Human T-lymphotrophic virus type I– (HTLV-I–) associated myelopathy/tropical spastic paraparesis (HAM/TSP) is a chronic, slowly progressive myelopathy caused by HTLV-I. The main neurologic findings are spastic paraparesis and urinary disturbance. The incidence of HAM/TSP among HTLV-I–infected individuals is estimated to be less than 1%. This suggests that occurrence of HAM/TSP requires additional factors, such as viral factors and host conditions.

Among 213 patients with HAM/TSP diagnosed at our university before 1993, 172 patients had no history of blood transfusion. Although HTLV-I was mainly transmitted by maternal milk, 151 patients did not begin to show symptoms of HAM/TSP until middle or old age. However, 21 of 213 patients presented symptoms at less than 15 years of age. These juvenile-onset patients appeared to have characteristic signs of short stature and hypocalcemia. Among them, three juvenile-onset patients with HAM/TSP and pseudohypoparathyroidism type Ia (PHP Ia) have already been reported.

The purpose of the current study was to clarify whether short-stature patients with HAM/TSP had a tendency to exhibit signs and symptoms during early age and whether this was related to PHP Ia.

**Methods.** HAM/TSP was diagnosed according to World Health Organization diagnostic guidelines. We classified the heights of HAM/TSP patients using the table of Japanese average height against sex and ages (1995), and we examined 14 patients with HAM/TSP complicated with short stature for PHP Ia (table 1). We applied the following criteria for diagnosis of PHP Ia: 1) serum levels of calcium, phosphorus, and parathyroid hormone (PTH); 2) short stature, round face, obesity, slight mental retardation, and short metacarpi—signs of Albright’s hereditary osteodystrophy (AHO); 3) resistance to PTH loading test (Ellsworth–Howard test, E-H test); and 4) α-subunit of the stimulatory guanine nucleotide-binding protein (Gsa) abnormality. We used the Wechsler Adult Intelligence Scale (WAIS) to determine IQ.

The renal resistance for external PTH was examined from urinary cAMP excretion in response to 100 units of human recombinant PTH 1–34 (Asahi Chemical Ind., Tokyo, Japan) (E-H test). We set a <1 μmol increase of urinary excretion after PTH injection for 1 hour as positive. Erythrocyte membrane prepared by Dodge’s procedure was subjected to 10% sodium dodecyl sulfate polyacrylamide gel electrophoresis and transferred to a nitrocellulose membrane. Western blotting was conducted with anti-Gsa antibody (K-20 antibody; Santa Cruz Biotechnology, Inc., Santa Cruz, CA) and peroxidase conjugated rabbit anti-IgG antibody (Jackson Immunoresearch Laboratories, West Grove, PA) as a secondary antibody.

Twenty milliliters of heparinized blood was collected with the patient’s permission, and lymphocytes were separated using a Ficoll–Hypaque solution (Mono-Poly Resolving Medium; Dainippon Pharmaceutical Co., Osaka, Japan). Total cellular RNA was extracted with 1 mL of RNAzol B (Cinna Biotecx, Houston, TX) per 10^6. Five micrograms of RNA were subjected to Northern blotting with a [32P]-labeled Gsa cDNA.

**Results.** Among the 294 patients with HAM/TSP who were examined before 1995, 51 were found to have short stature (less than −1 × SD against Japanese average height). Among them, 34 were adult-onset patients and 17 were juvenile-onset patients. Furthermore, among the short-stature patients measured against Japanese average height, the rate of juvenile-onset patients was significantly higher (table 2). The short-stature patients tended to manifest the signs and symptoms during early age.

Twenty-nine patients with juvenile-onset HAM/TSP (4 men, 25 women) were identified among the 294 patients with HAM/TSP. Their heights are plotted in the figure. These findings show that juvenile-onset patients were mainly those with short stature.

The clinical features of 14 short-stature patients with HAM/TSP are shown in table 1. Neither round face nor obesity was found in these patients. A younger brother of Patient 14 (aged 44 years, height 150 cm [−3.3 × SD]) and two sisters of Patient 2 had HAM/TSP and short stature; however, extensive examination was not allowed.

The immunoreactivity of Gsa, the 45 kDa molecular weight of human erythrocyte membrane, was reduced in 11 patients and in the youngest sister (aged 38 years,
The mRNA expression of Gsα was reduced in Patient 3 and her mother, Patient 4, Patient 7 and his mother, and Patient 13, compared with that in normal controls (table 1). Only a few patients were examined because of the large blood volume collection necessary for mRNA preparation. These findings indicate that eight patients possibly had PHP Ia and four patients possibly had pseudopseudohypoparathyroidism (PPHP).

Discussion. PHP is a metabolic disorder characterized by AHO and resistance to PTH. PHP Ia and PPHP are genetically the same disease. The decreased activity and the low protein levels of Gsα are responsible for PHP Ia.4 We diagnosed four patients with PPHP who had no hormone resistance despite a Gsα deficiency.

Although PHP is clinically diagnosed by the E-H test, we used the E-H test for several patients because the current patients had urinary disturbances. Furthermore, most patients with a normal serum calcium level had normal reactions to PTH in the E-H test.5 We have no method to diagnose PHP Ib (PTH receptor abnormality), PHP Ic (adenylate cyclase deficiency), and PHP type II. Therefore, we only diagnosed PHP Ia and the variant-type PPHP in the patients with HAM/TSP.

Autosomal dominant transmission is a known inheritance pattern of PHP Ia.4 Among the families of 12 patients diagnosed with PHP Ia or PPHP, two of their

Table 1  Clinical and laboratory findings of the short stature patients with human T-lymphotropic virus type 1–(HTLV-1–) associated myelopathy/tropical spastic paraparesis

<table>
<thead>
<tr>
<th>Patient no.</th>
<th>Age, y/sex</th>
<th>Height, cm (SD)*</th>
<th>Age at onset</th>
<th>HTLV-1 titer†</th>
<th>Ca (8.5–10.5 mg/dL)</th>
<th>P (2.5–4.5 mg/dL)</th>
<th>HS-PTH (160–520 pg/mL)</th>
<th>1,25 (OH)2D3 (20–76 mg/dL)</th>
<th>Short meta-carpus</th>
<th>WAIS IQ</th>
<th>RBC Gsα</th>
<th>Lymphocytic Gsα mRNA</th>
<th>Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>57/F</td>
<td>140 (2.4)</td>
<td>Childhood</td>
<td>2048</td>
<td>9.0</td>
<td>3.7</td>
<td>200</td>
<td>ND</td>
<td>ND</td>
<td>Decreased ND</td>
<td>ND</td>
<td>Decreased ND</td>
<td>PHP Ia</td>
</tr>
<tr>
<td>2</td>
<td>72/F</td>
<td>134 (2.8)</td>
<td>Infant</td>
<td>8192</td>
<td>8.5</td>
<td>4.4</td>
<td>270</td>
<td>18.3 Positive</td>
<td>+ 76</td>
<td>Decreased ND</td>
<td>ND</td>
<td>PHP Ia</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>55/F</td>
<td>140 (3.0)</td>
<td>Childhood</td>
<td>2048</td>
<td>8.8</td>
<td>4.1</td>
<td>340</td>
<td>58 Positive</td>
<td>+ 83</td>
<td>Decreased Decreased</td>
<td>PHP Ia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>71/M</td>
<td>137 (2.2)</td>
<td>59 y</td>
<td>131,072</td>
<td>8.1</td>
<td>4.2</td>
<td>290</td>
<td>ND Positive</td>
<td>82 Decreased</td>
<td>Decreased PHP</td>
<td>Ia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>48/F</td>
<td>144 (2.2)</td>
<td>Childhood</td>
<td>32,768</td>
<td>8.4</td>
<td>3.7</td>
<td>300</td>
<td>ND Negative</td>
<td>+ 62 Decreased</td>
<td>Decreased PHP</td>
<td>Ia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>70/F</td>
<td>138 (2.0)</td>
<td>66 y</td>
<td>2048</td>
<td>8.4</td>
<td>3.5</td>
<td>310</td>
<td>ND ND Decreased</td>
<td>ND Decreased</td>
<td>ND PHP Ia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>44/M</td>
<td>149 (3.4)</td>
<td>Childhood</td>
<td>65,536</td>
<td>8.4</td>
<td>2.9</td>
<td>360</td>
<td>16 ND Decreased</td>
<td>Decreased Decreased</td>
<td>PHP Ia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>75/F</td>
<td>131 (2.7)</td>
<td>60 y</td>
<td>8192</td>
<td>8.6</td>
<td>3.7</td>
<td>250</td>
<td>28.5 Positive Decreased ND</td>
<td>Decreased ND</td>
<td>Decreased PHP</td>
<td>Ia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>18/F</td>
<td>132 (4.9)</td>
<td>15 y</td>
<td>4096</td>
<td>8.6</td>
<td>5.4</td>
<td>ND</td>
<td>36.8 ND Decreased</td>
<td>ND Decreased</td>
<td>ND PHP Ia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>27/F</td>
<td>146 (2.5)</td>
<td>13 y</td>
<td>8192</td>
<td>8.6</td>
<td>3.8</td>
<td>330</td>
<td>ND Negative</td>
<td>56 Normal</td>
<td>Normal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>42/F</td>
<td>140 (3.1)</td>
<td>10 y</td>
<td>65,536</td>
<td>9.4</td>
<td>3.9</td>
<td>320</td>
<td>ND ND Negative</td>
<td>ND Normal</td>
<td>Normal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>50/F</td>
<td>143 (2.4)</td>
<td>35 y</td>
<td>8192</td>
<td>8.0</td>
<td>3.2</td>
<td>ND</td>
<td>ND ND Decreased</td>
<td>65 Decreased</td>
<td>ND PHP Ia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>67/F</td>
<td>143 (1.2)</td>
<td>30 y</td>
<td>4096</td>
<td>8.2</td>
<td>3.1</td>
<td>410</td>
<td>55 Negative</td>
<td>ND ND Decreased</td>
<td>PHP Ia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>47/F</td>
<td>127 (5.5)</td>
<td>Childhood</td>
<td>2048</td>
<td>8.6</td>
<td>3.7</td>
<td>950</td>
<td>16.5 Positive + 78 ND ND</td>
<td>Decreased PHP</td>
<td>PHP Ia</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Patients 2, 3, and 14 were previously reported.1

* How many SD the patients were shorter than Japanese average heights against sex and age (1995).

† HTLV titer was determined by the particle agglutination method (Fujiwara Inc., Tokyo, Japan). Normal range of serum is less than 16-fold and CSF is less than fourfold.

HS-PTH = hypersensitive PTH, assayed with HS-PTH determination kit (YAMASA, Japan); E-H = Ellsworth–Howard; WAIS = Wechsler Adult Intelligence Scale; RBC = red blood cell; ND = not determined; PPHP = pseudopseudohypoparathyroidism; PHP = pseudohypoparathyroidism.

Figure. The relation of the heights to the age of male (A) and female (B) juvenile-onset patients with human T-lymphotropic virus type 1–associated myelopathy/tropical spastic paraparesis (HAM/TSP). Many juvenile-onset patients were apparently recognized with short stature compared with adult-onset patients and standard Japanese individuals. Japanese average heights against age and sex (1995) are shown by solid lines. Solid diamonds, adult-onset patients with HAM/TSP; open squares, juvenile-onset patients with HAM/TSP.

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mothers had PHP Ia or PPHP. The mother of Patient 14 was possibly diagnosed with PPHP because of slightly shorter stature (aged 71 years, height 145 cm \([\text{standard height}] - 0.6 \times \text{SD}\) ), WAIS IQ score of 85, and hypocalcemia (serum calcium level, 8.6 mg/dL). The current findings suggest that these three patients inherited the PHP gene from their mothers and that HTLV-I had been originally transmitted to their mothers by their fathers. Many of the patients’ siblings had slightly shorter stature, and most of the current patients were the younger children in their families. However, further investigation was impeded by the death of the other patients’ parents.

The annual period prevalence of PHP was 3.4 per million people in 1997 in Japan. Variable clinical severity possibly calculates the number of patients with PHP less than the true number. Results of the current examination suggest that PHP is possibly not a rare disease; however, the incidence of PHP in HAM/TSP appeared high.

Abnormality of PHP is caused in part by reducing 1,25-dihydroxyvitamin D\(_3\) \((1,25-\text{(OH)}_2\text{D}_3)\). 1,25-(OH)_2D_3 is recognized not only as a calcium regulator but also as an immunoregulatory hormone. Vitamin D deficiency is often accompanied by infections such as tuberculosis. 1,25-(OH)_2D_3 has an inhibitory effect on the release of interleukin-2 (IL-2) and interferon-\(\gamma\) from peripheral blood mononuclear cells. Levels of IL-2 mRNA of peripheral blood mononuclear cells from HAM/TSP patients are significantly increased compared with those from asymptomatic HTLV-I carriers and patients with ATL. IL-2 activates polyclonal proliferations of HTLV-I–infected T cells.

1,25-(OH)_2D_3 inhibited the proliferation of MT-2 cells and the HTLV-I infected T-cell line in a time- and dose-dependent manner. These findings suggest that patients with PHP had an inappropriate immune defense system caused by decreased 1,25-(OH)_2D_3, which might be a host factor required for development of HAM/TSP.

Many kinds of diseases have been described in relation to HAM/TSP, such as T-lymphocyte alveolitis, Sjögren syndrome, arthropathy, uveitis, and PHP. These diseases, except for PHP, were probably caused by infiltrations of HTLV-I–infected T cells to the target organ. In contrast, HTLV-I infection does not induce PHP, but PHP may be a risk factor for the occurrence of HAM/TSP.

### References

HTLV-1–associated myelopathy/tropical spastic paraparesis with pseudohypoparathyroidism
Naoko Machigashira, Yoshihiro Yoshida, Sha-yan Wang, et al.
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