Doppler Cerebrovascular Examination: Improved Results with Refinements in Technique

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SUMMARY Doppler ultrasonic assessment of extracranial carotid occlusive disease has been modified to decrease the incidence of false positive and negative diagnoses. The technique, which assessed directional flow in the frontal artery and the influence of sequential compression of each temporal, infraorbital, facial and common carotid artery, was performed on 152 vessels visualized by contrast arteriography. Presence or absence of significant (> 50%) stenosis or occlusion of the internal carotid artery was identified correctly in 150 vessels (98.7%). Inasmuch as the classic temporal artery compression test only detected 39 of the 61 abnormal Doppler studies (64%), the more complete examination is recommended for screening patients for significant carotid artery obstruction.

DOPPLER ULTRASONIC assessment of supraorbital artery flow response to temporal artery compression, as described by Brockenbrough,\(^1\) has been useful to detect non-invasively obstruction of the extracranial internal carotid artery. Normally, flow in the supraorbital artery, a branch of the ophthalmic artery, is directed out of the orbit and is augmented by temporal artery compression. In the presence of significant stenosis or occlusion of the internal carotid artery, flow in the supraorbital artery may be reversed and may diminish or be obliterated by temporal artery compression.

Most investigators only employ the temporal artery compression maneuver when performing a Doppler cerebrovascular examination\(^2\)-\(^4\) and a significant number (5-27%) of false positive and negative diagnoses have been reported. Many other sources of collateral circulation, both extracranial and intracranial, may exist in obstruction of the internal carotid artery and are detectable only by additional compression maneuvers.\(^6\) In this paper, we describe the technique and the improved results of a more complete Doppler cerebrovascular examination.

Methods

Technique

The patient was studied in the supine position with the eyes gently closed. A directionally-sensitive Doppler ultrasonic velocity detector\(^*\) (8-10 MHz) was used to avoid misinterpreting a change in flow direction as a normal augmentation response (fig. 1). Blood flow direction was determined by dominance of the audio output of the instrument on one side of stereo earphones. Permanent analogue recordings, as depicted in this paper, may be obtained on a strip chart recorder with forward flow registered above, and reversed flow below, the zero velocity baseline. Using coupling gel, the Doppler probe was gently positioned over the frontal artery at the supero-medial aspect of the orbit above the inner canthus of the eye. The frontal artery, a branch of the ophthalmic artery, is preferable to the supraorbital artery for Doppler examination since its flow signal was louder and it was less likely to be confused with a palpebral branch of the temporal artery.\(^7\) The following three steps in the examination were then performed:

1. **Determination of flow direction in the frontal artery:** Normally, flow in the frontal artery is directed out of the orbit toward the forehead. Reversal flow in the frontal artery indicates extracranial collateral flow in the presence of significant stenosis (> 50% reduction in diameter relative to the diameter of the normal vessel distal to the lesion) or occlusion of the extracranial internal carotid artery.\(^8\) The source of the collateral flow was determined by step 2 of the examination. Normal directional flow in the frontal artery did not exclude significant internal carotid artery obstruction with intracranial collateral from the opposite carotid or vertebrobasilar system. Intracranial collateral circulation was documented by step 3 of the examination. Rarely, normal directional flow in the frontal artery may be associated with extracranial collateral circulation and be detectable by step 2 of the examination.

2. **Compression of all branches of the external carotid arteries:** Sequential compression of the superficial temporal, infraorbital, and facial arteries on each side of the head was performed to document the presence of extracranial collateral circulation associated with significant obstruction of the internal carotid artery. With the free hand of the examiner each superficial temporal artery was compressed in turn. Simultaneous compression of both infraorbital arteries, and then both facial arteries, can be carried out with one hand. An abnormal frontal artery flow response during simultaneous bilateral compression should lead to individual compression of external carotid artery branches to determine the sources of reversed frontal artery flow. Normally, compression of the branches of the external carotid arteries should result in either no change or an augmentation of flow in the frontal artery. The examiner must be careful to avoid moving the Doppler probe or the patient's head during these compression maneuvers. In the presence of reversed flow in the frontal artery, the source of extracranial collateral was documented by diminution or obliteration of frontal artery flow when the external carotid branch was compressed. The importance of compressing extracranial...
arteries on the contralateral side of the head is demonstrated in figure 2.

Sequential compression of all aforementioned branches of the external carotid arteries should be carried out even if directional flow in the frontal artery is normal. Figure 3 illustrates the Doppler recording of a patient whose normally-directed frontal artery flow velocity was augmented by temporal artery compression but was obliterated by ipsilateral facial artery compression. The patient proved to have a 95% stenosis of the ipsilateral internal carotid artery in the neck. Presumably the facial artery supplied flow via the angular and nasal arteries to the ophthalmic artery, permitting normal directional flow in the frontal artery from its junction with the nasal artery within the orbit.

3. Common carotid artery compression: The final step of the examination was to compress the common carotid artery to exclude intracranial collateral circulation in the presence of normal directional flow in the frontal artery. This step was not required in the presence of reversed frontal artery flow, which is sufficient to document significant obstruction of the internal carotid artery. The common carotid artery was compressed low in the neck to avoid stimulating the carotid sinus or dislodging emboli from the carotid bifurcation. The common carotid is somewhat mobile and must be stabilized between the tips of the fingers during compression. Compression is necessary for only one or two heartbeats to define the response of flow in the frontal artery. Normally, ipsilateral common carotid compression will diminish, obliterate or occasionally cause reversal of flow in the frontal artery. In the presence of such a response, the contralateral common carotid artery need not be compressed. If frontal artery flow is unchanged or is augmented by ipsilateral common carotid compression, significant obstruction of the internal carotid artery was present. In such an instance, common carotid artery compression mimics compression of all branches of the ipsilateral external carotid artery. If the frontal artery flow was diminished or obliterated by contralateral common carotid artery compression, the latter vessel was serving as a source of collateral via the intracranial circle of Willis (fig. 4). If frontal artery flow was unaffacted or augmented by sequential compression of each common carotid artery, internal carotid artery obstruction was present with intracranial collateral via the vertebrobasilar system.

A summary of the steps and the possible responses of the cerebrovascular examination are depicted in the algorithm of figure 5.

Patients Studied

Complete Doppler cerebrovascular examinations have been performed on 227 consecutive patients referred to our laboratory with a history of previous stroke or transient ischemic attack or the presence of an asymptomatic carotid bruit. The accuracy of the Doppler examination in detecting significant stenosis or occlusion of the internal carotid artery was assessed by carotid arteriography of 152 carotid arteries. Interpretations of the Doppler and angiographic

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**Figure 1.** Normal and abnormal frontal artery flow responses to temporal artery compression. Velocity analogue tracings above and below zero baseline indicate flow out of and into orbit, respectively.

**Figure 2.** Frontal artery reversed flow obliterated during compression of contralateral facial artery. The flow was not affected by compression of the ipsilateral superficial temporal artery.
studies were independently assessed by experienced observers. A stenosis was defined as significant (> 50%) if the diameter of the origin of the internal carotid artery was less than one-half the diameter of the normal distal extracranial internal carotid artery on at least one view of a biplane arteriogram.

Results

The Doppler ultrasonic examination correctly identified the presence or absence of significant obstruction of the internal carotid artery in all but two of the 152 vessels visualized by arteriograms, for an overall accuracy of 98.7%. One internal carotid artery with arteriographic evidence of 80% stenosis was associated with normal frontal artery flow dynamics by Doppler ultrasound. However, there was associated external carotid artery stenosis of that carotid bifurcation, which is a recognized cause of a false negative Doppler examination. Combined stenoses of the external and internal carotid arteries may result in maintenance of the normal pressure gradient between the internal and external carotid systems via the ophthalmic artery. The other false negative Doppler diagnosis was associated with total occlusion of an internal carotid artery. No explanation for the erroneous Doppler finding was evident, although an intracranial collateral branch from the external carotid artery, such as the middle meningeal or anterior deep temporal artery, could not be excluded.

Of the 227 patients evaluated by Doppler ultrasound for suspected cerebrovascular disease, abnormal examinations were noted in 61 vessels of 51 patients (23%). Table 1 depicts the identified source of collateral in these 61 abnormal examinations. Extracranial collateral circulation was evident in 92% of the abnormal examinations. The ipsilateral temporal artery was the source of collateral in only 64% of the cases. Intracranial collateral circulation from the contralateral carotid artery was present in 7% of the abnormal examinations. One patient had a combined intracranial-extracranial collateral pathway involving the contralateral internal carotid and ophthalmic artery. Flow then passed via the nasal artery over the bridge of the nose to flow retrograde in the frontal artery of the affected side.

Discussion

The results of our more complete Doppler ultrasonic evaluation of cerebrovascular disease emphasize the fallibility of assessing only the temporal artery contribution to ophthalmic artery collateral flow. In this study, the ip-

<table>
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<th>Source of Collateral</th>
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</tr>
<tr>
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</tr>
<tr>
<td>Ophthalmic</td>
<td></td>
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silateral temporal artery was the source of collateral circulation in less than two-thirds of the abnormal Doppler examinations. Had the procedure only involved a temporal artery compression maneuver with a non-directional Doppler, 36% of the abnormal examinations would have been overlooked. The use of a directionally-sensitive Doppler detector would have permitted correct identification of reversed frontal artery flow in approximately 90% of the abnormal examinations. However similar accuracy could be obtained with a non-directional Doppler instrument if other branches of the external carotid arteries, including the ipsilateral and contralateral infraorbital and facial arteries, were compressed. Muller et al. and Maroon and colleagues have also emphasized the importance of compressing these sources of potential extracranial collateral circulation when performing a Doppler examination.

Intracranial circulation from the contralateral internal carotid artery provided collateral flow in 7% of our patients with abnormal Doppler examinations. Collateral circulation via the circle of Willis can only be assessed by determining the frontal artery flow response to transient common carotid artery compression. Although this procedure was emphasized by Brockenbrough, few other investigators have routinely performed this maneuver during a Doppler cerebrovascular examination. Although the potential hazard of cerebral thromboembolism following this procedure exists, this complication has been rare in our experience. The risk is minimized if the common carotid artery is compressed low in the neck for only the few seconds necessary to assess the frontal artery flow response. In approximately 1,000 examinations, we have not seen only one episode of neurologic deficit following this procedure in a patient who was having repeated transient ischemic attacks daily. In a personal communication Brockenbrough reported witnessing only two transient ischemic attacks following common carotid compression in over 4,000 examinations. We feel that the risks of this procedure are far outweighed by the benefits of improved diagnosis when this technique is incorporated into the Doppler cerebrovascular examination.

Despite the accuracy of a complete Doppler evaluation in detecting significant internal carotid artery obstruction, one must keep in proper perspective the role of this technique in diagnostic and therapeutic decision. Many patients with transient ischemic attack or stroke harbor lesions in the extracranial internal carotid artery which do not significantly narrow the lumen. Such lesions would not be detected by Doppler ultrasound and yet might be amenable to carotid endarterectomy. We have found that about two-thirds of patients with operable lesions in the extracranial internal carotid artery have a stenosis of less than 50% on arteriography. We, therefore, feel that all patients with symptoms of hemispheric transient ischemic attacks or stroke should undergo arteriography regardless of the results of the Doppler examination. Nevertheless, the Doppler examination is useful to screen patients in whom hemodynamic obstruction of the internal carotid artery may play a pathogenetic role. The procedure is useful to screen patients with manifestations of vertebrobasilar insufficiency, ambiguous cerebral symptoms not typical of hemispheric or vertebrobasilar insufficiency (headache, syncope), or an asymptomatic carotid bruit. Doppler examination may also be useful to screen patients objectively for therapeutic trials, especially in prospective studies of the efficacy of antinocagulant, anti-platelet, or operative therapy. Finally, the procedure is helpful to define significant carotid obstruction in high-risk patients such as those with hyperlipidemia, hypertension, or a strong family history of cardiovascular or cerebrovascular disease. We feel that these applications may be aided by the improved accuracy of the more complete Doppler cerebrovascular examination described in this paper.

References

Doppler cerebrovascular examination: improved results with refinements in technique.
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