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The features of CT findings in patients with high-altitude pulmonary edema

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High-altitude pulmonary edema (HAPE)

- **HAPE is a non-cardiogenic permeable pulmonary edema that occurs in susceptible young individuals rapidly ascent above altitudes of 2,500 m.**
- **The hypoxic pulmonary vasoconstriction plays the leading role in the pathogenesis of HAPE, which causes exaggerated pulmonary hypertension, subsequently vascular leakage through overperfusion, stress failure, or both in the pulmonary circulation structure.**
- **The radiological features of HAPE are not only the decisive criterion in the diagnosis and follow-up of HAPE but also a very essential element in the investigation of mechanisms of HAPE.**

Purpose

- **The features of radiographic findings in patients with HAPE have been reported previously elsewhere. However, the features of computed tomographic (CT) findings in such patients have not yet been analyzed and reported.**
- **We analyzed the features of CT findings in patients with HAPE in the present study, in order to update the clinical information of HAPE and share our clinical experiences with other colleagues worldwide.**

Subjects

- **The subjects included 15 patients with HAPE who were suffered from HAPE when climbing mountains of 2,450 m to 3,190 m above sea level in Japan Alps.**
- **Diagnostic criteria of HAPE:**
  - **① Onset of typical symptoms, including cough and dyspnea at rest, after arrival at high altitude.**
  - **② Absence of signs of infection, such as nasal discharge, sore throat, or fever.**
  - **③ Presence of pulmonary rales and cyanosis.**
  - **④ Prompt disappearance of symptoms and signs after a few days of treatment by bed rest and therapy with supplemental oxygen.**
  - **⑤ Presence of pulmonary edema pattern in chest roentgen graphic findings.**

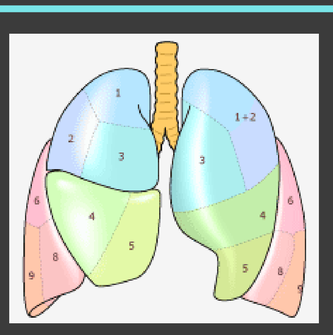
Clinical characteristics of subjects

Mean age, yrs	37.3 (range:15-67)
Sex （M : F）	12 : 3
Average altitude, m	2,955 (range:2,450-3,190)
Average days from arriving the altitude to appearing symptoms	1.54 (range:0-3)
Average days from appearing symptoms to hospital admission	1.63 (range:1-3)
Average days of recovery *	5.2 (range:1-10)
Blood gas analysis under room air, mean	
pH	7.45 (range: 7.40-7.48)
PaO_2, mmHg	36.1 (range: 28-50)
$PaCO_2$, mmHg	32.2 (range: 28-37)

* The recovery was defined by the improvement of oxygen saturation to more than 95% without oxygen supplement.

Methods

- **CT scanning was immediately taken after they were admitted to Shinshu University Hospital, Matsumoto, Japan at altitude of 600 m.**
- **The severity of abnormal shadows was graded using a scoring system in which 0-4 points were scored in each of the three zones in each lung. In addition, the distribution of abnormal shadows on the lung regions was evaluated. Furthermore, the patterns of edema shadows on CT images were analyzed.**



Zones in lungs

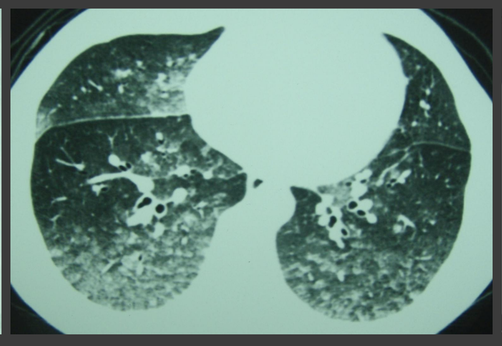
Right lung	Left lung
Upper lobe	Upper division
Middle lobe	Lingular division
Lower lobe	Lower lobe

In each of the three zones in each lung, the severity of edema shadows was graded using the following scoring system:

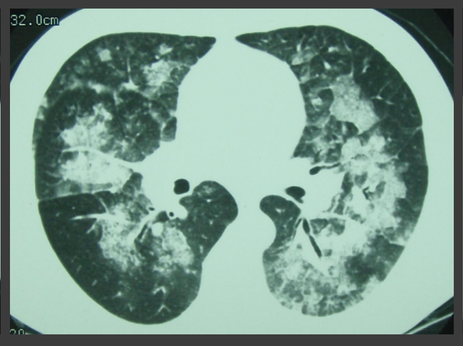
Score 0 : normal parenchyma
1 : questionable pathologic areas
2 : undoubted abnormal shadows of less than 50% of the lobe
3 : nonconfluent abnormal shadows of more than 50% of the lobe
4 : alveolar, partly confluent abnormal shadows

Chest CT in HAPE

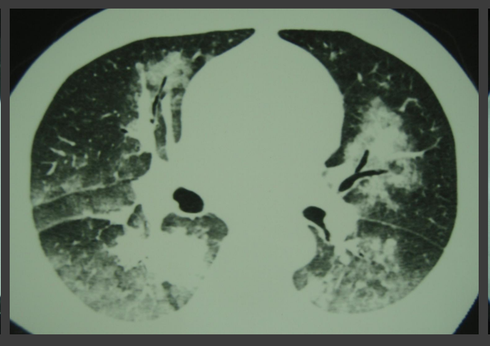
Ground-grass opacity in the periphery of the right upper lobe



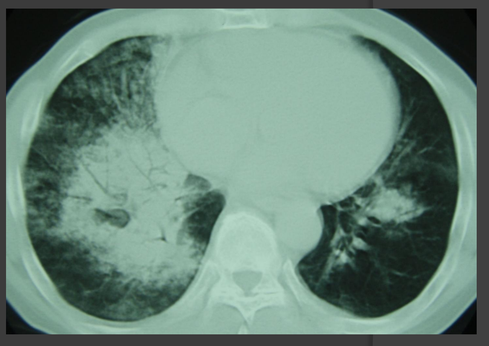
Nodular opacity and ground-glass opacity in the bilateral lung bases



Patchy areas of consolidation distributing along bronchovascular bundles



Consolidation distributing along bronchovascular bundles



Airspace consolidation in the right lower of the lung

Score of edema shadows

Right lung (n=15)	Mean score in zone
Upper lobe	3.06
Middle lobe	2.80
Lower lobe	3.46
Mean score in lung	3.10

Left lung (n=15)	Mean score in zone
Upper division	2.00
Lingular division	1.73
Lower lobe	2.40
Mean score in lung	2.04

- **The mean score in zone was higher in the lower zone than the other two zones of both lungs.**
- **The mean score in lung was higher in the right lung than the left lung.**

Distributions of edema shadows

Distribution	Non-balanced	Balanced
Side (n = 15)	Right 7 Left 1	7
Zones (n = 15)	Upper 0 middle 1 (lingular) Lower 8	6
Centricity (n = 15)	Central 7 Peripheral 7	1
Ventral or Dorsal (n = 15)	Ventral 0 Dorsal 7	8

- **The edema shadows were equally distributed in the central and the peripheral regions.**
- **The abnormal edema shadows were distributed more frequently in the dorsal than ventral regions in the 7 patients with non-balanced distribution. However, there was no distribution difference of the edema shadows between the dorsal and ventral regions in the other 8 patients with balanced distribution.**

Patterns of edema shadows

Pattern of edema shadow (n =15)	Positive	Negative	Unknown
Pleural effusion	2 (13%)	13	0
Airspace consolidation	13 (87%)	2	0
Ground-grass attenuation	9 (60%)	4	2
Traction bronchiectasis	0 (0%)	15	0
Thickening of bronchovascular bundle	13 (87%)	1	1
Thickening of interlobular septa	5 (33%)	0	10

- **Both of the patterns of airspace consolidation and thickening of bronchovascular bundle were presented in 13 patients (87%) .**
- **The ground-glass opacity were presented in 9 patients (60%).**
- **Pleural effusion was observed in 2 patients (13%).**
- **Traction bronchiectasis was not found in any of the patients.**

Discussion

- **Chest radiographs in patients with HAPE in early time showed a patchy, peripheral distributions of edema because of heterogeneous hypoxic pulmonary vasoconstriction.**
  Vock P, et al. Chest 100: 1306-1311, 1991
- **The radiographic manifestation in patients with HAPE in advanced cases and during recovery showed more homogeneous and diffusive pattern of shadows because of redistribution of blood flow to previously underperfused areas.**
  Vock P, et al. Chest 100: 1306-1311, 1991
- **In this study, patchy distribution of edema shadows was observed in only 2 patients (13%); however, homogeneous and diffusive consolidation was presented in 13 patients (87%). It was because the patients in this study were mostly in an advanced stage of HAPE at the time of admission.**
- **Pulmonary edema usually presents as a bilateral butterfly configuration with symmetrical homogeneous density.**
- **In the present CT findings of patients with HAPE, the abnormal edema shadows were more likely to occur in the lower zone than the other two zones of both lungs, and more frequently in the right lung than the left lung. Vock et al. (CHEST 1991) also reported similar results on the chest roentgen graphic examination.**
- **These characteristics of CT findings in HAPE might be related to the distribution of pulmonary blood flow that is richer physiologically in the lower zone than the other zones, meanwhile, more affluent in the right lung than the left lung.**

Conclusion

- **The chest CT scanning in patients with HAPE was featured by the abnormal edema shadows mostly in the right lower zone of the lungs. The edema shadows were frequently distributed in the dorsal region of the lung.**
- **Airspace consolidation and thickening of bronchovascular bundle were the major patterns on the chest CT scanning imagine in patients with HAPE.**