Recanalization of Intracranial Carotid Occlusion Detected by Duplex Carotid Sonography

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We studied three patients with internal carotid artery occlusion at the siphon who had recanalization during 1 month of close observation. Angiography and duplex carotid sonography (DCS) were repeated serially in each patient. Blood flow patterns detected by DCS were classified into three patterns by specific angiographic changes. The distal occlusive flow pattern on DCS corresponds to internal carotid artery occlusion at the siphon angiographically, the median flow pattern on DCS corresponds to partial recanalization, and a normal flow pattern on DCS indicates almost complete recanalization. Since DCS can be easily repeated, the exact time of recanalization can be determined noninvasively. In all three patients, hemorrhagic infarction observed on computed tomograms occurred at the time of recanalization detected by DCS. DCS demonstrates that recanalization is one of the mechanisms of hemorrhagic infarction. (Stroke 1989;20:680–686)

In cerebral embolism, recanalization occurs very commonly, ranging from 40% to 75%. When recanalization occurs, cerebral infarction may become hemorrhagic and clinical conditions may be aggravated. Recanalization can be diagnosed on serial angiograms, but repeated angiography is impractical and not without risk during the acute illness. For this reason, it is difficult to tell the exact time of recanalization by the limited number of angiographic examinations.

Duplex carotid sonography (DCS) is very useful to diagnose internal carotid artery occlusion and can be easily repeated. We have performed serial DCS examinations on three patients with intracranial carotid artery occlusion and have found that DCS can indicate the exact time of recanalization.

Case Reports

DCS examinations were carried out with a Diasonics DRF 400V (Milpitas, California). The duplex probe consisted of a 10-MHz imaging transducer and a 4.5-MHz pulsed Doppler transducer.

From April 1984 to December 1987, we performed 1,586 DCS examinations. Among them, 66 patients had internal carotid artery occlusion, 48 at the origin and 18 at the siphon. We performed serial DCS examinations during the acute period of cerebral infarction in 17 of these 66 patients; nine had occlusion at the origin and 18 at the siphon. We performed angiography in all eight patients with occlusion at the siphon, and the results indicated that five indeed had occlusion at the siphon and three had recanalization by the time of angiography. Recanalization was noted on serial angiograms in three of the five patients who had occlusion at the siphon. In these three patients, internal carotid artery blood flow patterns on DCS have been studied and can be classified into three patterns: 1) distal occlusive flow pattern: blood flow signals are detected only during the systolic phase but cannot be detected during the diastolic phase; 2) median flow pattern: between 1 and 3; and 3) normal flow pattern: blood flow is the same as in normal persons.

Case 1. A 60-year-old man was admitted to our hospital because of an inability to speak. He had been living alone and did well until a day before admission, when a friend noted his inability to speak. On admission he was somnolent, his temperature was 36.1°C, his pulse was 60/min and regular,
FIGURE 1. Case 1. Left: Doppler flow pattern of left internal carotid artery on admission. Right: Frontal view of left carotid angiogram on admission.

FIGURE 2. Case 1. Left: Doppler flow pattern of left internal carotid artery on seventh hospital day. Right: Frontal view of left carotid angiogram on eighth hospital day.

FIGURE 3. Case 1. Left: Doppler flow pattern of left internal carotid artery on 15th hospital day. Right: Frontal view of left carotid angiogram on 28th hospital day.
and his respiration rate was 20/min. His supine blood pressure was 128/80 mm Hg. Neurologic examination revealed that he had nonfluent aphasia, left conjugate deviation of his eyes, right hemiparesis, and right homonymous hemianopsia. Laboratory examinations showed increased serum creatine kinase concentration, up to 1,053 (normal range 33–64) IU/ml, but electrocardiography (ECG) showed no evidence of myocardial infarction. On admission, a distal occlusive flow pattern was noted in the left internal carotid artery by DCS (Figure 1, left). Diagnosis by DCS was an occlusion of the left internal carotid artery at the siphon; this diagnosis was confirmed by angiography (Figure 1, right). On his seventh hospital day, DCS findings changed to a median flow pattern (Figure 2, left). On his eighth hospital day, angiography demonstrated that the embolus had moved distally and the left anterior cerebral artery was visualized from the ipsilateral internal carotid artery, but still no filling of the middle cerebral artery was noted (Figure 2, right). On his 15th hospital day, the DCS Doppler flow pattern of the left internal carotid artery improved to a normal flow pattern (Figure 3, left). On his 28th hospital day, recanalization was confirmed angiographically (Figure 3, right). During these episodes his clinical conditions were not aggravated, and transient atrial fibrillation was found on ECG. Hemorrhagic infarction was noted on a cranial computed tomogram (CT scan) on his 14th hospital day even though no anticoagulation therapy was given to this patient (Figure 4).

Case 2. A 75-year-old woman had been treated for hypertension, cardiomegaly, and arrhythmia for the past 10 years. She was well until the evening of admission, when her family found her with disturbed consciousness. On admission she was somnolent, her temperature was 36.0°C, her pulse was 76/min and irregular. Her supine blood pressure was 170/80 mm Hg. Neurologic examination revealed left-sided neglect, right conjugate deviation of her eyes, left hemiplegia, and left homonymous hemianopsia. Results of laboratory examinations were unremarkable. Atrial fibrillation was noted on ECG. On admission, DCS demonstrated a distal occlusive flow pattern of the left internal carotid artery (Figure 5, left); the diagnosis was confirmed by angiography on her third hospital day (Figure 5, right). On her eighth hospital day, DCS findings changed to a median flow pattern. On her 10th hospital day, the DCS Doppler flow pattern of the left internal carotid artery improved to a normal flow pattern (Figure 6, left). On her 12th hospital day, recanalization was confirmed angiographically (Figure 6, right). During these episodes her clinical conditions were unchanged. Hemorrhagic infarction was noted by cranial CT on her 10th hospital day even though no anticoagulation therapy was administered (Figure 7).

Case 3. A 76-year-old woman had been treated for angina pectoris and atrial fibrillation for 3 years prior to admission. She was well until the morning of admission, when her family found her with disturbed consciousness. On admission she was somnolent but fully oriented. Her temperature was 36.0°C, her pulse was 76/min and irregular. Her supine blood pressure was 170/80 mm Hg. Neurologic examination revealed left-sided neglect, right conjugate deviation of her eyes, left hemiplegia, and left homonymous hemianopsia. Results of laboratory examinations of her urine and blood were unremarkable. Atrial fibrillation was noted on ECG. On admission, a distal occlusive flow pattern of the right internal carotid artery was noted by DCS (Figure 8, left); the diagnosis was confirmed by angiography (Figure 8, right). On her second hospital day she complained of headache, and DCS findings changed to a median flow pattern. On her third hospital day she became semicomatose, but on her fifth day her level of consciousness improved to somnolence. On her sixth hospital day, the DCS Doppler flow pattern of the right internal carotid artery improved to a normal
**FIGURE 5.** Case 2. Left: Doppler flow pattern of left internal carotid artery on admission. Right: Lateral view of left carotid angiogram on third hospital day.

**FIGURE 6.** Case 2. Left: Doppler flow pattern of left internal carotid artery on 10th hospital day. Right: Lateral view of left carotid angiogram on 12th hospital day.

**FIGURE 7.** Case 2. Unenhanced computed tomograms on (left) third, (center) 14th, and (right) 21st hospital day. Hemorrhagic infarction was noted on 10th hospital day.
**Figure 8.** Case 3. Left: Doppler flow pattern of right internal carotid artery on admission. Right: Lateral view of right carotid angiogram on admission.

**Figure 9.** Case 3. Left: Doppler flow pattern of right internal carotid artery on sixth hospital day. Right: Lateral view of right carotid angiogram on sixth hospital day.

**Figure 10.** Case 3. Unenhanced computed tomograms on (left) second and (right) 10th hospital day. Hemorrhagic infarction was noted on eighth hospital day.
flow pattern (Figure 9, left) and recanalization was confirmed angiographically (Figure 9, right). During these episodes we did not use any anticoagulation therapy. Hemorrhagic infarction was noted by cranial CT on her eighth hospital day (Figure 10).

**Discussion**

We describe three patients with internal carotid artery occlusion at the siphon with subsequent recanalization and associated hemorrhagic infarction. Since these patients had atrial fibrillation without substantial atherosclerosis, cerebral embolism was the most likely diagnosis. In these patients, DCS showed three flow patterns of the internal carotid artery. The first pattern was the distal occlusive flow pattern, in which angiography showed complete occlusion of the internal carotid artery at the siphon. The third flow pattern was the normal flow pattern that is usually found in persons who do not have any occlusion; when DCS showed this pattern, angiography showed no occlusion in the internal carotid artery nor in the M1 portion of the middle cerebral artery. The second flow pattern was the median flow pattern, a pattern in between the first and third patterns. This second pattern indicates that the embolus has moved or incompletely lysed and partial recanalization has occurred; blood flow of the internal carotid artery was slightly increased, and this second pattern was observed only transiently. We found that the embolus moved distally and that only the anterior cerebral artery was visualized by angiography during this period in Case 1.

In these three patients recanalization was noted by DCS and confirmed by angiography. We consider that DCS alone is sufficient to recognize recanalization of an internal carotid artery occlusion.

Compared with CT findings, previous cerebral infarction changed to hemorrhagic infarction concurrent with recanalization, which was promptly detected by DCS (Figure 11).

In 1958, Lehrer initially demonstrated recanalization by serial angiography. Since then, angiography has been performed serially in cerebral infarction to detect recanalization. Recanalization usually occurs within 48–72 hours after the onset of occlusion, but it has been difficult to tell the exact time of recanalization angiographically. We have previously demonstrated the distal occlusive flow pattern in the internal carotid artery in five of five patients with carotid artery occlusion at the siphon and in three of four patients with middle cerebral artery occlusion at the M1 portion. Analysis of these three current patients suggest that the internal carotid artery flow pattern on DCS is a simple and easy way to detect recanalization.

Fisher and Adams postulated that downstream migration of the embolus after its initial impact leads to extravasation of blood via reflow into the damaged vessels. In our three patients, the appearance of hemorrhagic infarction on CT scans correlated with recanalization detected by DCS. Hemorrhagic infarction occurs by several hypothetical mechanisms. Our study supports the importance of recanalization in hemorrhagic transformation.

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**References**


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