



High-Altitude Cerebral Edema Evaluated with MRI: A Case Report

고소 뇌부종의 자기공명영상 소견: 증례 보고

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High-altitude cerebral edema (HACE) is a rare life-threatening condition observed in individuals who climb high altitudes. This report describes the case of a 38-year-old man who recently climbed a 5000-m-high mountain, showing the following radiologic findings at 3 different anatomical locations: 1) increased T2 signal intensity (SI) without restricted diffusion, with full recovery in the posterior limb of the left internal capsule; 2) increased T2 SI with restricted diffusion, with full recovery in the splenium of the corpus callosum; and 3) increased T2 SI with restricted diffusion and microbleeds, resulting in bilateral encephalomalacia in the globus pallidus. Herein, we report the concurrent typical and atypical radiologic findings of this rare condition caused by vasogenic and cytotoxic edema.

Index terms Brain Edema; Internal Capsule; Corpus Callosum; Globus Pallidus;
Magnetic Resonance Imaging

INTRODUCTION

High-altitude cerebral edema (HACE) is a fatal condition, which primarily occurs due to hypoxia and decreased barometric pressure associated with high altitudes. The prevalence of HACE was 0.5–1.0% in a select group of individuals scaling heights over 4500 m (1). The characteristic finding of HACE is increased signal intensity (SI) on T2-weighted MRI with diffusion restriction in the splenium of the corpus callosum, showing full recovery on follow-up. A few studies performed CT and MRI on HACE (1, 2). However, to our knowledge, no previous studies reported 3 different radiologic findings simultaneously in 1 patient.

CASE REPORT

A 38-year-old man who had climbed a 5000-m-high mountain in China 5 days ago pre-

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sented with general weakness and urinary incontinence. Because of these symptoms, he returned to Korea and was referred to our hospital. Despite being fully conscious and lucid, he was acutely indisposed. His cardiorespiratory parameters were within the normal limits; the blood pressure was 124/72 mm Hg, with oxygen saturation of 98% and blood glucose level of 105 mg/dL. The coordination between his upper and lower limbs was normal. He reported no contact with poisonous substances, such as carbon monoxide, 3,4-methylenedioxymethamphetamine (MDMA), cocaine, opiates, or cyanide. A brain CT scan revealed bilateral hypoattenuation in the globus pallidus and splenium of the corpus callosum (Fig. 1A), without any evidence of recent intracranial hemorrhage. There were no abnormal attenuations indicative of venous thrombus on the CT scan. A 1.5 tesla brain MRI scan revealed high SI on an axial T2-weighted image (Fig. 1B) and fluid-attenuated inversion recovery (FLAIR) sequences involving bilateral globus pallidus, posterior limb of the left internal capsule, and splenium of the corpus callosum (Fig. 1C). The diffusion-weighted imaging (DWI) and apparent diffusion coefficient (ADC) maps showed restricted diffusion in bilateral globus pallidus and splenium of the corpus callosum (Fig. 1D). On the gradient echo sequences (GRE), microbleeds with dark SIs were observed bilaterally in the globus pallidus. No abnormal dark SI was noted in the posterior limb of the left internal capsule and splenium of the corpus callosum (Fig. 1E). There were no remarkable findings on T1-weighted images. Supportive treatment including intravenous dexamethasone and Cerebrolysin[®] (EVER Pharma; Unterach, Austria) was initiated. The patient was hospitalized for 1 week with complete functional recovery after 24 hours of admission. He was discharged on the seventh day, with advice to avoid further expeditions to high altitudes. The follow-up brain MRI after 5 weeks revealed complete resolution of the previously noted diffusion restriction in the splenium of the corpus callosum. However, encephalomalacia developed bilaterally in the globus pallidus (Fig. 1F).

DISCUSSION

At high altitudes, hypoxia elicits responses that result in sustained vasodilatation, with impaired cerebral autoregulation, elevated capillary pressure, and leakage, resulting in edema formation (3). Because of hypoxic cerebral vasodilatation, autoregulation may become transiently impaired, inducing a forceful increase in capillary hydrostatic pressure that promotes vasogenic edema, subsequent to the mechanical disruption of the blood-brain barrier and accumulation of vascular endothelial growth factor and reactive oxygen species (4). Vasogenic edema preferentially spreads through the white matter, which is more sensitive to the imbalances in the demand and supply of cellular energy, resulting in fluid accumulation along the direction of orientation of the myelin fibers. The white matter has an orderly network of extracellular channels and offers little resistance to invasion by edematous fluid, while gray matter consists of tightly packed cellular structures (5).

The characteristic finding of HACE on MRI is increased SI on T2-weighted images with restricted diffusion, particularly in the splenium of the corpus callosum, which is fully reversed on recovery (1). Our case showed consistent radiologic findings with increased T2 and FLAIR SI and diffusion restriction in the splenium of the corpus callosum, along with full recovery.

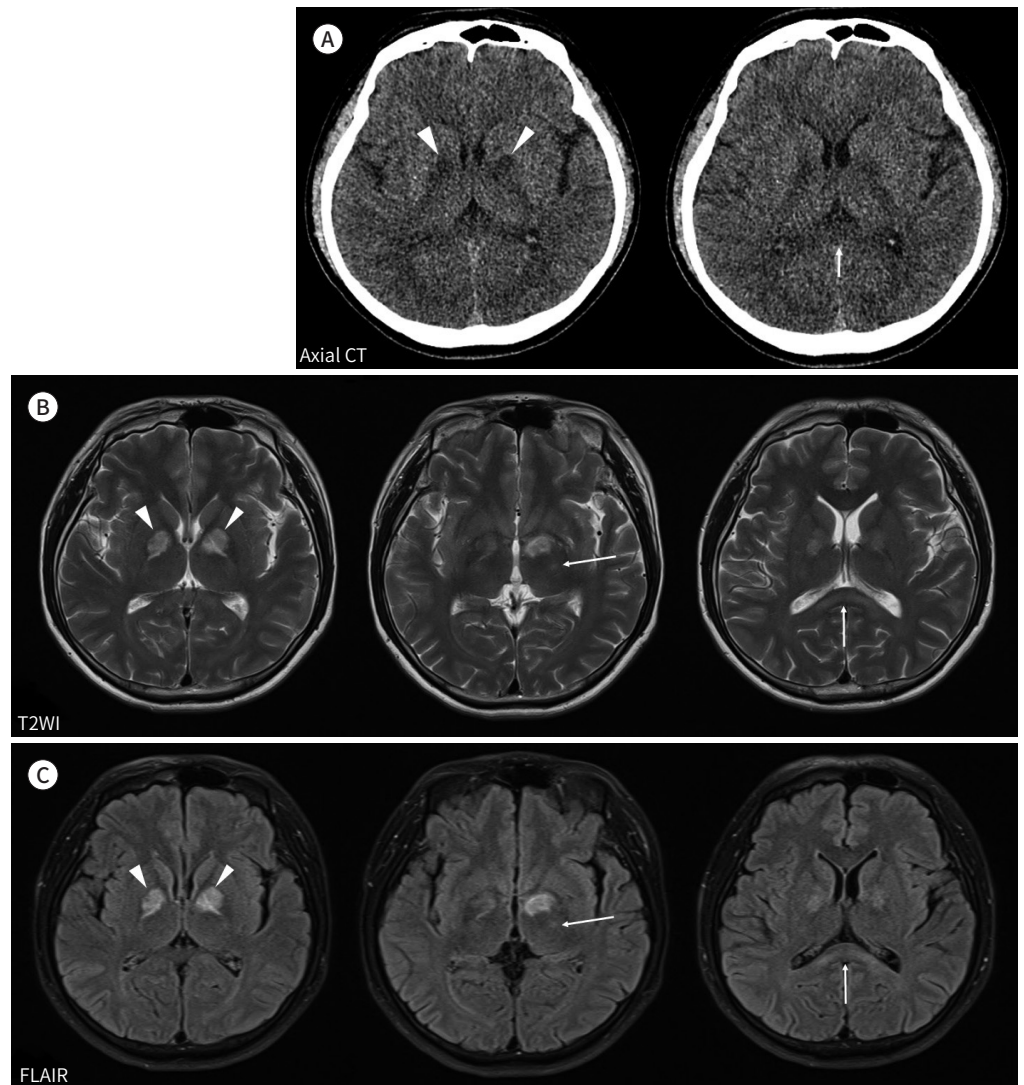
Fig. 1. CT and MRI findings of a 38-year-old man with general weakness and urinary incontinence after climbing a 5000-m-high mountain.

A. Axial CT scan image shows low attenuation in bilateral globus pallidus (arrowheads) and the splenium of the corpus callosum (arrow).

B. Axial T2WI shows a high SI in bilateral globus pallidus (arrowheads), the posterior limb of the left internal capsule (arrow in the middle image), and the splenium of the corpus callosum (arrow in the right image).

C. Axial FLAIR image shows high SI in bilateral globus pallidus (arrowheads), the posterior limb of the left internal capsule (arrow in the middle image), and the splenium of the corpus callosum (arrow in the right image).

FLAIR = fluid-attenuated inversion recovery, SI = signal intensity, T2WI = T2-weighted image



The diffusion restriction observed in the splenium of the corpus callosum can be explained by its unique vascular permeability. Owing to the short arterioles in its anatomy and lack of pressure drop along the vessels to provide protection from decreased perfusion and ischemia (5), the corpus callosum may be rendered more vulnerable to edema in the presence of hypoxic cerebral vasodilatation. Moreover, the neurons, astrocytes, and oligodendrocytes of the corpus callosum have a high density of receptors, including cytokine and glutamate receptors and other excitatory amino acids, toxins, and drug receptors (6), which tends

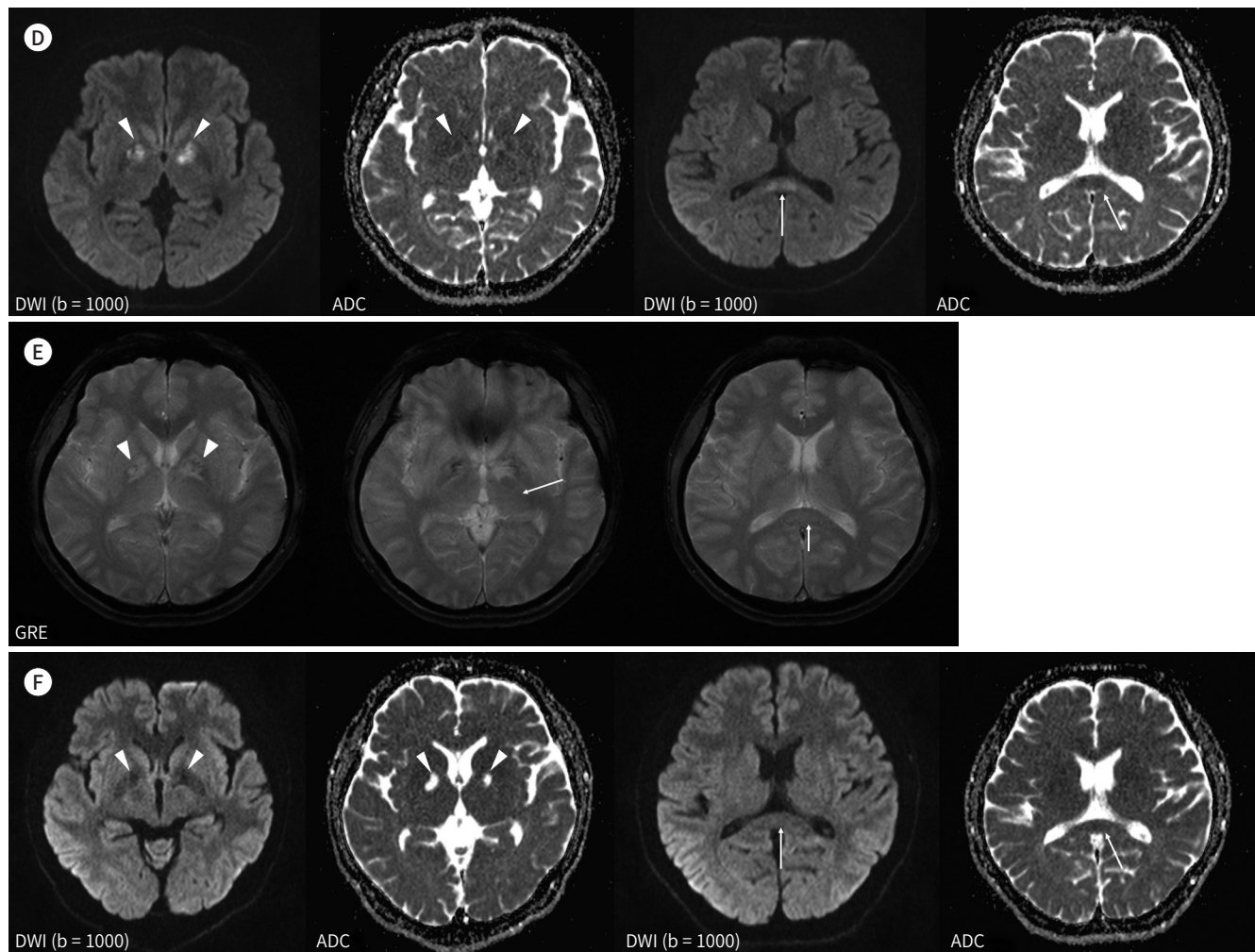
Fig. 1. CT and MRI findings of a 38-year-old man with general weakness and urinary incontinence after climbing a 5000-m-high mountain.

D. There are high SIs on the axial DWI image of high b-value (1000 s/mm²) and dark SI on the axial ADC map, revealing diffusion restriction in bilateral globus pallidus (arrowheads) and the splenium of the corpus callosum (arrows).

E. Axial GRE image shows dark SI with microbleeds in bilateral globus pallidus (arrowheads). No abnormal SI is noted in the posterior limb of the left internal capsule (arrow in the middle image) and splenium of the corpus callosum (arrow in the right image).

F. Follow-up axial DWI of high b-value (1000 s/mm²) and ADC map images show focal encephalomalacia in bilateral globus pallidus (arrowheads), contrary to the fully recovered previously restricted diffusion in the splenium of the corpus callosum (arrows).

ADC = apparent diffusion coefficient, DWI = diffusion-weighted imaging, GRE = gradient echo sequences, SI = signal intensity



to cause cytotoxic edema in the corpus callosum. This suggests the coexistence of both vasogenic and cytotoxic edema in the corpus callosum before progressing to irreversibility.

Increased T2 and FLAIR SI were also seen in the posterior limb of the left internal capsule, without restricted diffusion. Typically, the posterior limb of the internal capsule is affected by hypoglycemic encephalopathy with high SI on T2 and with low SI on T1 and has restricted diffusion (7). However, radiological examination of this patient showed a discrepancy between the T1-weighted image and the diffusion restriction. Furthermore, the patient did not have a history of diabetes, and the initial blood glucose level was within the normal range. The follow-up scan showed a full recovery of the posterior limb of the left internal capsule.

Moreover, in this case, additional increased T2 and FLAIR SI with restricted diffusion and

microbleeds were noted bilaterally in the globus pallidus, with encephalomalacia on the follow-up scan. This is suggestive of the sequela of cytotoxic edema in the gray matter, which consists of tightly packed cellular structures, unlike the white matter (5). Since this radiologic finding is atypical to HACE, a superimposed ischemic disorder should be considered. The globus pallidus is typically selectively spared, following a hypoxic-ischemic insult, in contrast to the caudate and putamen (8). However, the reverse occurs in rare cases. The most common cause of bilateral globus pallidus necrosis is fatal carbon monoxide poisoning (9). Additionally, fatalities associated with MDMA, cocaine, opiate, and cyanide poisoning have been reported (9). As this patient denied having any contact with these poisonous substances, it could be attributed to altitude-related anoxic brain damage that is observed in ischemic-hypoxic encephalopathy. As the pathophysiology of HACE appears to involve reversible vasogenic and cytotoxic edema that progresses to microvascular disruption (10), the microbleeds in the globus pallidus can be explained by HACE rather than any other condition.

In conclusion, the pathophysiological features of HACE are as follows: 1) reversible vasogenic edema in the posterior limb of the left internal capsule; 2) reversible vasogenic and cytotoxic edema in the corpus callosum; and 3) irreversible cytotoxic edema that progresses to microvascular disruption, causing bilateral microbleeds in the corpus callosum, which results in encephalomalacia. The initial DWI and ADC maps can be used as key indicators of treatment response and prognostic markers for future glial changes, except for atypical vascular permeability in the splenium of the corpus callosum. Detecting microbleeds with GRE imaging may also aid in the diagnosis, staging, and management of this serious condition.

Author Contributions

Conceptualization, L.B.H., H.Y.J., K.J.W.; data curation, H.S., L.B.H.; formal analysis, H.S., L.B.H.; investigation, H.Y.J., K.J.W.; methodology, L.B.H., H.Y.J.; project administration, H.Y.J., K.J.W.; supervision, L.B.H., H.Y.J., K.J.W.; validation, H.Y.J.; visualization, H.S., K.J.W.; writing—original draft, H.S.; and writing—review & editing, L.B.H., H.Y.J., K.J.W.

Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

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고소 뇌부종의 자기공명영상 소견: 증례 보고

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고소 뇌부종은 높은 산을 오르는 이들에게서 발생하는 드문 질환이다. 저자들은 5000 m를 등반했던 38세 남자의 자기공명영상에서 해부학적 위치에 따른 세 가지 영상소견 및 각기 다른 결과를 보인 증례를 소개한다. 이는 1) T2 강조 영상에서 고신호강도를 나타내면서 제한 확산은 없고, 추적 관찰 영상에서 완전한 회복을 보인 왼쪽 속섬유막뒤틀다리, 2) T2 강조 영상에서의 고신호강도가 있고 제한 확산을 보였으며 이후 완전한 회복을 보인 뇌량의 팽대, 그리고 3) T2 강조 영상에서 고신호강도를 나타냈고 제한 확산 및 미세 출혈을 보였던 양측 창백핵을 추적 관찰한 결과 뇌연화증이 나타난 사례이다. 일부에서는 고소 뇌부종의 전형적인 자기공명영상 소견이 나타났고, 다른 부분에서는 비전형적인 소견을 보였으며, 이는 각각 뇌세포의 구조적 차이 및 혈관성부종과 세포독성부종의 차이에 기인한 것으로 생각되며 이에 대해 보고하는 바이다.

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