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Chest Ultrasonography for the Diagnosis and Monitoring of High-Altitude Pulmonary Edema*

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Background: **The comet-tail technique of chest ultrasonography has been described for the diagnosis of cardiogenic pulmonary edema. This is the first report describing its use for the diagnosis and monitoring of high-altitude pulmonary edema (HAPE), the leading cause of death from altitude illness.**

Methods: **Eleven consecutive patients presenting to the Himalayan Rescue Association clinic in Pheriche, Nepal (4,240 m) with a clinical diagnosis of HAPE underwent one to three chest ultrasound examinations using the comet-tail technique to determine the presence of extravascular lung water (EVLW). Seven patients with no evidence of HAPE or other altitude illness served as control subjects. All examinations were read by a blinded observer.**

Results: **HAPE patients had higher comet-tail score (CTS) [mean ± SD, 31 ± 11 vs 0.86 ± 0.83] and lower oxygen saturation (O_2Sat) [61 ± 9.2% vs 87 ± 2.8%] than control subjects ($p < 0.001$ for both). Mean CTS was higher (35 ± 11 vs 12 ± 6.8, $p < 0.001$) and O_2Sat was lower (60 ± 11% vs 84 ± 1.6%, $p = 0.002$) at hospital admission than at discharge for the HAPE patients with follow-up ultrasound examinations. Regression analysis showed CTS was predictive of O_2Sat ($p < 0.001$), and for every 1-point increase in CTS O_2Sat fell by 0.67% (95% confidence interval, 0.41 to 0.93%, $p < 0.001$).**

Conclusions: **The comet-tail technique effectively recognizes and monitors the degree of pulmonary edema in HAPE. Reduction in CTS parallels improved oxygenation and clinical status in HAPE. The feasibility of this technique in remote locations and rapid correlation with changes in EVLW make it a valuable research tool.** ***(CHEST 2007; 131:1013–1018)***

Key words: acute mountain sickness; high-altitude pulmonary edema; hypoxia; mountaineering; pulmonary edema; ultrasound

Abbreviations: AMS = acute mountain sickness; CTS = comet-tail score; EVLW = extravascular lung water; HAPE = high-altitude pulmonary edema; O_2Sat = oxygen saturation; PAWP = pulmonary artery wedge pressure

High-altitude pulmonary edema (HAPE) is the leading cause of death from altitude illness.[1] Chest ultrasonography using the comet-tail technique has recently been shown to effectively detect pulmonary edema and quantify extravascular lung water (EVLW) in hospitalized patients. This technique relies on the creation of "comet-tail" artifacts

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by multiple microreflections of the ultrasound beam within water-thickened interlobular septa when pulmonary edema is present.[2–6] This ultrasonographic technique, which is feasible in remote locations, can offer an important diagnostic aid in HAPE. As a research tool, it may also allow clarification of the time course of EVLW shifts in HAPE. We report on our clinical experience using the comet-tail technique in a remote, high-altitude setting, particularly for the diagnosis and monitoring of HAPE.

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Materials and Methods

Patients and Clinical Treatment

From March 3, 2006, to May 20, 2006, 11 consecutive patients with a clinical diagnosis of HAPE were treated at the Himalayan Rescue Association clinic in Pheriche, Nepal (4,240 m). No patients seen at the clinic with a diagnosis of HAPE during that period were excluded from this report. The clinical diagnosis, which was based on the Lake Louise consensus definition of HAPE, was made prior to performing ultrasonography.[7] All other patients who underwent chest ultrasonography using the comet-tail technique for clinical evaluation at the clinic during that time period (with the exception of one patient who had a clinical diagnosis of acute mountain sickness [AMS] and rales on chest examination) were used as control subjects. Admission vital signs were obtained at rest in a seated or near-supine (for patients unable to sit) position as soon after presentation as the patient could be situated in a chair or bed. Discharge vital signs were obtained at rest in the seated position for all patients. Oxygen saturation (O_2Sat) was measured by finger pulse oximetry with patients breathing ambient air. Clinical features are described in Table 1. By our institutional standards, this type of report does not require institutional review board approval or written informed consent from patients.

All 11 HAPE patients were treated with oxygen, nifedipine, and acetazolamide. Eight HAPE patients received additional sildenafil and salmeterol, and one patient received additional salmeterol only. The HAPE group included one patient who had been treated with all these agents, dexamethasone, and ceftriaxone for 12 h before presentation; the dexamethasone and ceftriaxone were discontinued on arrival. Two patients received treatment for concurrent diagnoses: one patient with high-altitude cerebral edema received dexamethasone, and one patient with

Table 1—*Clinical Characteristics of HAPE and Control Patients at Presentation

Characteristics	HAPE	Control
Total patients	11	7
Age, yr		
Mean	34 ± 12	34 ± 9.1
Range	21–54	22–50
Male/female gender	9/2	5/2
National origin		
Nepal	7 (includes 2 Sherpa)	3 (includes 1 Sherpa)
Other	1 each for Japan, United States, Canada, and Poland	2 for Unites States; 1 each for Germany and Australia
Medical history	Chronic musculoskeletal pain (n = 1); regular alcohol use (three drinks/d)[n = 1]; tobacco use (three cigarettes/wk)[n = 1]	Hypertension (n = 1)
History of altitude illness	AMS (n = 2); headache (n = 1)	None
Heart rate, beats/min	121 ± 20	77 ± 6.5
Range	77–150	72–88
Respiratory rate, breaths/min	35 ± 8.3	12 ± 2.1
Range	20–50	8–14
O_2Sat, %	61 ± 9.2	87 ± 2.8
Rales		
Bilateral, all fields	4	0
Bilateral, localized	4	0
Unilateral	3	0
Cyanosis		
Central	2	0
Peripheral	3	0
None	6	7
Maximum altitude, m		
> 5,000	4	2
4,500–5,000	7	1
< 4,500	0	4
Concurrent diagnosis	Gastroenteritis (n = 1); high-altitude cerebral edema (n = 1)	Nocturnal periodic breathing (n = 2); high-altitude cough (n = 2); bruised rib (n = 1)

*Data are presented as No. of patients or mean ± SD unless otherwise indicated.