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ORIGINAL RESEARCH

Altitude-Related Disorders on Mount Kilimanjaro, Tanzania: Two-Year Survey in a Local Referral Center

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Introduction—A significant number of climbers on Mount Kilimanjaro are affected by altitude-related disorders. The aim of this study was to determine the main causes of morbidity and mortality in a representative cohort of climbers based on local hospital records.

Methods—We conducted a 2-y retrospective chart review of all patients presenting to the main referral hospital in the region after a climb on Mount Kilimanjaro, including all relevant records and referrals for postmortem studies.

Results—We identified 62 climbers who presented to the hospital: 47 inpatients and 15 outpatients. Fifty-six presented with high altitude illness, which included acute mountain sickness (n=8; 14%), high altitude pulmonary edema (HAPE) (n=30; 54%), high altitude cerebral edema (HACE) (n=7; 12%), and combined HAPE/HACE (n=11; 20%). The mean altitude of symptom onset ranged from 4600±750 m for HAPE to 5000±430 m for HAPE/HACE. The vast majority of inpatients (n=41; 87%) were improved on discharge. Twenty-one deceased climbers, most having died while climbing (n=17; 81%), underwent postmortem evaluation. Causes of death were HAPE (n=16; 76%), HAPE/HACE (n=3; 14%), trauma (1), and cardiopulmonary (1).

Conclusions—HAPE was the main cause of death during climbing as well as for hospital admissions. The vast majority of climbers who presented to hospital made a full recovery.

Keywords: high altitude pulmonary edema, high altitude cerebral edema, mortality, morbidity, Kilimanjaro, Africa

Introduction

Globalization and travel have made mountaineering increasingly accessible to climbers. Each year, over 35 million people visit destinations with altitudes >3000 m above sea level.[1] Mount Kilimanjaro (5895 m) in Tanzania is the highest mountain in Africa. The ascent by the "tourist route" requires no technical climbing expertise and is attempted by an estimated 35,000 to 40,000 climbers annually.[1-4] The reported summit success rates vary from 53 to 61% for a 4- to 5-d climb[2,3] to 88% for a 6-d climb.[4] The main limiting factor is high altitude illness (HAI) from rapid ascent.[2-4] The reported rate of acute mountain sickness (AMS) varies from 75 to 77% for a 4- to 5-d ascent to 53% for a 6-d ascent.[4] HAI includes AMS, high altitude pulmonary edema (HAPE), and high altitude cerebral edema (HACE). Although AMS is a common, benign disorder of altitude, HAPE and HACE are relatively uncommon, life-threatening conditions.[5]

We classify causes of death as HAI and those not related to HAI. We conducted a retrospective chart review to identify the occurrence and outcomes of HAI in climbers who presented to Kilimanjaro Christian Medical Centre (KCMC). KCMC is a consultant hospital situated in Moshi at the foot of Mount Kilimanjaro. It is a

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specialized referral center covering an area of approximately 150,000 km^2, including the northern zone of Tanzania, and has a catchment population of 15 million people. It is the only hospital in the region with an intensive care and postmortem examination facility.

Methods

We reviewed the medical records of climbers presenting to KCMC or sent to KCMC for postmortem investigation from January 2016 to December 2017. We received ethical clearance from the Kilimanjaro Christian Medical University College. The National Institute of Medical Research Publication committee in Dar es Salaam, Tanzania approved this study.

We obtained the hospital files of those presenting to the emergency department (ED) or admitted to the medical unit or medical intensive care unit of KCMC with a diagnosis of one of the high altitude disorders. We recorded demographic, clinical, and altitude-related data and reviewed laboratory results, x-rays, and computed tomography (CT) images of the head. We defined AMS using the Lake Louise 2018 criteria including headache with a score of 3 or greater, with at least 1 point for headache being diagnostic.[6] HAPE and HACE were also defined using the Lake Louise criteria.[5] Two neurologists with experience in high altitude disorders independently reviewed the clinical diagnosis in each case. For each missing patient record, we made every attempt to reconstruct information about the patient's condition through ED and medical intensive care unit logbooks and laboratory and radiology investigation results. In the few cases of incomplete data, we only included the basic patient characteristics recorded for all patients upon hospital registration, such as age, sex, admission duration, and country of origin.

We reviewed the logbook in the department of pathology. A postmortem-certified cause of death is a legal requirement for all deaths occurring in non-Tanzanian nationals. We recorded deaths that occurred in climbers on Mount Kilimanjaro and the altitudes at which they occurred. All bodies were examined at the pathology department of KCMC. A probable or confirmed cause of death was determined on the basis of autopsy findings and/or history of symptoms and signs before death. A team of 2 pathologists and 2 neurologists reviewed clinical histories and relevant findings and agreed on the likely cause of death. We present data as mean±SD with range, as appropriate.

Results

Sixty-two patients (36 male, 26 female) presenting with high altitude–related disorders were identified and comprised the study group (Table 1). For 4 patients (2 inpatients and 2 outpatients) whose hospital case files were missing, we made a likely diagnosis based on ED registry books, nursing records, and laboratory tests and imaging. Of the 62 patients, most were inpatients (n=47; 76%); the remainder (n=15; 24%) were outpatients. Patients originated from 24 countries from 5 continents. Of the 10 Tanzanian patients, 5 were tourist climbers, 4 were porters, and 1 was a rescue team member.

Information on the altitude at which patients developed symptoms was available for 38 patients: 4600±750 (range 2500–5895) m for HAPE, 4300±570 (range 3500–4700) m for HACE, and 5000±430 (range 4600–5700) m for HAPE/HACE. Outpatients (n=15, age 31±3 y, range 15–54 y) mostly had HAPE (n=8; 53%) and AMS (n=6; 40%), with HACE only seen once (n=1; 7%).

Eight patients declined admission, none of whom reported back to this hospital. The remaining 7 climbers did not require admission and were treated and discharged. The age of inpatients (n=47) was 39±2 (range 14–67) y. The duration of hospital stay was 2±0.9 (range 1–5) d. Inpatients had HAPE (n=22; 47%), HAPE/HACE (n=11; 23%), HACE (n=6; 13%), and AMS (n=2; 4%). One of the patients with HACE/HAPE died soon after being admitted in a comatose state. This patient was added to the list of deaths.

Six patients (13%) had non-HAI-related disorders: Three patients had new-onset seizures that occurred while climbing. The likely causes were excessive alcohol intake in 1 and hyponatremia in 2 patients (one had psychogenic polydipsia and ingested up to 6 L of fluid per day and the other had persistent hyponatremia). A history of thunderclap headache was present in 1 patient, who was found on CT angiography of the head to have reversible cerebral vasoconstriction syndrome (RCVS) with minimal subarachnoid hemorrhage. Repeat CT angiography on day 3 of admission showed normalization of vessel caliber and reduction of blood in the subarachnoid space. The fifth patient, "who presented with respiratory distress," had a history of bronchiectasis and recurrent bronchitis. Symptoms resolved with a course of antibiotics. The sixth patient had a traumatic brain injury as a result of a fall not preceded by HAI and died soon after admission.

Results of fundoscopy were available for 23 patients and were abnormal in 8 patients. Abnormalities were papilledema (n=4), retinal hemorrhages (n=2), retinal hemorrhages with papilledema (n=1), and vitreous hemorrhage (n=1). Chest x-ray results were available for 36 patients and were abnormal in 13 patients. Abnormalities were pulmonary edema (n=11; 31%) and pulmonary opacifications (n=2; 6%). CT of the head was available

Table 1. Patient characteristics

Characteristics	*Inpatients (n=47)*	*Outpatients (n=15)*
Sex		
Male	28	7
Female	19	8
Age, mean±SD (range), y	39±2 (14–67)	31±3 (15–54)
Nationality, n		
Tanzania	8	2
Africa except Tanzania	5	1
Continents other than Africa	34	12
Diagnosis		
AMS	2	6
HAPE	22	8
HACE	6	1
HAPE/HACE	11	
Non-HAI related	6	
Chest x-ray, n=36		
Pulmonary edema	9	2
Pulmonary edema/opacifications	2	
Normal	23	
CT brain, n=8		
Cerebral edema	1	
Subarachnoid hemorrhage	1	
Traumatic brain injury	1	
Normal	5	
Admission length, mean±SD (range), d	2±0.9 (1–5)	
Outcome		
Discharge with improvement	30	7
Improved/requested discharge	11	8
Air transfer to Kenya	4	
Death	2	
Readmission	0	
Altitude, mean±SD (range), m, n=38		
HAPE	4700±590 (3700-5700)	4200±1225 (2500-5895)
HACE	4300±570 (3500-4700)	
HAPE/HACE	5000±430 (4600-5700)	altitude not available

AMS, acute mountain sickness; HACE, high altitude cerebral edema; HAI, high altitude illness; HAPE, high altitude pulmonary edema.

for 8 patients and was abnormal in 3 patients. Abnormalities were severe penetrating skull fracture with extensive hematoma and brain herniation, RCVS with subarachnoid hemorrhage, and diffuse cerebral edema compatible with HACE.

OUTCOMES

Clinical course

Four inpatients were airlifted to Nairobi, Kenya: 2 with HAPE/HACE, 1 with new-onset seizures, and 1 with RCVS. Three had uneventful recoveries. The fourth patient, with HAPE/HACE, was in critical condition when transferred; his outcome is not known. Two patients were admitted in coma, each with a Glasgow Coma Scale score of 3 and signs of brain death. Both died shortly after admission. One patient died as a result of a fall with severe traumatic brain injury without a history of HAI. The other deceased patient had a clear history of HAPE/HACE. All other in- and outpatients had recovered fully at discharge. No patient returned for further care.

Deaths

The hospital autopsy registry during the study period comprised a total of 21 climbers (20 male and 1 female), of whom 19 were tourists and 2 were porters (Figure 1). The estimated mortality rate among tourist climbers, using a denominator of 40,000 tourist climbers annually, is 23 per 100,000, or 1 per 4350 tourist climbers. The deceased originated from 15 countries, with most coming from Tanzania (n=4) and Germany (n=3). The age was

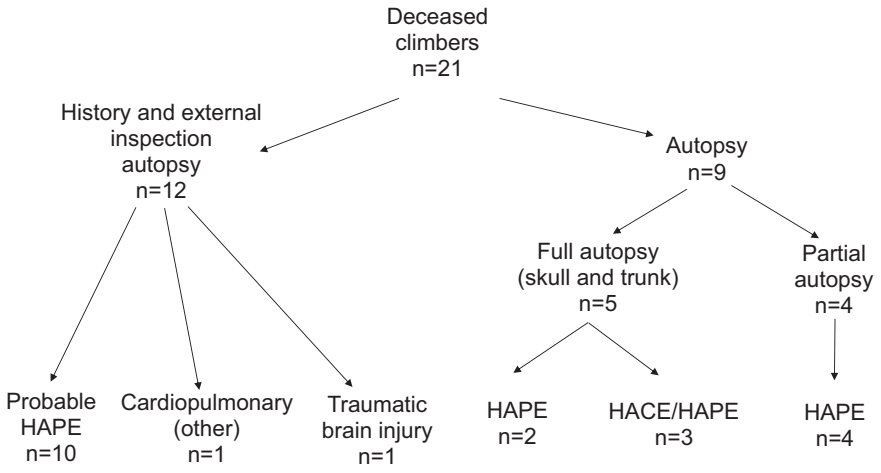

Figure 1. Causes of death in 21 climbers on Mount Kilimanjaro as assessed by postmortem examination.

48±4 (range 18–81) y. Seventeen individuals died during climbing, 2 died within 24 h of arriving back to their hotel after completion of their climbs, and 2 inpatients died at KCMC hospital. For 13 climbers, the altitude at which death occurred was known, 5000±200 (range 3800–5895) m.

Only external inspection autopsy was available for 12 climbers, for whom official permission to perform an invasive autopsy was not granted. Of these 12 climbers, 10 had histories and external examinations compatible with HAPE. One climber successfully summited and died a day after arriving back to his hotel. He had no external abnormalities apart from marked cyanosis, suggesting a cardiac or pulmonary cause. The remaining climber had external signs consistent with severe traumatic brain injury.

A total of 9 autopsies were carried out, 5 of which involved the skull and trunk and 4 the trunk only. Of the 5 full autopsies, the cause of death in 3 was confirmed HACE/HAPE; in 2, it was confirmed to have been HAPE. In all 4 truncal autopsies, the cause of death was confirmed to have been HAPE.

Discussion

HAPE was the main cause of hospital admissions and death in this series of climbers. The low frequency of AMS likely underrepresents the incidence of AMS on the mountain. The most likely explanation is that climbers with AMS recover with descent and do not seek medical care. The postmortem series suggests that HAPE was the most common cause of death of climbers on Mount Kilimanjaro.

The postmortem series involved 21 deaths, 17 of which occurred while climbing. A previous postmortem study reported a similar pattern, involving 25 deaths—14 HAI related and 11 non–HAI related—in climbers on Mount Kilimanjaro.[7] In that study, the main HAI-related causes of death were HAPE (n=5; 36%), HAPE and HACE (n=8; 57%), and HACE (n=1; 7%).[7]

In the present study, the mean age of deceased climbers was 48 y. There was a male:female ratio of 20:1. In contrast, the pattern in the concurrent hospital series is that of a slightly younger age group, with a mean age of 37 y and an almost equal ratio of 1.3:1. The previous postmortem series also reported a mean age of 52 y,[7] but the increased ratio of 2.1:1 reflected the 2.3:1 m:f ratio recorded in climbers during the study period. Demographic data of the source population of 40,000 climbers, however, is not known.

The majority of HAI cases and deaths occurred at higher altitudes on Mount Kilimanjaro, ranging from 4600±750 m for HAI in inpatients to 5000±200 m in deceased climbers. This range is similar to those reported for HAI-related deaths (4950±670 m) in the previous autopsy study[7] and is consistent with the major causal role of hypoxia in HAI and in deaths. In addition to HAI, seizure and trauma were causes of morbidity and mortality. Trauma is an uncommon cause of morbidity and mortality on Kilimanjaro. In the previous autopsy study on Kilimanjaro, there were only 3 deaths from trauma in 8 y.[7] This is in contrast to other mountains of similar or greater altitude requiring technical climbing skills, where trauma is frequently a leading cause of death.

A major contributory cause to the mortality on Kilimanjaro is the relative ease and speed of ascent to higher altitudes, which typically involves climbing at a rate of

over 1000 m·d^{-1}. When climbing above 2500 to 3000 m, international guidelines recommend ascending at a rate of 300 to 600 m·d^{-1} with a 24 h rest day every 3 to 4 d.[8]

The estimated mortality rate of 23 per 100,000 or 1 per 4350 climbers was higher than in the earlier study, which found a mortality rate of 13.8 per 100,000 or 1 per 7300 climbers.[7] The number of climbers increased from 22,700 annually during the previous study (1996–2003)[7] to a recently estimated 35,000 to 40,000 annually.[1] The mortality rates are roughly comparable to mortality figures described in the Himalayas for mountains with altitudes of 4000 to 6000 m.[9] Above 6000 m in the Himalayas, mortality increases steeply and is proportionate to increasing altitude.

LIMITATIONS

This was a referral-hospital based study, which necessarily reflects the more serious forms of HAI and does not reflect the overall pattern of HAI that occurs on Mount Kilimanjaro. Because AMS and mild HAPE improve with descent, many climbers do not seek hospital care. Longer term follow-up data were not available in this study because most climbers leave the region soon after descending from the mountain. For logistical reasons, the study period had to be limited to 2 y, restricting the sample size. The in-hospital CT scanner was not available for one fourth of the research period. The number of autopsies performed was limited. Some only involved the trunk due to legal restrictions and relatives declining postmortem examination of the brain, so the frequency of HACE may have been underestimated in this study.

Conclusions

HAPE was the main cause of HAI in climbers presenting to the hospital and the main cause of death. The majority of deaths occurred during climbing. Non-HAI disorders were relatively uncommon. The majority of climbers attending or admitted to hospital with HAI-related disorders made a full recovery. We hope that increased knowledge of the causes of illness and death on Mount Kilimanjaro will help to decrease them in the future.

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