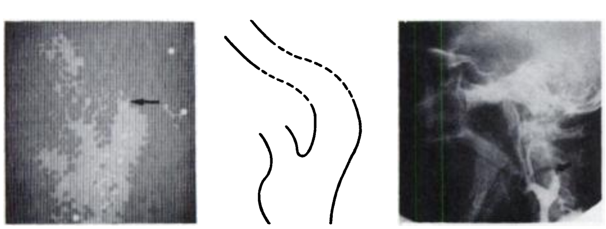

FIG. 3. Left complete occlusion, LAO view (left). Left carotid angiogram, lateral view (right).

Some estimate of the minimal amount of narrowing, as determined angiographically, that can be detected in this manner is available from this series. It appears to be highly sensitive above 50% reduction in diameter. Sensitivity drops sharply between that level and 25% shrinkage. Ulcerated, nonstenotic lesions can probably not be detected unless the wall becomes nondistensible in that area. So far we have no evidence for this; nor could we distinguish stenosis from occlusion, except that with total or near-total occlusion of the internal carotid, loss of pulsatility appeared to extend to the common carotid as well.

However, other widely used noninvasive screening techniques also have their limitations. Doppler analysis of flow in the supraorbital vessels (an anastomotic area between the internal and external systems) is insensitive below 75% occlusion (*3*). Oculoplethysmography has somewhat greater sensitivity but is cumbersome to apply and is nonlocalizing (*4*).

Two-dimensional ultrasonic scans of the carotid bifurcation may be obtained by both articulated arm scanners (B-scanners) and more flexible, real-time equipment (*5,6*). Relatively small plaques may be detected provided they ae sufficiently dense to be echogenic, but "soft" (echolucent) stenoses of considerable size,

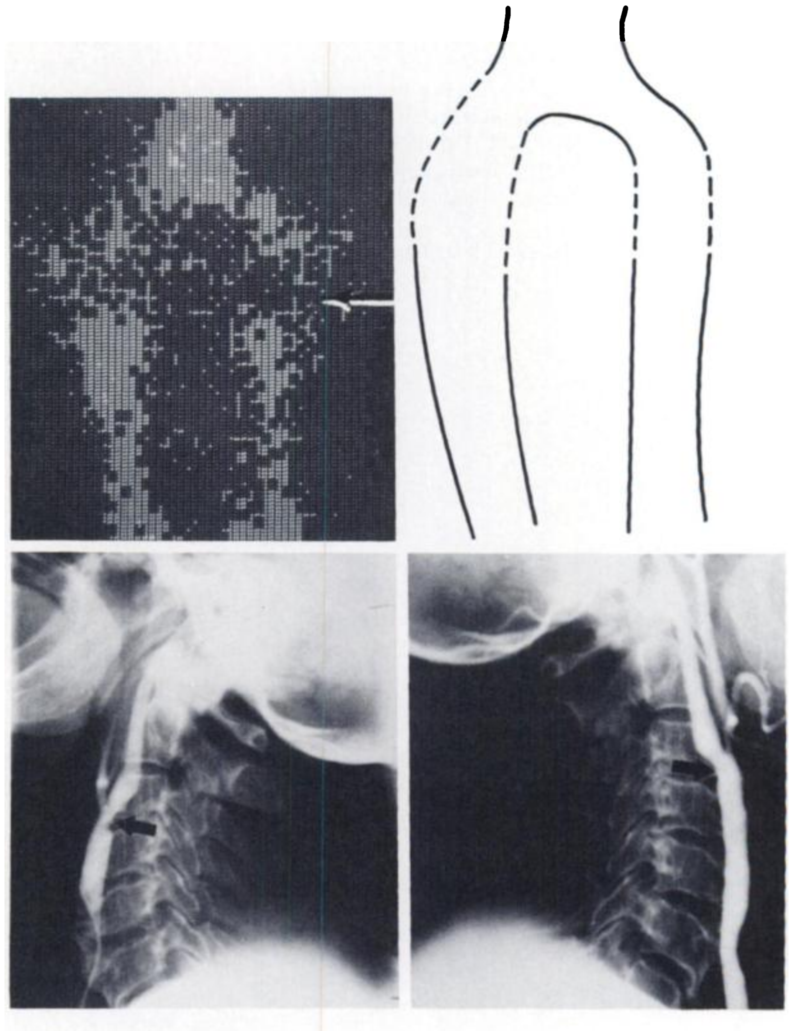

FIG. 4. Left Moderate (50%) stenosis, anterior view (upper left); left carotid angiogram (lower left). Note also equivocal evidence of disease on right (upper left). Right carotid angiogram reveals mild (25%) stenosis (lower right).

even causing total occlusion, can be missed. The use of pulsed or continuous-wave Doppler ultrasound yields information additional to imaging techniques because of the capability for analysis of flow patterns within the vessels. Fast-Fourier frequency spectrum analysis is a further improvement, and the combination of pulsed Doppler with two-dimensional imaging allows positive identification of the vessel and the area within the lumen from which the signal is obtained (duplex scan).

While sometimes capable of detecting occlusions as small as 10 percent (although sensitivity drops from 96% to 70% below 50% occlusion), this duplex technique at present appears to lack specificity: when compared with arteriography, the false-positive rate is high (*7,8*).

CONCLUSION

Since atherosclerosis is a systemic disease, it is advisable to screen patients being evaluated for coronary disease for the presence of vascular stenosis in other areas. We have demonstrated that a well-validated coronary screening test can, with no modification of hardware and a minimum of extra software support, be adapted to this purpose in the carotid vessels. It appears at this early stage to rival other noninvasive techniques in detection of moderate to severe extracerebral carotid artery disease.

Application to other peripheral vasculature, particularly the aortoiliac region, is worth exploring as well, since disease there tends to co-exist with coronary disease even more frequently than does disease of the cerebral vasculature (*1*).

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Announcement and Call for Abstracts

The Annual Meeting of the Missouri Valley Chapter, SNM, will be held September 23–25, 1983 at the Old Mill Holiday Inn in Omaha, Nebraska. The meeting will be co-chaired by Merton A. Quaife, M.D. and Maria Nagel, CNMT. The program will feature current information on a variety of topics including SPECT, NMR, monoclonal antibodies, correlative imaging, and personal stress management. The Third Annual Les Wood Lecture will be presented by an invited speaker. Commercial exhibits will be present.

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Ten minute oral presentations of contributed papers will be Saturday afternoon. 200 word abstracts should be sent to:

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The Richard E. Peterson Young Investigators Award will be presented for the best paper given by a young investigator or technologist from the Missousi Valley Chapter. The best paper given by a technologist from the Missouri Valley Chapter will receive 50% of their expenses to the Annual SNM meeting to present their paper.

Deadline for abstracts July 1, 1983