Accelerated Brain Infarction in Hypertension Complicated by Hereditary Heterozygous Protein C Deficiency

Seiji Kazui, MD; Yoshihiro Kuriyama, MD; Toshiyuki Sakata, PhD; Masahiko Hiroki, MD; Kotaro Miyashita, MD; Tohru Sawada, MD

Background: Protein C deficiency leads to reduced inhibition of coagulation and an increased likelihood of thrombosis. It is widely accepted that the most common syndromes associated with protein C deficiency are venous thrombosis and pulmonary thromboembolism, whereas arterial thrombosis is rare. Here we describe two patients with hypertension and hereditary heterozygous protein C deficiency who developed multiple lacunar infarcts.

Case Descriptions: Patient 1 was a 46-year-old man with a history of hypertension who developed a right upper quadrantanopia and gradually progressive intellectual and behavioral deterioration. Patient 2 was a 61-year-old man with history of hypertension and two episodes of right-sided motor weakness who developed left sixth and seventh cranial-nerve palsies and reduced pinprick sensation in the right extremities. In both patients, magnetic resonance imaging revealed multiple small lesions in the pons as well as the bilateral basal ganglia, thalamus, corona radiata, and other subcortical structures, which are consistent with lacunar infarcts. Protein C activity and antigen levels were reduced to approximately one half of normal in these two patients, as well as in some of their family members who had no other serological or coagulation abnormalities. A diagnosis of heterozygous protein C deficiency type I was thus established.

Conclusions: Although it remains uncertain whether protein C deficiency itself increases the risk of cerebral artery thrombosis, it may predispose a patient to develop multiple brain infarctions in association with hypertension. (*Stroke*, 1993;24:2097-2103.)

Key Words • cerebral infarction • hypertension • protein C

Protein C, a vitamin K-dependent plasma protein synthesized in the liver, is well known to play an important role in regulating coagulation. Activation of protein C is initiated by complex formation between thrombin and thrombomodulin on endothelial cells. Activated protein C, in conjunction with protein S, is a potent physiological inhibitor of factors Va and VIIIa and potentially is an activator of fibrinolysis. Protein C deficiency thus leads to a loss of clotting system regulation and a propensity for pathological thrombosis. It is widely accepted that the most common manifestations of this disease are venous thrombosis and pulmonary thromboembolism; however, arterial thrombosis only rarely complicates protein C deficiency.

We recently encountered two patients with multiple brain infarctions associated with hereditary heterozygous protein C deficiency.

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Case Reports

Patient 1

A 46-year-old man, a post office clerk with a history of hypertension for 20 years, developed a right-sided visual disturbance 6 months before admission. His colleagues in his office noticed deterioration of his ability to write and calculate. Members of his family also became aware that he was indifferent and depressed. The patient was then admitted to our institute for evaluation of his medical condition on April 25, 1991. He had no arrhythmia, cardiac disease, diabetes mellitus, hyperlipidemia, or smoking habit.

On admission, his blood pressure was 156/96 mm Hg. His pulse was regular at 58 beats per minute. The results of general physical examination were normal. The patient was alert but slightly disoriented to time. On the Mini-Mental State Exam, he scored 23 of 30. Neurological examinations disclosed a right upper homonymous quadrantanopia and exaggerated deep tendon reflexes bilaterally. The hematocrit was 41.7%. Serological tests for syphilis, anticardiolipin antibodies, and lupus anticoagulant were all negative. Magnetic resonance imaging (MRI) studies were carried out using a 1.5-T system (Siemens Corp) with a slice thickness of 4 mm. Axial T1- and T2-weighted images were obtained with spin-echo pulse sequences (T1: repetition time, 600 milliseconds; echo time, 17 milliseconds; T2: repetition
FIG 1. Magnetic resonance images in patient 1 showing numerous areas of low signal intensity on T1-weighted spin-echo images (a-d, i-l: repetition time, 600 milliseconds; echo time, 17 milliseconds) and areas of high signal intensity on T2-weighted spin-echo images (e-h, m-p: repetition time, 2800 milliseconds; echo time, 90 milliseconds) in the pons, left occipital lobe, corpus callosum, basal ganglia, thalami, coronae radiatae, and other subcortical structures. These lesions were seen on T2-weighted images as high signal intensity areas. A neuroradiologist (K.M.), who was unaware of the clinical status of the patient, counted 50 lacunar infarcts, in all, on the MRI (Fig 1). Cerebral angiography revealed an occlusion of the left posterior cerebral artery but no occlusive changes in other extracranial or intracranial arteries (Fig 2).

Patient 2
This patient was a 61-year-old man, an electrical engineer, with a history of hypertension for 13 years as well as two episodes of motor weakness of the right side approximately 10 years before admission. On January 3, 1992, he suddenly developed vertigo with vomiting and inability to walk and was admitted to our institute the...
next morning. He was a smoker but had no evidence of arrhythmia, cardiac disease, diabetes mellitus, or hyperlipidemia.

On admission, his blood pressure was 176/108 mm Hg. His pulse was 76 beats per minute without arrhythmia. A general physical examination revealed no abnormality. The patient was alert and well oriented to time, space, and person. On the Mini-Mental State Exam, he scored 30 of 30. Neurological examinations disclosed left sixth and seventh cranial-nerve palsies and impaired sensation for pinprick in the right extremities. These findings suggested an infarct on the left side of the pontine tegmentum. The hematocrit was 43.2%. Serological tests for syphilis, anticardiolipin antibodies, and lupus anticoagulant were all negative. MRI studies demonstrated numerous foci of low signal intensity on T1-weighted images, which were found to be hyperintense on T2-weighted images in the pons, internal capsules, basal ganglia, thalami, corona radiatae, and other subcortical regions (Fig 3). The gadolinium—diethylenetriamine pentaacetic acid infusion study demonstrated marked enhancement in the tegmentum of the left side of the pons. The number of lacunar infarctions totaled 36. Cerebral angiography revealed no occlusive changes in extracranial or intracranial arteries (Fig 4).

Because of the multiple brain infarcts seen in these two patients, coagulation studies were undertaken for the two subjects described and their available family members.

Methods

Coagulation studies were performed approximately 6 months after the onset of stroke for patient 1 and after 1 month for patient 2. The patients were not receiving anticoagulants.

Venous blood samples were collected in 3.8% sodium citrate anticoagulant. Each tube was immediately inverted gently several times and then centrifugated at 3000 rpm for 10 minutes at 4°C. The supernatant was then placed in plastic tubes and stored frozen at −80°C until used.

Routine coagulation tests, including prothrombin time, activated partial thromboplastin time, and fibrinogen assay were performed according to standard procedures. Fibrin degradation products were measured by the latex coagulation method using LPIA FDP (Teikokuzoki-seiyaku, Tokyo, Japan). Activities of antithrombin III, plasminogen, α2-plasmin inhibitor, and factor X were evaluated by the chromogenic substrate method; all kits were obtained from Kabi Vitrum AB (Stockholm, Sweden). α2-Inhibitor activity was measured by the chromogenic substrate method (Behringwerke, Marburg, FRG). Plasma prekallikrein was measured with the chromogenic substrate S-2302 from Kabi Vitrum AB. Activities of α1—macroglobulin, α1—antitrypsin, and plasminogen were assayed by the turbidimetric immunoassay using the corresponding antiserum supplied by Behringwerke. Protein induced by vitamin K absence—II (PIVKA-II) was measured with the PIVKAL test (Teikokuzoki-seiyaku). Protein C antigen was measured by electroimmunoassay with the protein C test (Teijin, Tokyo, Japan). Protein C amidolytic activity was determined by a thrombin-activated assay with chromogenic substrate S-2236 (Kabi Vitrum AB), and protein C anticoagulant activity was measured using commercially available kits from Diagnostica Stago (Asnières-Sur-Seine, France). Free protein S was quantitated by electroimmunoassay using the protein S test (Teijin). Protein S activity was measured according to the method described by Suzuki and Nishioka. C4b binding protein antigen was measured by a turbidimetric immunoassay using antiserum supplied by Diagnostica Stago.

Results

An isolated decrease of protein C activity was found in both patients and in some of their family members.
Patient 1 and His Family

In patient 1, the results of coagulation studies were all within normal range except for protein C levels (Tables 1 and 2). Protein C amidolytic and anticoagulant activities were found to be 52% and 54%, respectively, and the protein C antigen level was also reduced to 54%. Thus, a diagnosis of heterozygous protein C deficiency type 1 was established in this patient. The mother and two sons of the propositus, who were asymptomatic, also had protein C concentration of approximately one half of the normal range; however, his brother and sister had normal protein C levels (Table 2).

Patient 2 and His Family

A diagnosis of heterozygous protein C deficiency type 1 was also established in patient 2, because protein C amidolytic and anticoagulation activities were reduced to 43% and 50%, respectively, and the protein C antigen level was at 57%, while the results of other coagulation studies were all within normal range (Tables 1 and 2).
The sister of the propositus, who was asymptomatic, also had protein C levels at approximately one half of the normal range; however, his son had a normal protein C concentration (Table 2).

**Discussion**

There have been several case reports of arterial ischemic stroke associated with protein C deficiency. In the majority of these patients, computed tomographic and/or MRI studies revealed large lesions encroaching on the cerebral cortices. Angiography or duplex carotid or transcranial Doppler ultrasonography showed that major cerebral vessels were involved, including the internal carotid, middle cerebral, posterior cerebral, and anterior cerebral arteries. Some authors have described thrombotic occlusion of the internal carotid artery in association with protein C deficiency, while others have noted recanalization of the middle cerebral artery, which suggested an embolic mechanism.

In the present series, patient 1 had posterior cerebral artery occlusion that caused cortico-subcortical infarction in the occipital lobe, which was classified as atherothrombotic according to the system of the National Institute of Neurological Disorders and Stroke. However, the vast majority of the patient’s infarcts were small and were located in the basal ganglia, internal capsule, thalamus, corona radiata, centrum semiovale, and pons. These lesions could thus be regarded as lacunar infarcts.

It is well known that lacunar infarcts most often result from the occlusion of small arteries (usually less than 200 μm in diameter) by lipohyalinosis, which is a hypertensive cerebral vasculopathy. Our two patients also had a history of hypertension for more than 10 years. Thus, it is unclear whether protein C deficiency itself was the sole cause of infarction in our patients. Their most characteristic MRI findings were multiple lacunar infarcts. It is known that hypertension can cause white matter lesions without stroke symptoms in the

<table>
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<tr>
<th>Table 1. Coagulation Tests in Patients 1 and 2</th>
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<td><strong>Patient 1</strong></td>
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<tr>
<td>Prothrombin time, %</td>
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<tr>
<td>International ratio</td>
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<td>Activated partial thromboplastin time, s</td>
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<tr>
<td>Fibrinogen, mg/dL</td>
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<td>Antithrombin III activity, %</td>
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<td>α2-Plasmin inhibitor activity, %</td>
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<td>Fibrin degradation products, μg/mL</td>
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<td>C1-inhibitor activity, %</td>
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<td>α2-Macroglobulin, mg/dL</td>
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<td>α1-Antitrypsin, mg/dL</td>
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<td>Plasma prekallikrein, %</td>
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<td>Factor X, %</td>
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<td>Protein induced by vitamin K absence-II, μg/mL</td>
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elderly. However, our patients had small, round, and circumscribed lesions in the basal ganglia and other subcortical regions without any confluent lesions. To avoid overdiagnosis, we defined lacunar infarcts as small subcortical or pontine lesions of decreased intensity on T1-weighted images and hyperintensity on T2-weighted images, according to the recommendation of Shimada et al.27 Fisher23 performed a detailed pathological study of lacunar infarcts in a series of 1042 consecutive autopsies. In 114 cases, he found 376 lacunar infarcts, with an average of approximately 3 per brain and a maximum of 15 lacunes in a single patient. Ishii et al28 studied 30 necropsy cases of vascular dementia with lacunar infarcts and found that the number of lacunes varied from 6 to 24 per patient. In comparison with these studies, far more lacunes were observed in our patients, since 50 were noted in patient 1 and 36 in patient 2. Mileitch et al29 have stated that heterozygous protein C deficiency is not necessarily an important risk factor for thrombosis. In addition, Wong and coauthors30 have reported that the distribution of thrombomodulin varies among the different regions of the human brain, with significantly less thrombomodulin in the putamen, pons, and mesencephalon than in the neocortex. The thrombin-thrombomodulin complex activates protein C approximately 20 000 times more rapidly than thrombin alone.31

Therefore, we suggest that protein C deficiency may have accelerated the development of lacunar infarcts in the deep structures of brain in our patients in association with long-standing hypertension. Coagulation studies should be performed in patients with a large number of lacunes, even when they are hypertensive. Our two case reports may help to illuminate the multifactorial pathogenesis of brain infarction. It is to be hoped that a prospective study will be undertaken to investigate the relation between heterozygous protein C deficiency and brain infarction.

References

### TABLE 2. Protein C Levels and Other Coagulation Parameters in Patients 1 and 2 and Their Family Members

<table>
<thead>
<tr>
<th>Patient 1 and relatives</th>
<th>Protein C*</th>
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<td>Sex</td>
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<td>Sister</td>
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<td>Son 1</td>
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<td>Son 2</td>
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<td>Patient 2 and relatives</td>
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<td></td>
<td>Sex</td>
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<td>Sister</td>
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<td>Son</td>
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*Values show percentages of normal plasma levels.
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