Cerebral hemorrhage in Fabry disease

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Abstract

Fabry disease is an X-linked lysosomal storage disorder resulting from α-galactosidase A deficiency. Although ischemic stroke is recognized as an important manifestation of Fabry disease, hemorrhagic stroke is considered to be rare. Here, we report our recent clinical experience with 3 hemizygous male patients with Fabry disease who developed cerebral hemorrhage. One patient had classic type Fabry disease with p.Ala37Val mutation and others had cerebrovascular variant with p.Glu66Gln mutation. Degeneration of the cerebral small arteries secondary to deposition of glycosphingolipids and aging, in addition to hypertension and antiplatelet/anticoagulant agents, are considered to be contributing factors for hemorrhage. Fabry disease is frequently associated with not only ischemic but also hemorrhagic stroke, especially in elderly patients.

Fabry disease is an X-linked lysosomal storage disorder in which deficiency of α-galactosidase A (α-Gal A) leads to progressive accumulation of globotriaosylceramide and related glycosphingolipids in vascular endothelial lysosomes of the kidneys, heart, skin, and brain[1]. Stroke is one of the major complications of Fabry disease[2] and has been described in ≥ 25% of patients[3-6]. In patients with the classic phenotype, levels of α-Gal A activity are very low or undetectable, and progressive glycosphingolipids accumulation leads to renal, cardiac, and cerebrovascular manifestations and early death[1]. On the other hand, patients with substantial levels of residual α-Gal A activity have milder phenotypes, including renal[7] and cardiac[8] variant. Another atypical variant of Fabry disease has been reported, with manifestations limited to the cerebrovascular system[9, 10]. Although cerebral infarction is recognized as an important manifestation of Fabry disease[2, 9, 11], cerebral hemorrhage seems to be underrecognized in this disorder. Here, we report our recent clinical experience with 3 hemizygous male patients with Fabry disease suffering cerebral hemorrhage.

Materials and Methods

α-Gal A activity was determined using a fluorescent substrate as previously described[12]. Briefly, 40 μL of McIlvan buffer (0.1 M citrate, 0.2 M NaH_2PO_4, 36.8 : 63.2, pH 6.0) were added to 96 microwell plates. Three mm punch of dried blood spots were added into the buffers and processed for extraction at room temperature for 2 hours. Thirty μL of blood extract were transferred into another 96 microwell plate. One hundred μL of the reaction mixture (3.5 mM 4-MU galactosylpyranoside, 100 mM citrate, 200 mM phosphate, 100 mM

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N- acetylgalactosamine) were added into each well of the microplates and incubated at 37 °C for 24 hours. The reaction was terminated with 150 μL of termination solution (300 mM glycine, NaOH, pH10.6) immediately after the reaction. Fluorescent intensity from the 4-methylumbelliferones in the wells was measured with fluorescent plate reader（BIO-TEK）at 450 nm. One unit (AgalU) of enzymatic activity was equal to 0.34 pmol of 4-methylumbelliferyl-D-galactopyranoside cleaved/h/disc. For DNA analysis, total genomic DNA was extracted from leukocytes of patients. All 7 exons of the *GLA* gene were amplified by polymerase chain reaction (PCR), and the amplification products were analyzed by a direct sequencing method. This study was approved by the Ethical Committee of Shinshu University School of Medicine and informed consent was obtained from each patient.

Case reports

Patient 1 The patient was a 49-year-old Japanese man. His mother developed cryptogenic cerebral infarction at age 52 and his younger brother was diagnosed as having Fabry disease based on renal failure and decreased α-Gal A activity. He developed proteinuria at age 25 with progressively deteriorated renal function and became dependent on hemodialysis at age 46. At age 44, a diagnosis of Fabry disease was made based on clinical findings, family history, and decreased α-Gal A activity. Enzyme replacement therapy was started with biweekly infusions of agalsidase-β at age 47. At age 49, he developed acute onset of right-sided weakness and aphasia and was admitted to a local hospital. CT scan revealed a left thalamic hemorrhage with ventricular perforation (Figure 1A,B). He was referred to our hospital for biochemical

and molecular diagnosis. Measurement of α-Gal A activity in the whole blood revealed 4.6 AgalU (normal >17.0) and direct DNA sequencing of the *GLA* gene revealed a single base sequence change (c.110C>T) causing substitution of a alanine reside with valine at codon 37 (p.Ala37Val) (Figure 2A).

Patient 2 The patient was an 83-year-old Japanese man. There was no family history suggesting Fabry disease. He had been well until 76 years old, when he developed hypertension. At age 81, he developed aphasia and was admitted to a local hospital. Brain MRI showed cerebral infarction in the left temporal lobe, and antiplatelet therapy (aspirin 100 mg/day) was started. Two months later, he suddenly developed dysarthria and a diagnosis of left putaminal hemorrhage was made (Figure 1C,D). Antiplatelet therapy was discontinued after this episode. At age 83, he noticed weakness in the right arm and was diagnosed with recurrence of cerebral infarction. He was referred to our hospital to determine the pathogenesis of recurrent cerebrovascular events. Measurement of α-Gal A activity in the whole blood revealed 11.6 AgalU (normal >17.0) and direct DNA sequencing of the *GLA* gene revealed a single base sequence change (c.196G>C) causing substitution of a glutamate reside with glutamine at codon 66 (p.Glu66Gln), suggesting that his recurrent episodes of stroke were caused by Fabry disease (Figure 2B).

Patient 3 The patient was a 74-year-old Japanese man, who had been in good health except a history of compression fracture of the lumbar spine. There was no family history suggesting Fabry disease. At age 73, he suddenly noticed vertigo and nausea, and was

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admitted to a local hospital. Brain MRI showed lacunar infarctions in the left pons and right

cerebellar hemisphere. He was diagnosed as having cryptogenic cerebral infarction and

treated with aspirin (100 mg/day). At age 74, he was admitted to our hospital to investigate

the pathogenesis of cerebral infarction. Measurement of α-Gal A activity in whole blood

revealed 12.3 AgalU (normal >17.0) and direct DNA sequencing of the *GLA* gene showed

c.196G>C (p.Glu66Gln) mutation (Figure 2C). Based on these findings, he was diagnosed

with Fabry disease and enzyme replacement therapy with agalsidase-β was started. A month

later, he developed consciousness disturbance and a diagnosis of right thalamic hemorrhage

with ventricular perforation was made (Figure 1E,F).

Discussion

Clinical information is available for only 4 patients with Fabry disease who developed

cerebral hemorrhage (Table 1)[8, 13-15]. Three patients were hemizygous males with classic type

[8, 13, 14] and 1 was a heterozygous female[15]. All 4 patients had renal dysfunction and 3 had

uncontrolled hypertension. None of the patients received enzyme replacement therapy. The

patients presented here were all hemizygous males (Table 1). Patient 1 had classic type Fabry

disease with p.Ala37Val mutation, and patients 2 and 3 had cerebrovascular variant phenotype

with p.Glu66Gln mutation[7, 16]. Although only 4 patients have been reported previously, our

recent clinical experience with 3 patients suggests that cerebral hemorrhage is a relatively

common underrecognized complication of Fabry disease[17]. Indeed, the incidence rate of

cerebral hemorrhage was reported to be about 3-fold higher in Fabry stroke group (14.3%)

than non-Fabry stroke group (5.0%)[9], although detailed information regarding hemorrhage was not described.

The pathophysiological mechanism of cerebral hemorrhage in Fabry disease remains to be elucidated but may be attributable to several factors. Most likely, the hemorrhage is a consequence of uncontrolled hypertension secondary to renal dysfunction. In fact, our patient 1 was treated with chronic hemodialysis and patients 1 and 2 had hypertension, although their blood pressures were well controlled by antihypertensive drugs. On the other hand, our patient 3 had neither hypertension nor renal dysfunction, suggesting that there should be other contributing factors for cerebral hemorrhage. In Fabry disease, deposition of glycosphingolipids occurs predominantly in the lysosomes of endothelial, perithelial, and smooth-muscle cells of blood vessels. Glycosphingolipids deposition in cerebral large arteries leads to the development of the dolichoectasia which is commonly seen in Fabry patients. Cerebral aneurysm of large arteries[18, 19] and subsequent subarachnoid hemorrhage[19] are also reported in some patients. Recently, it is reported that cerebral small artery disease, which is known to be associated with lacunar infarction, white matter lesions (leukoaraiosis), and cerebral hemorrhage, rather than large artery stroke, is frequently observed in Fabry disease[5, 6, 20]. These findings suggest that the underlying degeneration of the cerebral small arteries, secondary to the deposition of glycosphingolipids in the vessel wall, could be a strong contributing factor for cerebral hemorrhage in Fabry disease. Aging is thought to be another important contributing factor[6], as our patients, especially patients 2 (83 years old) and 3 (74

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years old), were elderly compared to average Fabry patients. Finally, there is no doubt that antiplatelet and anticoagulation therapies were partially responsible for cerebral hemorrhage.

Enzyme replacement therapy can clear microvascular endothelial deposits of glycosphingolipids from the kidneys, heart, and skin in patients with Fabry disease, reversing the pathogenesis of the chief clinical manifestations of this disease. Although a tendency to normalization of cerebral vessel compliance and regional cerebral hyperperfusion has been demonstrated in patients with the disease after enzyme replacement therapy[21], beneficial effects of this treatment on the incidence of stroke in Fabry disease have not yet been demonstrated. Reasons for the failure of enzyme replacement therapy yet to affect stroke incidence in the disease include the irreversible damage done by the time patients develop such late complications. Thus, such treatment should be started earlier in the natural history of the disease.

In conclusion, Fabry disease is frequently associated with cerebrovascular complications, including not only ischemic but also hemorrhagic stroke. Antiplatelet and/or anticoagulation therapies are necessary for most patients with Fabry disease. However, care should be taken in the administration of such therapies considering the increased risk of cerebral hemorrhage.

References

1.   Brady R.O., Schiffmann R. Clinical features of and recent advances in therapy for

        Fabry disease. *JAMA*. **284**, 2771-2775 (2000).

2.   Mitsias P., Levine S.R. Cerebrovascular complications of Fabry's disease. *Ann Neurol*.

        40, 8-17 (1996).

3.   MacDermot K.D., Holmes A., Miners A.H. Anderson-Fabry disease: clinical

        manifestations and impact of disease in a cohort of 98 hemizygous males. *JAMA*. **38**,

        750-760 (2001).

4.   Grewal R.P. Stroke in Fabry's disease. *J Neurol*. **241**, 153-156 (1994).

5.   Buechner S., Moretti M., Burlina A.P., Cei G., Manara R., Ricci R., et al. Central

        nervous system involvement in Anderson Fabry disease: a clinical and MRI

        retrospective study. *J Neurol Neurosurg Psychiatry*. **79**, 1249-1254 (2008).

6.   Crutchfield K.E., Patronas N.J., Dambrosia J.M., Frei K.P., Banerjee T.K., Barton

        N.W., et al. Quantitative analysis of cerebral vasculopathy in patients with Fabry

        disease. *Neurology*. **50**, 1746-1749 (1998).

7.   Nakao S., Kodama C., Takenaka T., Tanaka A., Yasumoto Y., Yoshida A., et al. Fabry

        disease: Detection of undiagnosed hemodialysis patients and identification of a "renal

        variant" phenotype. *Kidney Int*. **64**, 801-807 (2003).

8.   Nakao S., Takenaka T., Maeda M., Kodama C., Tanaka A., Tahara M., et al. An

        atypical variant of Fabry's disease in men with left ventricular hypertrophy. *N Engl J*

Med. **333**, 288-293 (1995).

9. Rolfs A., Bottcher T., Zschiesche M., Morris P., Winchester B., Bauer P., et al.

   Prevalence of Fabry disease in patients with cryptogenic stroke: a prospective study.

   Lancet. **366**, 1794-1796 (2005).

10. Schiffmann R., Ries M. Fabry's disease - an important risk factor for stroke. *Lancet.*

    366, 1754-1756 (2005).

11. Moore D.F., Ye F., Schiffmann R., Butman J.A. Increased signal intensity in the

    pulvinar on T1-weighted images: A pathognomonic MR imaging sign of Fabry disease.

    AJNR Am J Neuroradiol. **24**, 1096-1101 (2003).

12. Chamoles N.A., Blanco M., Gaggioli D. Fabry disease: enzymatic diagnosis in dried

    blood spots on filter paper. *Clin Chim Acta.* **308**, 195-196 (2001).

13. Bass B.H. Angiokeratoma corporis diffusum. *Br Med J.* **1**, 1418 (1958).

14. Wise D., Jellinek E.H., Wallace H.J. Angiokeratoma corporis diffusum. A clinical

    study of eight affected families. *Q J Medicine.* **31**, 177-206 (1962).

15. Steward V.W., Hitchcock C. Fabry's disease (angiokeratoma corporis diffusum). A

    report of 5 cases with pain in the extremities as the chief symptom. *Pathol Eur.* **3**,

    377-388 (1968).

16. Yoshitama T., Nakao S., Takenaka T., Teraguchi H., Sasaki T., Kodama C., et al.

    Molecular genetic, biochemical, and clinical studies in three families with cardiac

    Fabry's disease. *Am J Cardiol.* **87**, 71-75 (2001).

17.   Sims K., Politei J., Banikazemi M., Lee P. Stroke in Fabry disease frequently occurs

before diagnosis and in the absence of other clinical events: natural history data from

the Fabry Registry. *Stroke.* **40**, 788-794 (2009).

18.   Maisey D.N., Cosh J.A. Basilar artery aneurysm and Anderson-Fabry disease. *J

Neurol Neurosurg Psychiatry.* **43**, 85-87 (1980).

19.   Sakuishi K., Hashimoto A., Ugawa Y., Tuji S. An experience of enzyme therapy on

adult-onset atypical Fabry's disease. *Shinkeinaika.* **62**, 62-69 (2005) (in Japanese).

20.   Moore D.F., Kaneski C.R., Askari H., Schiffmann R. The cerebral vasculopathy of

Fabry disease. *J Neurol Sci.* **257**, 258-263 (2007).

21.   Moore D.F., Altarescu G., Ling G.S.F., Jeffries N., Frei K.P., Weibel T., et al. Elevated

cerebral blood flow velocities in Fabry disease with reversal after enzyme replacement.
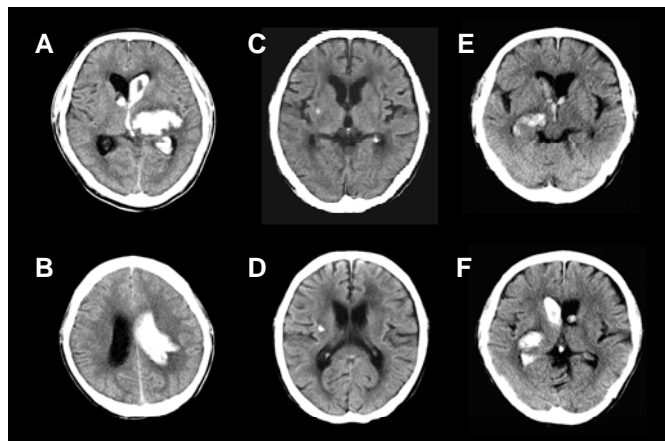
Stroke. **33**, 525-531 (2002).

Figure legend

Figure 1. Brain CT scans of patients with Fabry disease. (A, B) Brain CT of patient 1 showed large left thalamic hematoma with rapture into the lateral, third, and fourth ventricles and associated hydrocephalus. (C, D) Brain CT of patient 2 showed minor left putaminal hemorrhage and diffuse ischemic change in bilateral cerebral white matter. (E, F) Brain CT of patient 3 showed right thalamic bleeding with extension into the lateral and third ventricles.

Figure 2. Direct nucleotide sequencing of the PCR-amplified DNA of the *GLA* gene. (A) The sense strand of the DNA from patient 1. Vertical arrow indicates nucleotide 110 (exon 1), where a hemizygous C→T transversion resulted in an amino acid substitution p.Ala37Val. (B, C) The sense strand of the DNA from patient 2 (B) and patient 3 (C). Vertical arrow indicates nucleotide 196 (exon 2), where a hemizygous G→C transversion resulted in an amino acid substitution p.Glu66Gln.
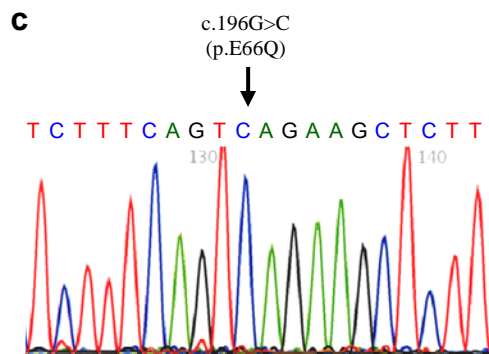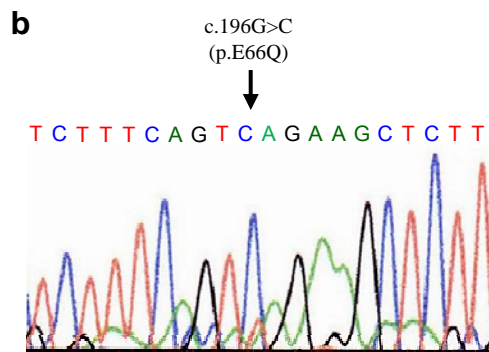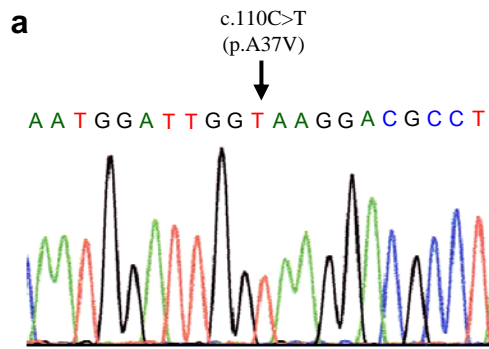
Table 1 Clinical features of Fabry disease patients with cerebral hemorrhage

Patient (reference number)	Age	Sex	Renal dysfunction	Cardio-myopathy	Cerebral infarction	Other complications	Hyper-tension	ERT	Antiplatelet / anticoagulant	*GLA* gene mutation
1*	49	M	+ (HD)	+	–	hypohidrosis	+ (good control)	+	–	A37V
2*	83	M	–	–	+	–	+ (good control)	–	aspirin	E66Q
3*	74	M	–	–	+	–	–	+	aspirin	E66Q
4 (8)	62	M	+	+	–	–	+ (poor control)	–	n. d.	M296I
5 (13)	38	M	+	n. d.	n. d.	angiokeratoma	+ (poor control)	–	n. d.	n. d.
6 (14)	42	M	+	n. d.	n. d.	angiokeratoma acroparesthesia	+ (poor control)	–	n. d.	n. d.
7 (15)	57	F	+	+	n. d.	dementia	n. d.	–	n. d.	n. d.

*Patients described in this paper.　ERT, enzyme replacement therapy.　HD, hemodialysis.　n.d., not described.

Nakamura et al. Figure 1

a

c.110C>T
(p.A37V)

↓

A A T G G A T T G G T A A G G A C G C C T

b

c.196G>C
(p.E66Q)

↓

T C T T T C A G T C A G A A G C T C T T

c

c.196G>C
(p.E66Q)

↓

T C T T T C A G T C A G A A G C T C T T

Nakamura et al. Figure 2