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Reversible Ischemia Determined by Xenon-Enhanced CT after 90 Minutes of Complete Basilar Artery Occlusion

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Summary: Intraarterial thrombolytic therapy decreases mortality in the treatment of acute basilar artery occlusion. An acute decrease in cerebral blood flow (CBF) (<12 mL/100 g per minute) has been reported to invariably result in infarction. We report a case of acute basilar artery occlusion, recanalized within 90 minutes, with reversal of CBF of less than 6 mL/100 g per minute. After reperfusion, areas with persistent CBF of 6 mL/100 g per minute resulted in infarctions on subsequent CT studies. Parenchymal viability is possible after 90 minutes of posterior CBF of 6 mL/100 g per minute.

Recanalization of the basilar artery with intraarterial thrombolysis has been shown to improve outcome for patients with acute ischemic stroke due to basilar artery occlusion (1–3). Angiography, CT, and MR imaging are insufficient for determining the degree of ischemia or the reperfusion effects of arterial recanalization in the acute stage (4). We report a case of acute basilar artery occlusion treated 90 minutes after stroke onset with intraarterial urokinase in which cerebral blood flow (CBF) studies with xenon-enhanced CT were used to assess the degree of ischemic insult to brain tissue both before and after reperfusion therapy. CBF mapping was used to determine the posterior CBF after 90 minutes of basilar artery occlusion and complete arterial recanalization.

Case Report

A 53-year-old man with a medical history of hypertension, myocardial infarction, and unstable angina successfully treated with coronary angioplasty was brought to the emergency department for acute onset of slurred speech and right-sided weakness, although his symptoms improved before arrival. During the examination, the patient became suddenly unresponsive with pinpoint pupils. Visual field testing could not be completed. An immediate CT scan showed only an increased intravascular radiodensity of the distal basilar artery. A xenon CT CBF study performed within 1 hour of symptom onset showed perfusion defects in two axial sections, corresponding to the territories supplied by the superior cerebellar arteries (SCAs) and the posterior cerebral arteries (PCAs) (Fig 1A).

The ischemia in the PCA distribution was more severe on the left side (mean CBF, 6 ± 2 mL/100 g per minute) than on the right (mean CBF, 10 ± 2 mL/100 g per minute). Significant portions of the occipital lobes bilaterally showed CBF of 6 mL/100 g per minute or less (Fig 1A). Angiography immediately after xenon CT showed complete occlusion of the distal basilar artery below the origin of the SCAs (Fig 1B). Urokinase was infused into the distal basilar artery and PCAs using 200,000 U of urokinase per sequence of infusion every 10 to 15 minutes, to a total of 800,000 U. The posttreatment injections showed complete recanalization of the basilar artery, with third-order branch occlusion of the right PCA and occlusion at the P2 segment of the left PCA (Fig 1C).

An immediate postthrombolytic xenon CT CBF study was performed 4 hours after the initial onset of coma. The CT scan was unchanged. A CBF study showed reperfusion as hyperemia in the right PCA and bilaterally in the SCA distributions (mean CBF, 61 ± 10 mL/100 g per minute). The parenchyma supplied by the left PCA continued to show markedly reduced blood with CBF less than 6 mL/100 g per minute (Fig 1D). The patient was then transferred to the intensive care unit. A CT scan repeated after 2 days revealed hypodensities suggestive of infarctions and/or edema in both occipital lobes and in the territories partially supplied by the PCA (Fig 1E). A third CT scan, performed 12 days from admission, showed an evolving left occipital lobe hemorrhagic infarct without mass effect (Fig 1F). The hypodensity previously appreciated in the right occipital lobe had resolved (Fig 1F). On hospital day 34, the patient intermittently followed commands but became acutely hypotensive with severe respiratory distress. He died of a presumed pulmonary embolism. Authorization for autopsy was denied.

Discussion

The effect of reperfusion therapy has been studied primarily for occlusions of the anterior circulation (4–6). Some studies have shown improved patient outcome after administration of intraarterial thrombolytics for acute-onset basilar artery occlusions (1–3). Patient survival rates, however, remain disappointing, at approximately 50%, despite angiographic demonstration of complete arterial recanalization (1–3). To gain insight into the CBF effects of basilar artery occlusion followed by thrombolytic recanalization in our patient, we obtained pre- and postthrom-

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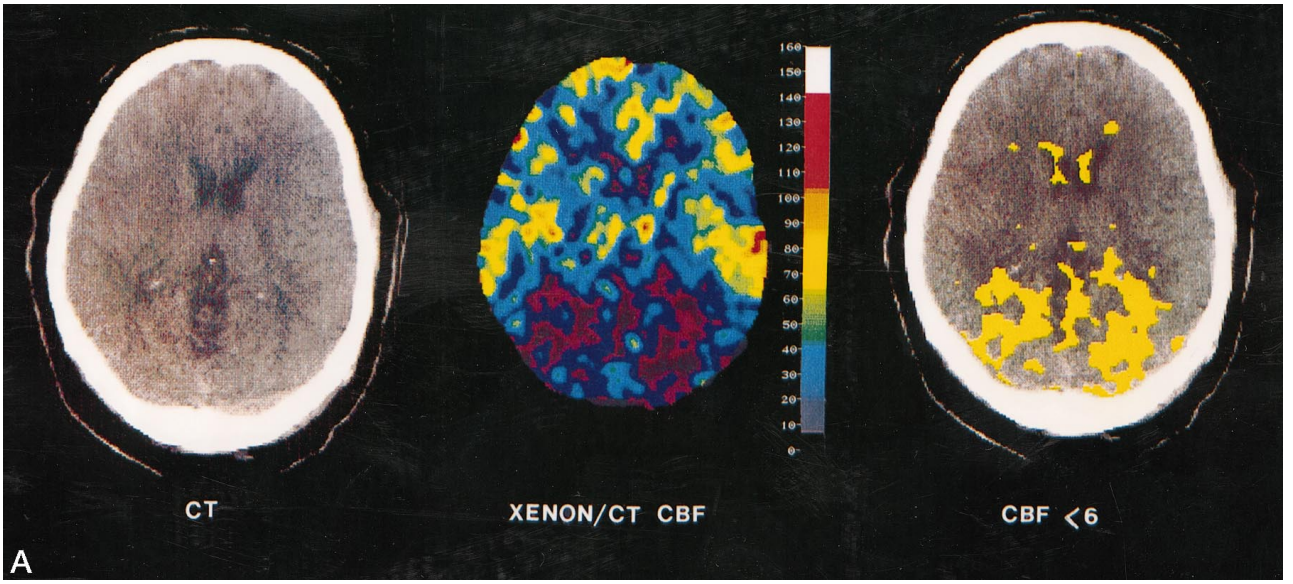


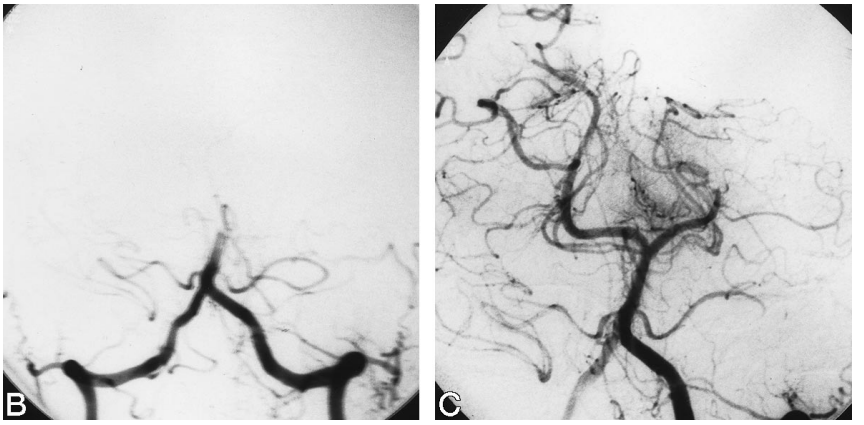


FIG 1. 53-year-old man with acute onset of slurred speech and right-sided weakness and a medical history of hypertension, myocardial infarction, and unstable angina successfully treated with coronary angioplasty.

A, Prethrombolytic xenon CT study within 1 hour of acute deficit shows profound ischemia with CBF of less than 6 ± 1 mL/100 g per minute (*yellow*) in the occipital lobes bilaterally and symmetrically. Reduced flow is localized predominantly to the PCA distributions.

B, Angiogram (anteroposterior view) shows occlusion of the basilar artery below the level of the SCAs.

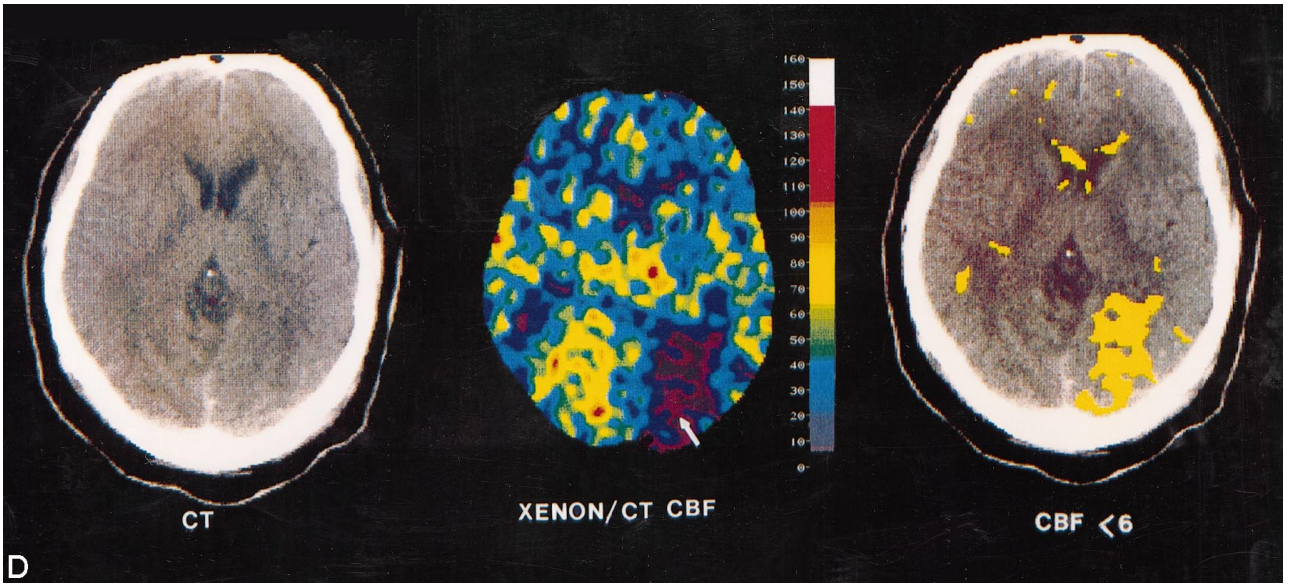
C, Postthrombolytic angiogram (anteroposterior view) shows recanalization of the basilar artery, with third-order branch occlusion of the right PCA and occlusion at the P2 segment of the left PCA.

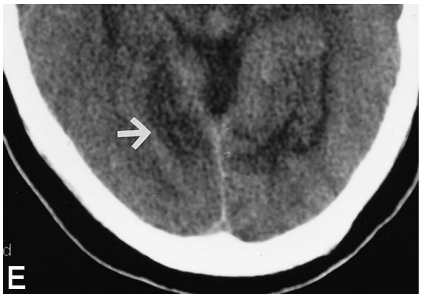
bolytic xenon CT CBF studies and correlated the results with the angiographic findings.

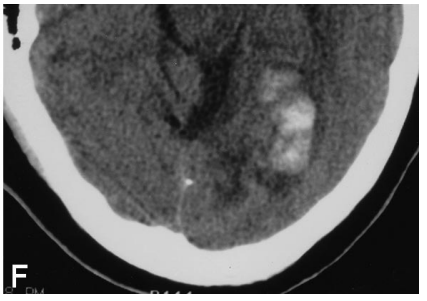
Angiography remains an important diagnostic and treatment tool for stroke patients. However, owing to its invasiveness, angiography cannot be used to serially survey the cerebral circulation days or weeks after thrombolytic therapy. Additionally, it does not depict vessels less than 100 μm in diameter, and is therefore less sensitive to CBF disturbances, such as no-reflow phenomena and postischemic hypoperfusion (7, 8). In the case presented here, the CBF map completely corresponded to the angiographic findings both before and after reperfusion therapy (Fig 1A–D). Prior to thrombolysis, profound ischemia was noted bilaterally throughout the territories supplied by the PCAs. After angiographic demonstration of acute basilar artery occlusion and subsequent arterial thrombolysis with complete arterial recanalization, the territories supplied by the SCAs and right PCA were noted to be mildly hyperemic on postthrombolytic xenon CT scans. The parenchyma supplied by the left PCA showed profoundly deficient flow, which corresponded to the P2 segment occlusion seen on the postthrombolytic angiogram (Fig 1D).

Comparisons of xenon CT studies before and after thrombolysis allow clinicians to quantify the degree of parenchymal ischemia before thrombolysis and its status after arterial recanalization. Xenon CT is a rapid, low-cost method for evaluating CBF in patients with acute stroke that can be easily added after a conventional CT study. Xenon CT studies provide quantitative CBF measurements of the entire blood flow range, including very low flow (<10 mL/100 g per minute), and has good anatomic resolution. A limitation of xenon CT is the difficulty in using it for studying CBF at the level of the low pons and medulla (anterior inferior cerebellar and posterior inferior cerebellar territories) owing to the presence of bone artifacts (9).

Previously, it has been reported that CBF of less than 12 mL/100 g per minute measured within the first 4 hours "invariably result[s] in infarction" (9). Yonas et al (10) have shown that after 60 minutes of intentional lateral striate artery clip occlusion, parenchyma with CBF below 8 mL/100 g per minute produced infarcts in baboons. Twenty minutes of lateral striate clip occlusion, however, did not produce infarcts in territories with similar CBF. This case of







D, Postthrombolytic xenon CT study within 4 hours of acute deficit shows marginal hyperemic flow in the right occipital lobe. CBF of less than 6 ± 1 mL/100 g per minute (*yellow*) persists in the left occipital lobe.

E and *F*, Unenhanced CT scans at the level of the occipital lobes 2 (*E*) and 12 (*F*) days after thrombolysis show a developing hemorrhagic infarction involving the left occipital lobe. In the medial right occipital lobe on day 2 (*E*), a focal radiolucency (*arrow*) has developed (presumably ischemic and/or edematous in nature), which has fully resolved by day 12 (*F*).

reversible ischemia at flows of 6 mL/100 g per minute after 90 minutes of complete basilar artery occlusion possibly suggests a lower threshold for irreversible ischemia in the posterior circulation. Prompt reperfusion, performed 90 minutes from onset of coma, most likely contributed to saving some ischemic brain tissue. This is supported by the fact that the hemorrhagic infarct evolved throughout the left occipital lobe, where CBF of 6 mL/100 g per minute persisted because of incomplete recanalization of the left PCA. The postthrombolytic CBF map corresponding to flow of 6 mL/100 g per minute or less correlates well with the infarcted brain areas seen on follow-up CT studies (Fig 1D–F). We believe that if the time to recanalization can be reduced, more ischemic brain tissue may be salvaged.

The pathophysiology of brain hemorrhage after reperfusion therapy is unknown. Risk factors for hemorrhage after stroke are advanced age, hypertension, severe stroke, and major signs of infarction on CT scans (4, 11). Ueda et al (12) reported an increased rate of hemorrhagic complications in patients with markedly low CBF preceding intraarterial thrombolysis. This is supported by the prethrombolytic xenon CT study in our patient, which showed profound reductions in CBF in the left occipital lobe, where the intracerebral hemorrhage later occurred. As no hemorrhage was observed in the right occipital lobe, it may be interesting to study the effects of reperfusion therapy on the rate of hemorrhagic transformation infarcts due to acute vascular occlusion.

Few studies in humans have analyzed CBF in the first hours after stroke; most have focused only on the anterior circulation (12, 13). Additionally, little is known of the effect of reperfusion therapy on CBF (12, 14). Pre- and postangioplasty xenon CT studies in patients with symptomatic cerebral vasospasm have shown that increasing local CBF to greater than 20 mL/100 g per minute results in neurologic improvement in 92% of patients (15).

Conclusion

It is our opinion that CBF studies performed within the first few hours from onset of stroke symptoms may answer the remaining questions concerning brain ischemia caused by acute vertebrobasilar artery occlusion. Most important, we may gain insight into parenchymal viability after reperfusion therapy. As shown by this case, xenon CT immediately after recanalization of the basilar artery shows that posterior CBF of 6 mL/100 g per minute may be suggestive of a threshold for reversible ischemia at 90 minutes of occlusion. Future studies are needed to determine whether immediate postthrombolytic xenon CT CBF studies may be helpful in identifying posterior circu-

lation thresholds for irreversible ischemia at varying durations of complete basilar artery occlusion. Most important, prospective, randomized studies are needed to identify the subset of patients who may benefit from acute thrombolytic therapy aimed at parenchymal salvage and reversal of ischemia.

References

1. Brandt T, von Kummer R, Muller-Kuppers M, Hacke W. **Thrombolytic therapy of acute basilar artery occlusion.** *Stroke* 1996;27: 875–881
2. Hacke W, Zeumer H, Ferbert A, Bruckman H, del Zoppo GJ. **Intra-arterial thrombolytic therapy improves outcome in patients with acute vertebrobasilar occlusive disease.** *Stroke* 1988;19:1216–1222
3. Zeumer H, Freitag HJ, Zanella F, Thie A, Arning C. **Local intra-arterial fibrinolytic therapy in patients with stroke: urokinase versus recombinant tissue plasminogen activator (r-tpa).** *Neuroradiology* 1993;35:159–162
4. Hacke W, Kaste M, Fieschi C, et al. **Intravenous thrombolysis with recombinant tissue plasminogen activator for acute hemispheric stroke: the European Cooperative Acute Stroke Study (ECASS).** *JAMA* 1995;274:1017–1025
5. Brott TG, Haley EC Jr, Levy DE, et al. **Urgent therapy for stroke, I: pilot study of tissue plasminogen activator administered within 90 minutes.** *Stroke* 1992;23:632–640
6. Jansen O, von Kummer R, Forsting M, Hacke W, Sartor K. **Thrombolytic therapy in acute occlusion of the intracranial internal carotid artery bifurcation.** *AJNR Am J Neuroradiol* 1995;16:1977–1986
7. Hossman KA. **Hemodynamics of post-ischemic reperfusion of the brain.** In: Weinstein PR, Faden AI, eds. *Protection of the Brain from Ischemia.* Baltimore: Williams & Wilkins; 1990:21–36
8. Ames A, Wright RL, Kowada M, Thurston JM, Majno G. **Cerebral ischemia, I: the no-reflow phenomenon.** *Am J Pathol* 1968;52:437–453
9. Yonas H, Pindzola RR, Johnson DW. **Xenon/computed tomography cerebral blood flow and its use in clinical management.** *Neurosurg Clin N Am* 1996;7:605–616
10. Yonas H, Gur D, Claassen D, Wolfson SK Jr, Moossy J. **Stable xenon-enhanced CT measurement of cerebral blood flow in reversible focal ischemia in baboons.** *J Neurosurg* 1990;73:266–273
11. The National Institute of Neurological Disorders and Stroke rt-PA Stroke Study Group. **Tissue plasminogen activator for acute ischemic stroke.** *N Engl J Med* 1995;333:1581–1587
12. Ueda T, Hatakeyama T, Kumon Y, Sakaki S, Uraoka T. **Evaluation of risk of hemorrhagic transformation in local intra-arterial thrombolysis in acute ischemic stroke by initial SPECT.** *Stroke* 1994;25:298–303
13. Alexandrov AV, Bladin CF, Elrich LE, Norris JW. **Noninvasive assessment of intracranial perfusion in acute cerebral ischemia.** *J Neuroimaging* 1995;5:76–82
14. Overgaard K, Sperling B, Boysen G, et al. **Thrombolytic therapy in acute ischemic stroke: a Danish pilot study.** *Stroke* 1993;24:1439–1446
15. Firlik AD, Kaufmann AM, Jungreis CA, Yonas H. **Effect of transluminal angioplasty on cerebral blood flow in the management of symptomatic vasospasm following aneurysmal subarachnoid hemorrhage.** *J Neurosurg* 1997;86:830–839

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