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# Noninvasive Screening of Extracranial Carotid Disease: Duplex Sonography with Angiographic Correlation

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Initial experience with a pulsed Doppler device coupled to a high resolution real-time sonographic scanner for noninvasive evaluation of extracranial carotid disease is reported. The primary objective was to evaluate patients with asymptomatic cervical bruits and/or equivocal histories of transient cerebral ischemia to determine which of them required further study with angiography. An assessment of the degree of extracranial carotid stenosis as well as the severity of atheromatous plaque formation was made and subsequently compared with the findings at angiography. During a 455 day period, a total of 501 patients were examined. In 150 arteries with complete angiography, correlation disclosed the noninvasive duplex technique to be 92% accurate in predicting which arteries would be significantly diseased. It is proposed that careful sonographic investigation of the extracranial carotid system is a safe and useful screening test for certain patients at risk for cerebrovascular accident.

To date, noninvasive tests of carotid artery disease have focused essentially on indirect measurement of internal carotid flow by study of the ophthalmic artery flow and pressure with supraorbital Doppler and oculoplethysmography and by direct evaluation of carotid bruits with continuous wave Doppler and phonangiographic analysis. Unfortunately the indirect studies cannot differentiate between chronic internal carotid artery occlusion, which is not usually amenable to surgical reconstruction, and high grade narrowing, which is often surgically correctable [1]. Atherosclerotic lesions may produce symptomatic reduction in cerebral flow by stenosis or occlusion of the internal carotid artery or focal intracranial ischemia by emboli arising from intimal ulceration [1]. Lesions of the carotid bifurcation are of particular interest as these may be amenable to surgical intervention and stroke prevention.

Until the noninvasive methods became available, examination of the cervical carotid system required conventional angiography in several projections. Despite refinement in techniques, this has an inherent risk in addition to the discomfort and cost of the procedure. Some authors describe considerable interobserver error in arteriographic interpretation, casting some doubt as to the absolute value of the angiogram as the "gold standard" for evaluation [2]. Others, however, believe the only real shortcoming of carotid arteriography in experienced hands is the occasional failure to demonstrate a small carotid ulceration.

Some authors recommend the use of several noninvasive tests to study the extracranial carotid system. Ackerman [3] suggested a "battery" of direct and indirect noninvasive procedures including bruit analysis, B-scan sonographic imaging, radionuclide angiography, facial palpation, Doppler sonography, and oculoplethysmography. He stated that the indirect tests depend on a hemodynamic change in the distal carotid system before they become positive and therefore will be falsely negative in the presence of ulcerations and atheromata that do not significantly narrow the lumen. Many tests also depend on comparison with a normal contralateral side and therefore will be of reduced efficacy or

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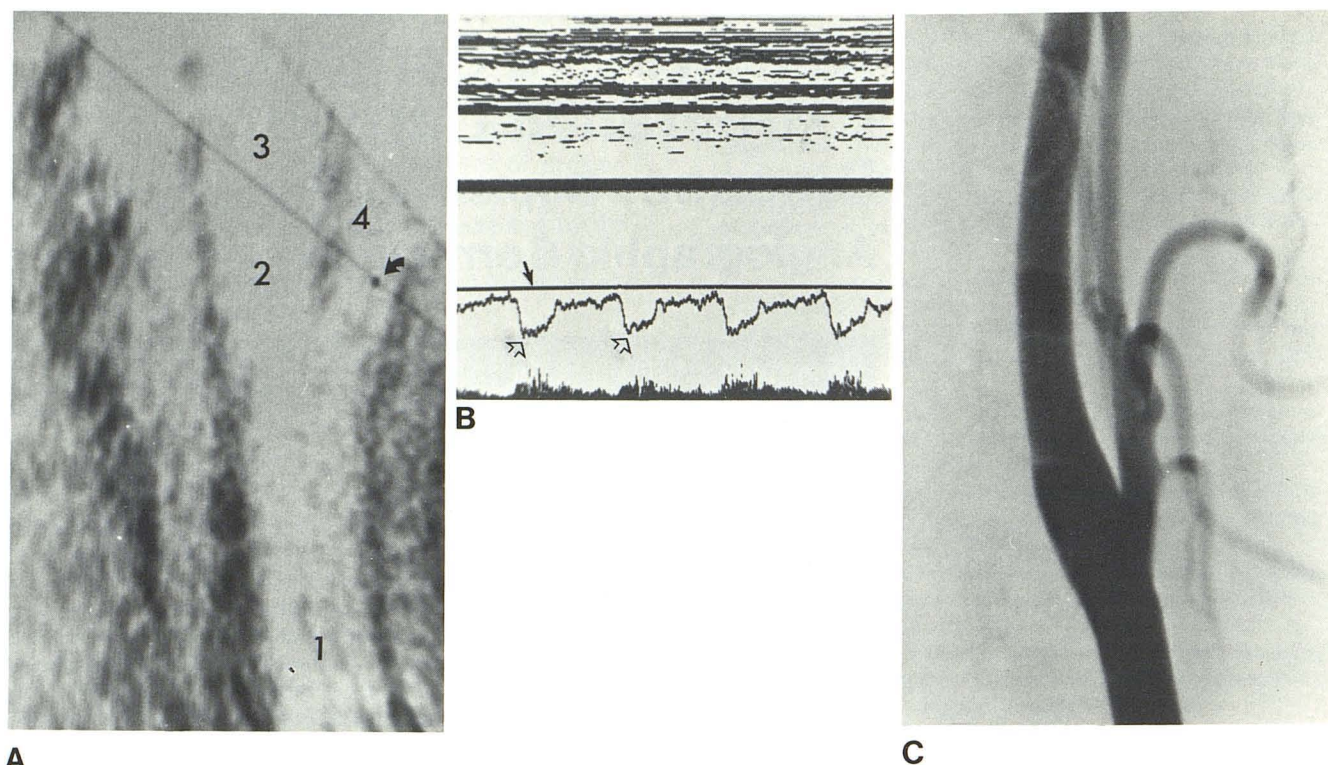


Fig. 1.—Normal carotid bifurcation. **A**, Freeze-frame image of real-time scan of bifurcation. Common carotid (1), internal carotid (2 and 3), and external carotid (4) arteries. Doppler probe sample volume is in lumen of proximal external carotid (arrow) interrogating this vessel for its flow characteristics. All vessels have smooth endothelial surface. This example represents most common configuration, with external carotid artery anteromedial to and smaller than internal carotid. **B**, Doppler signal trace (open arrows) in common carotid artery discloses regularly pulsatile flow in antegrade direc-

tion (i.e., below 0 or baseline) (closed arrow). Flow in opposite direction would manifest itself above baseline. Flow in normal common carotid artery approaches but does not reach 0 line. If it does ("flow to 0" phenomenon), there is strong suggestion that subsequent examination of more distal carotid tree will disclose internal carotid occlusion. **C**, Subtraction view of bifurcation in same patient as **A** and **B** confirms normal anatomy diagnosed on duplex sonogram.

falsely negative when there is bilaterally symmetric disease. Strandness [4] also pointed out limitations of the indirect tests such as supraorbital Doppler and oculoplethysmography stating they will detect only high grade stenoses or occlusion and that they cannot distinguish a stenosis from an occlusion.

Continuous wave Doppler examination records data all along the path of the sonographic beam and therefore does not allow precise and specific localization of the interrogating "sample volume" within the lumen of the vessel in question. B-mode imaging may be of limited value in patients with short thick necks as well as those in whom heavily calcified anterior wall plaque prevents clear delineation of the lumen beneath the shadowing plaque. Exuberant ventral plaques may lead to muting of the Doppler signal from the subjacent lumen, making interpretation of the frequency changes more difficult.

Duplex scanning seeks to avoid many of the limitations of the other noninvasive tests by combining high resolution real-time B-scan images for anatomic information together with pulsed Doppler data regarding intraluminal flow velocity for physiologic evaluation (fig. 1). We sought to evaluate this duplex system for screening patients with asymptomatic bruits to eliminate arteriography in some patients and to increase the percentage of positive arteriograms in others.

## Materials and Methods

During a 455 day period, 501 patients were referred for noninvasive extracranial carotid evaluation with various indications such as asymptomatic cervical bruits, equivocal transient ischemic attack histories, and prior carotid endarterectomies. A commercially available duplex carotid system (Mark V ATL, Advanced Technology Labs., Bellevue, Wash.) was used and all the examinations were performed by or under the direct supervision of one of the authors. The device employs a rotating array of three 5 MHz transducers to obtain a real-time image of the carotid vasculature. This is coupled to a single gate-pulsed Doppler probe. After localization of the vessel, the Doppler cursor or "sample volume" is easily and precisely placed in the lumen and the vessel is "interrogated" to locate areas of high frequency or coarsened Doppler signals that indicate stenotic or turbulent flow (fig. 1). Initially, a complete bilateral examination required about 40–60 min to perform; greater experience has allowed a substantial reduction such that all but the most difficult patients may be completely studied in under 30 min.

We graded the image of the vessels as to course, luminal characteristics, and plaque formation. Of principal importance was assessment of the audible Doppler signal at each point in the vessel, especially in areas where atheromata were visualized. These were subjectively evaluated and assigned values of 0–4+ where 0 was normal and 4+ represented high grade subtotal occlusion. Patients whose flow signals were 3+ or 4+ were considered to have lesions compromising the lumen by 50% or greater and arteriography was suggested if clinically acceptable (fig. 2).



Fig. 2.—Hemodynamically significant internal carotid stenosis. **A**, Large dorsal plaque (*closed arrow*) in proximal internal carotid is just 1–2 cm distal to normal appearing common carotid bifurcation. A few fine echoes are in apparent residual lumen just ventral to plaque. High frequency, coarse Doppler signals were heard at this site (*open arrows*) and a flow-reducing lesion was diagnosed. **B**, Carotid angiogram. Stenosis of proximal internal carotid artery.

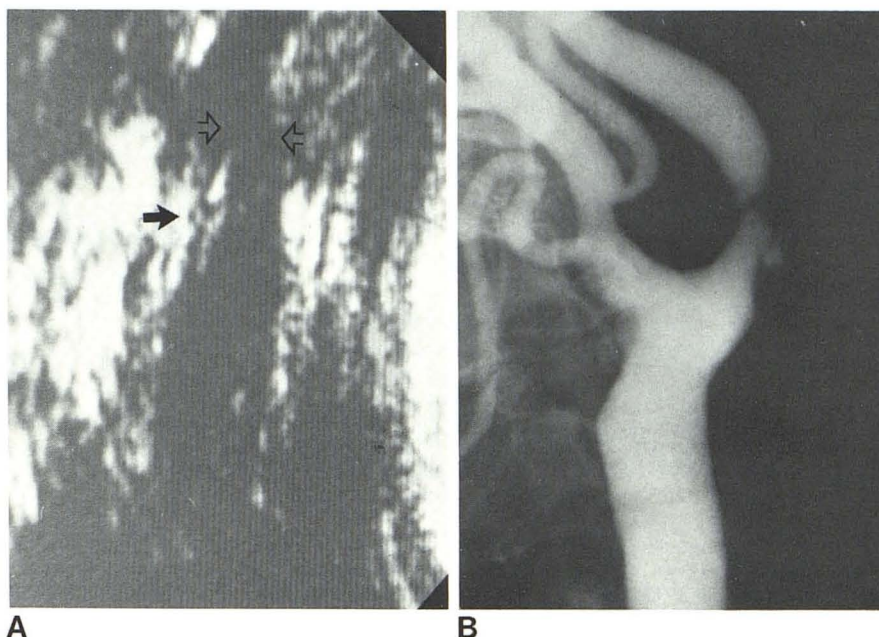


TABLE 1: Duplex Carotid Examinations Correlated with Angiography

Angiographic Finding	No. Arteries
False-negative	4
False-positive	8
True-negative	75
True-positive	63
Total	150

Note.—Accuracy rate = true-positive + true-negative/total no. arteries studied = 138/150 = 92%.

Early in our experience we performed angiography on numerous patients whose subjective Doppler signals were 2+ or less either to establish confidence in our procedure or as a result of strong clinical suspicion that significant obstruction was present despite the sonographic findings. A number of these patients contributed to our true-negatives (table 1). Other true-negatives arose as a result of our policy of doing complete bilateral angiography even when the sonogram suggested only a unilateral lesion. A true-positive result consisted of arteriographic proof of a correct prediction by sonography that a cervical carotid artery would contain a lesion reducing the luminal caliber by 50% or more. A true-negative result followed agreement between sonography and angiography that the vessel was either normal or narrowed to a degree *not* exceeding 50% of luminal dimension. We depended primarily on analysis of the audible Doppler frequency shifts to establish the degree of stenosis, using the B-scan images principally to guide in precise placement of the "sample volume."

To aid in systematic investigation of the vessel in question, we developed a work sheet for each patient containing history, physical findings (blood pressure, bruits, neurologic abnormalities), and appropriate spaces in which to record the real-time image appearance as well as the Doppler signal analysis for each of the areas of the carotid under study. We routinely recorded data from the common carotid artery, carotid bulb, and proximal internal carotid,

distal internal carotid, and external carotid arteries. The subclavian arteries were routinely imaged and the presence of flow determined. However, as they are visualized over only a short segment and as they run in a plane that does not provide convenient geometry for Doppler analysis, no detailed evaluation of the subclavian arteries was performed. The instrument is not presently capable of evaluating the origin of the brachiocephalic arteries with precision. We had a technical failure rate of 0.6% (three patients). These were due to either patient agitation or a very short thick neck placing the vessels distal to the focal zone of the transducer.

## Results

Our results are summarized in table 1. Three errors were made in the initial group of 30 patients; two of the three occurred in the first 2 weeks after operation. We believe these early mistakes were the result of interpreter inexperience rather than an inherent failure of the instrument or the protocol. Our principal objective was to determine which of a group of patients could be determined to have significant stenosis of the extracranial carotid system above the origin of the common carotid artery. Our subjective assessment of the degree of stenosis, based primarily on analysis of the audible Doppler signal and secondarily on the degree of atheromatous change visible on the real-time images, caused us to recommend arteriography on the patients whom we felt to have 50% or greater luminal diameter compromise (i.e., 75% reduction in cross-sectional area in the vessel). This determination does not necessarily establish the hemodynamic significance of a lesion, a finding which can currently be established only by angiography. The accuracy rate (true-positive plus true-negative divided by total arteries studied) is 92% to date.

We have had the opportunity to study several postend-arterectomy patients and have been able to definitively



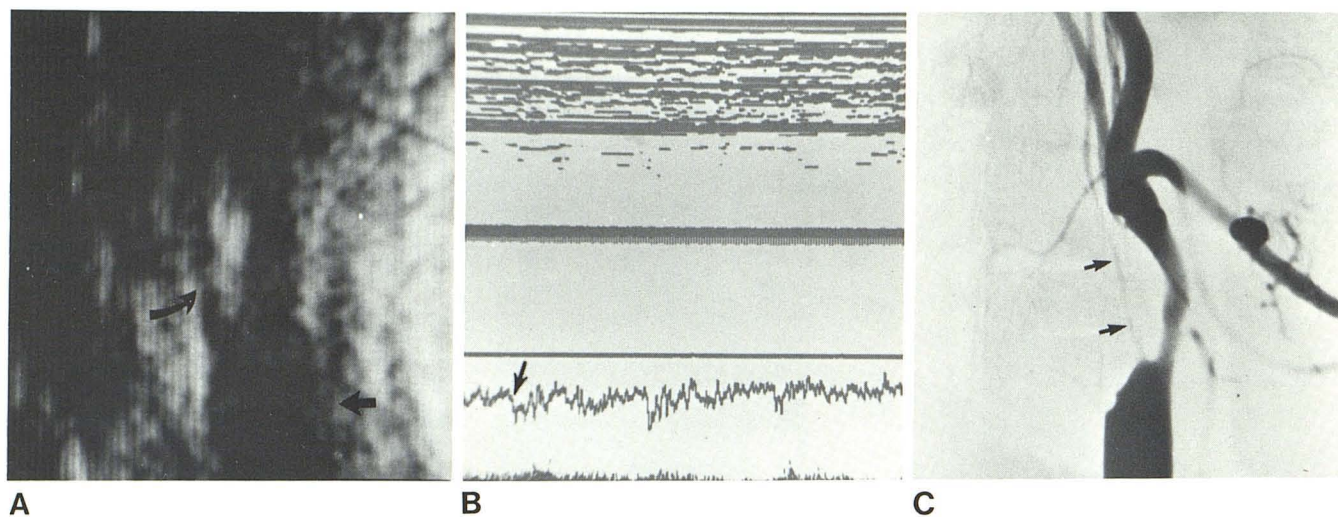


Fig. 3.—High grade internal carotid stenosis. **A**, Common carotid bifurcation (straight arrow) just proximal to large discrete plaque at internal carotid origin (curved arrow). There is acoustic shadowing beneath plaque. **B**, Doppler interrogation in area just ventral to plaque in **A** disclosed extremely high pitched, barely pulsatile flow (arrow) of coarse nature felt to represent

nearly occluded internal carotid lumen. **C**, Subtraction arteriogram confirms marked stenosis of internal carotid with small residual lumen (arrows). Multiple projections confirmed this was internal carotid and not ascending pharyngeal artery. Plaque formation also involves origin of external carotid.

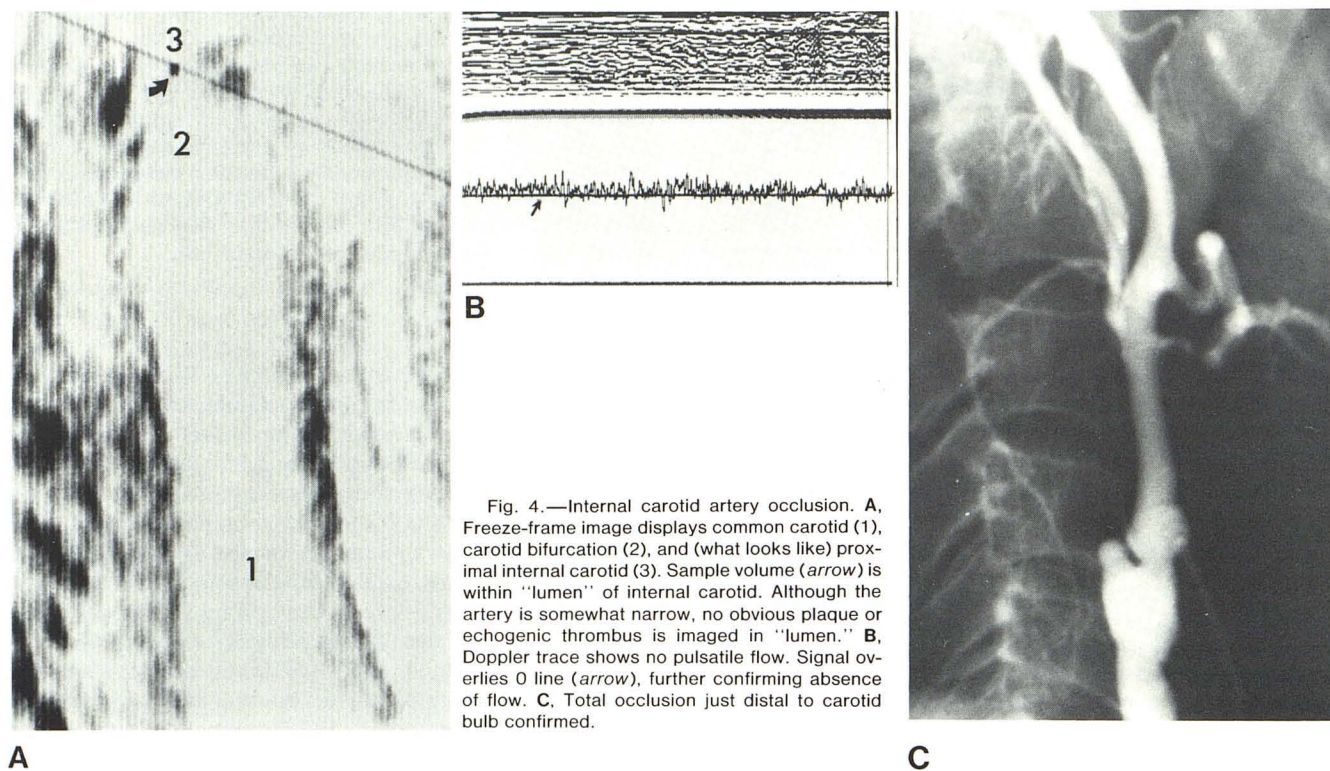


Fig. 4.—Internal carotid artery occlusion. **A**, Freeze-frame image displays common carotid (1), carotid bifurcation (2), and (what looks like) proximal internal carotid (3). Sample volume (arrow) is within "lumen" of internal carotid. Although the artery is somewhat narrow, no obvious plaque or echogenic thrombus is imaged in "lumen." **B**, Doppler trace shows no pulsatile flow. Signal overlies 0 line (arrow), further confirming absence of flow. **C**, Total occlusion just distal to carotid bulb confirmed.

establish patency in several cases as well as postoperative restenosis in one case. Figures 1–4 illustrate normal and pathologic arteries displaying real-time sonographic images, the graphical representation of the audible Doppler signal,

and the correlated arteriogram. Note that, as the Doppler probe is sensitive to the *direction* of flow with flow toward the sample volume appearing above the zero line, definitive comment on flow reversal can be made when appropriate.



## Discussion

The prevalence of carotid vascular disease, as well as its devastating consequences, has encouraged physicians to seek prophylactic intervention wherever possible. To do so currently requires the precise anatomic detail now available only with multiple-view cervical carotid angiography. The potential danger, discomfort, and expense of arteriography precludes its use as a screening test, especially in the asymptomatic patient. In our experience, the unique wedding of high resolution imaging of the carotid system with Doppler analysis of the flow pattern provides anatomic and physiologic data with sufficient accuracy to perform a triage function for subsequent arteriography.

Blackshear et al. [1] reported the correct diagnosis in 24 of 26 high grade stenoses or occlusion (92% accuracy) using a duplex scanning system such as ours in which the sonogram is used as a guide for precise placement of the pulsed Doppler "gate" or sample volume. The site of flow interrogation, the sample volume, has finite dimensions of about  $1.5 \times 1.5 \times 1.0$  mm and this property allows its positioning within a specific site in the vessel chosen by viewing the real-time image concurrently (figs. 1A and 4A). Visualization of the image alone by high resolution scanners is less satisfactory as we have seen vessels with a normal, nonatheromatous B-scan image that were subsequently proven to be totally occluded by analysis of the duplex Doppler information and eventual arteriography (fig. 4). This follows from the difficulty in distinguishing a noncalcified plaque or thrombus from blood [1]. Similarly, Baker [5] states that the pulsed Doppler alone is not usually sufficient for unequivocal diagnosis due to difficulty maintaining the sample volume in its desired position when there is no image available for correlation. Coupling the presence of harsh, high frequency Doppler signals with the visual real-time evidence of narrowing or plaque formation at the identical site in a vessel yields very strong evidence of a flow reducing

lesion. This method does not address itself to the physical state of the arterial intima, and unless ulceration is quite severe, it will not be detected.

In terms of patient selection, we believe the duplex examination is most important for those with asymptomatic cervical bruits, especially those in whom episodes of hypotension such as in a major surgical procedure may be anticipated. Noninvasive evaluation may also be indicated in those patients whose history and physical findings suggest, but are not conclusive for, transient ischemic attack. If classic transient ischemic attacks have occurred, in most cases patients will require cervical and cerebral arteriography to define the etiology of the ischemia. Lesions at the origin of the carotid and vertebral vessels, small ulcerative plaques, cavernous carotid occlusions, neoplasms, and aneurysms all can mimic simple transient ischemic episodes and will be detected only by arteriography.

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## REFERENCES

1. Blackshear WM Jr, Phillips DJ, Thiele BL, et al. Detection of carotid occlusive disease by ultrasonic imaging and pulsed Doppler spectrum analysis. *Surgery* **1979**;86:698-706
2. Blackshear WM Jr, Phillips DJ, Chikos PM, Harley JK, Thiele BL, Strandness DE Jr. Carotid artery velocity patterns in normal and stenotic vessels. *Stroke* **1980**;2:67-71
3. Ackerman RH. A perspective on noninvasive diagnosis of carotid disease. *Neurology (NY)* **1979**;29:615-622
4. Strandness DE Jr. The use and abuse of the vascular laboratory. *Surg Clin North Am* **1979**;59:707-717
5. Baker DW. Applications of pulsed Doppler techniques. *Radiol Clin North Am* **1980**;18:79-103