

**The Road to Shangri-La: New Road Construction and its Impact on Altitude
Sickness in the Nepali Himalayas**

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Abstract

Objective.—This study investigates the impact of motor vehicle travel along a newly constructed road from Besisahar (760 m) to Manang (3540 m) in Nepal on altitude sickness (including acute mountain sickness (AMS), high altitude cerebral edema (HACE) and high altitude pulmonary edema (HAPE)).

Methods.—We enrolled all patients diagnosed with altitude sickness in the Himalayan Rescue Association (HRA) Manang clinic in fall 2016. Phi coefficients were calculated to test for an association between Nepali ethnicity and rapid ascent by motor vehicle. A retrospective chart review looked at all altitude sickness patients from 2010 to 2016.

Results.—In fall 2016, more than half (53.8%) of altitude sickness patients traveled to Manang by motor vehicle, and one-third (33%) reached Manang from low altitude Besisahar in 2 or fewer days. Nepali ethnicity had a significant association with motor vehicle travel ($\phi +0.69$, $p < 0.0001$), as well as with rapid ascent to Manang ($\phi +0.72$, $p < 0.0001$). Compared to previous seasons, fall 2016 saw the highest number of patients with altitude sickness, as well as the highest number of patients traveling to Manang by vehicle and reaching Manang in 2 or fewer days, all showing a significant increase compared to season prior to the road's completion ($p = 0.0001$, $p < 0.0001$ and $p < 0.0001$, respectively).

Conclusions.—Rapid ascent by the newly-constructed road from Besisahar to Manang appears to be related to a significant increase in the number of patients with all forms of altitude sickness, especially among Nepalis. An educational intervention is urgently needed..

Introduction

Altitude sickness (Acute mountain sickness(AMS) and the life-threatening forms of high altitude cerebral edema, (HACE), and high altitude pulmonary edema (HAPE)) is a well-known occurrence among people traveling to elevations above 2500 m, and rapid ascent from low altitude is a known risk factor [1-5]. Gradual ascent, which allows time for acclimatization, is a cornerstone of altitude sickness prevention. In December 2014, construction of a new road to Manang, Nepal (3540 m) was completed along the Annapurna circuit, Nepal's most popular trekking route. The road provides cheaper and faster travel to Manang for locals and tourists alike, however traveling to Manang by motor vehicle often entails rapid ascent from low elevations. Current guidelines recommend travelers spend 2 or more nights at elevations of 2500-3000 m before ascending further [1,2]. Those traveling by jeep along the new road typically reach Manang (3540 m) in 1 or 2 days (i.e. 1 night or less), putting them at high risk of developing altitude sickness [2].

There is little data in the medical literature on the relationship between construction of new roads at altitude and altitude sickness. With massive road-building projects currently underway along the mountainous Chinese-Nepali border, the risks of rapid travel to altitude in the region may increase in the future. This brief report explores a connection between completion of Manang's new road and cases of altitude sickness diagnosed and treated at the Himalaya Rescue Association (HRA) Manang clinic.

Patients and Methods

THE REGION

Nepal's Annapurna Conservation Area (ACA) is the country's largest protected area, and includes over 100,000 residents of various cultural and linguistic groups living within its boundaries [6]. The mountaineous region draws over 60% of all Nepal's trekkers to its "Annapurna circuit," which circumnambulates the Annapurna massif [6]. The circuit passes through Manang, which was typically reached by foot from low elevation (Besisahar, 760 m) over 4 or more days. Trekkers pass through Manang on the way to the circuit's highest point - Throng-La pass (5416 m), as well as to Tilicho Lake (5000 m).

Since 1981, the HRA has staffed a clinic in Manang with physicians trained in managing altitude sickness. Altitude sickness is common along the Annapurna circuit, both among the foreign tourists that have traditionally dominated the trekking population, as well as among Nepali trekkers, porters, guides, pilgrims and locals. During most spring seasons, the clinic also sees altitude sickness among Nepalis traveling from lower elevations to the Manang district to gather "yarsagumba," (*Ophiocordyceps sinensis*), a parasitic fungus used in traditional Chinese medicine.

The road from Besisahar to Manang was completed in December 2014 and quickly became a common mode of travel to Manang. Prior to completion of the road, jeep or motorcycle travel was possible along certain portions of the tract.

STUDY DESIGN

All patients seen in HRA's Manang clinic in fall 2016 and diagnosed with — AMS, HACEHAPE [7,8]—were automatically enrolled in the study. The diagnoses of AMS, HACE, and HAPE were based on the Lake Louise Consensus [9]. We collected demographic and diagnostic information, including detailed information on ascent profile, number of travel days from Besisahar (760 m) to Manang (3540 m), and modes of travel. Additionally, we surveyed patients with altitude sickness who traveled to Manang by motorized vehicle to assess pre-existing knowledge regarding the risks of rapid ascent.

For the years 2010 to 2016, we conducted a retrospective chart review of all clinic notes from the HRA Manang clinic. We collected information on demographics and ascent profiles for all patients diagnosed with altitude sickness during this time period. The study was approved by the Nepal Health Research Council (NHRC), reference number, 1093).

STATISTICAL ANALYSIS

Data were analyzed using Microsoft Excel (Microsoft, Remond, WA) and IBM SPSS Statistics version 22 (IBM, Armonk, NY, USA) statistical software. We used χ^2 tests to look for an association between Nepali ethnicity and both a history of motor vehicle travel to Manang and having reached Manang from low altitude in 2 or fewer days. Phi coefficients were used to measure the strength of association, with values of +1 denoting perfect agreement, -1 denoting perfect disagreement, and 0 denoting no association. To compare values from fall 2016 to the mean values from 2010 through 2014, prior to the road's completion, one-sample permutation tests were used to assess

for an increase in total altitude sickness cases, cases of AMS, cases of HACE and/or HAPE, number traveling by vehicle, number reaching Manang in 2 or fewer days, and the percentage of total patients comprised by Nepalis.

Results

During fall 2016, 453 total patients were evaluated at the HRA Manang clinic, while 91 (20.1%) were diagnosed with altitude illness. The demographic and diagnostic breakdown of the study population is shown in **Table 1**. Of these 91 patients with altitude sickness, more than half (49, 53.8%) traveled by motorized vehicle for at least part of their travel to Manang from low altitude. One-third of patients (30, 33.0%) reached Manang from Besisahar in 2 or fewer days. Those traveling by vehicle accounted for 48 patients with AMS (57.8%), 2 with HACE (25%), and all 5 with HAPE (100%). Of note, 7 patients (7.7%) initially trekking toward Manang on foot took a vehicle the rest of the way once they began to feel ill with altitude symptoms, entailing further altitude gain.

Overall 39 Nepali patients were diagnosed with altitude sickness, comprising 42.9% of all altitude patients. Nepali patients were comprised of 27 trekkers, 4 guides/porters, and 8 locals/migrant workers (**Table 1**). Among Nepali patients, all but 3 (36) traveled to Manang by motorized vehicle (92.3%), while 28 reached Manang from low altitude in 2 or fewer days (71.8%). In comparison, among 52 non-Nepali patients, 12 traveled by motorized vehicle (23.1%), but only 2 reached Manang in 2 or fewer days (3.8%). Nepali ethnicity was significantly associated with having traveled by motor vehicle ($\phi +0.69$, $p < 0.0001$) and with having reached Manang in 2 or fewer days ($\phi +0.72$, $p < 0.0001$). The 37 Nepali patients traveling by vehicle accounted for 75.5% of all

altitude patients traveling by vehicle, including 1 of 8 HACE patients (12.5%), and 4 of 5 HAPE patients (80%).

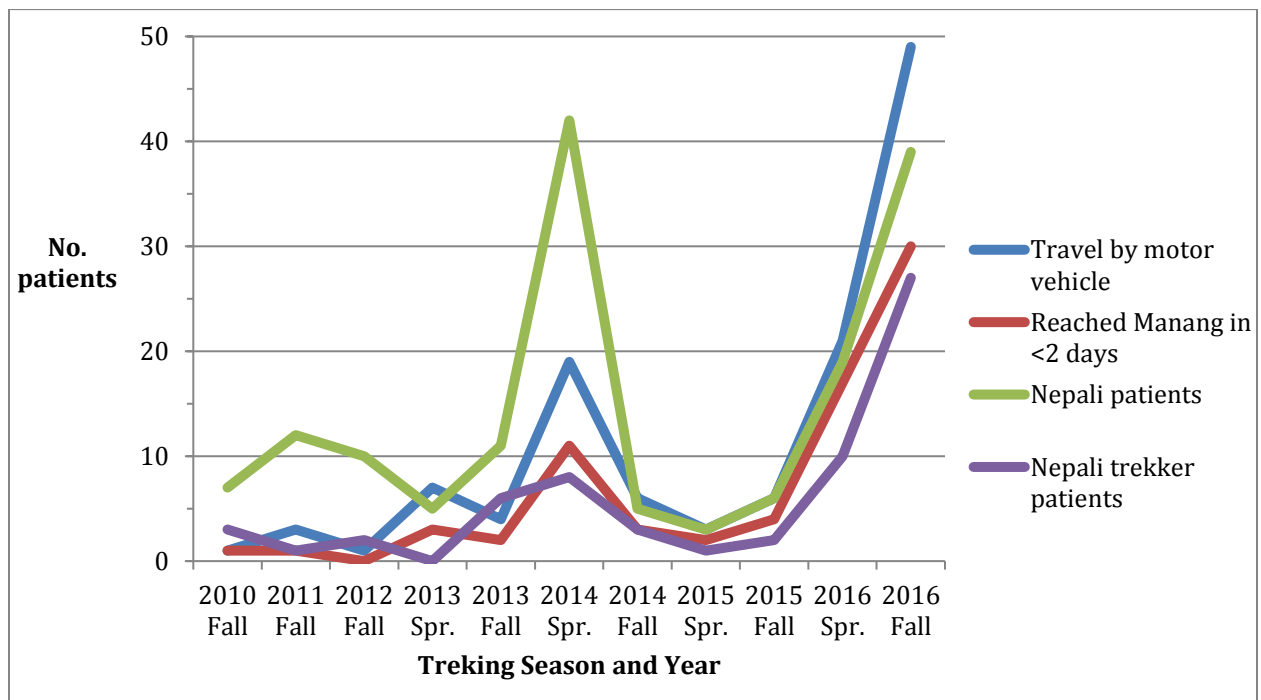
We surveyed 37 patients with altitude sickness who had traveled to Manang by vehicle. Prior knowledge was assessed by asking if they knew that rapid ascent to altitude could be dangerous. Twenty were aware of the danger (54.1%), while 17 were unaware (45.9%). Those claiming prior knowledge of the risks were questioned further, and the following reasons for traveling by vehicle were given: time limitations necessitated rapid travel to Manang; patients felt previous time spent at altitude was protective; some believed being of Nepali ethnicity, specifically being Gurung or Manangi, was protective.

For the years 2010 to 2016, data was available for 11 out of 14 seasons. During the time period analyzed, fall 2016 saw the highest number of patients with altitude sickness, as well as the highest numbers of patients traveling to Manang by vehicle and reaching high altitude in 2 or fewer days (**Table 2**). All three of these numbers were statistically higher than the mean prior to the road's completion in 2014 ($p=0.0001$, $p<0.001$, and $p<0.0001$, respectively). In fall 2016, patients with altitude sickness comprised the highest proportion of total clinic patients in a season (20.1%) during the time period analyzed. The number of AMS cases was highest in fall 2016 (83), a statistically significant increase when compared to the mean prior to road completion ($p=0.0003$). The second highest number of patients with HACE and/or HAPE were seen in fall 2016, though the number did not quite reach statistical significance when compared to the mean prior to the road's completion ($p=0.071$).

We found the second highest proportion of Nepali patients with altitude sickness in fall 2016 (42.9%), which was still significantly higher than the mean prior to the road's

completion ($p=0.019$). The proportion of Nepali patients in fall 2016 was second only to spring 2014 (56%) during which a surge of Nepali yarsagumba gatherers was seen. The number of Nepali trekkers with altitude sickness was highest in fall 2016, as was their proportional make-up of all altitude patients. Over the time period analyzed, increases were seen in the number of Nepali trekkers, the number of people traveling by motorized vehicle, and the number of people reaching Manang from low altitude in 2 or fewer days, especially in 2015 and 2016 after completion of the road (**Figure 1**).

Figure 1. Trends in demographics and travel characteristics among patients diagnosed with altitude sickness (AMS, HACE and HAPE) in Manang, Nepal from 2010-2016.



Discussion

This is the first study to explore the impact of new road construction on altitude sickness. We found that in fall 2016, HRA's Manang clinic saw the highest number of patients with all forms altitude sickness since 2010, with a majority of them traveling to Manang by motor vehicle and a large minority reaching high altitude from low elevation in 2 or fewer days. Since completion of the road to Manang in December 2014, the number of patients with altitude sickness has increased in tandem with the number of patients traveling by motorized vehicle and reaching Manang via rapid ascent, especially among Nepalis. It is particularly concerning that among patients with life-threatening forms of altitude sickness in fall 2016, all HAPE patients and two HACE patient had traveled by vehicle. Furthermore, our survey showed a significant knowledge deficit regarding the importance of gradual ascent in preventing altitude sickness. This finding is consistent with the results of a previous survey conducted among trekkers, porters and guides in the Annapurna region, which showed all groups lacking knowledge of altitude sickness prevention and recognition [10].

In this study Nepalis in particular appeared more prone to rapid ascent, a finding repeatedly demonstrated in studies of Nepalis on religious pilgrimage to Gosaikunda Lake (4300 m) [11-13]. This puts Nepalis at particular risk of altitude sickness, a trend shown in a previous study from the Annapurna region that found a significantly higher proportion of Nepalese staff and porters requiring evacuation compared with foreign nationals [14]. We believe that due to the easy accessibility of travel by road, life-threatening forms of altitude illness [7] will be more readily encountered among Nepalis

in Manang, who generally lack awareness of altitude sickness [10]. More altitude related dangers may lurk ahead in this vulnerable population, especially if some of them continue on over the Throng La pass already ill with AMS.

Road access has complex socioeconomic implications for Manang district. It provides cheaper and faster transport of goods and travel for the local population, as well as easier descent for medical care and more rapid evacuation of Nepalis who can rarely afford the costs of helicopter evacuation. The road carries obvious dangers as well, and the availability of cheaper, faster travel by motor vehicle is likely related to the increasing number of Nepali patients diagnosed with altitude sickness in HRA Manang clinic. Though precise numbers of Nepali trekkers traveling in Annapurna region are not available, anecdotal accounts from hotel owners in Manang and surrounding villages suggest that since the road's completion in December 2014 there has been a dramatic increase in Nepali tourists visiting Manang district, though the numbers transiently decreased after the 2015 earthquake. In particular, in 2016 a large number of university students from Nepal's cities visited Manang during brief school vacations. Motor vehicle travel minimized lodging and food costs, thereby offering a more attractive mode of travel to the Annapurna region. In 2016, travel to Manang and Mustang, a neighboring mountainous region, was common enough to have become a social media phenomenon among urban Nepali young adults.

While it is undoubtedly a good thing that Nepalis can now more easily see the natural grandeur of their own country, an experience once cost-prohibitive and dominated by foreigners, the dangers of the road are significant. In particular, the road offers an easy way for tired or ill trekkers to finish the journey to Manang by motor vehicle, or ascend

further toward the Throng La pass (5416m) when suffering from symptoms of altitude sickness. One American patient with AMS symptoms at 2600 m traveled the rest of the way by motorbike and developed symptoms of HAPE by the time of arrival in Manang (3540m).

An educational intervention is needed to increase awareness of altitude sickness and its prevention among those traveling to Manang by motor vehicle. The intervention should especially be geared toward educating Nepali locals and trekkers, emphasizing the dangers of rapid ascent, that Nepali ethnicity is not protective and that acclimatization lasts only briefly once traveling to low elevations. Possibilities for educational interventions include vernacular press releases in popular media or signs posted along the road and in tea houses from Besisahar.

The relationship between new road construction and altitude sickness is timely given significant road-building activity along the China-Nepal border. Others have documented altitude sickness aboard the region's Qinghai-Tibet railroad line, much of which is situated above 4000m [15], and China embarked on a massive road-building project into Tibet beginning in the 1950s and is currently extending that project into Nepal. At the time of publication, construction is proceeding along 8 different roadways connecting Nepal and China across the Himalayas, with 2 roads damaged in the 2015 earthquake being upgraded and 6 new roads being built [16,17].

LIMITATIONS

The study population was limited to only those presenting to HRA's Manang clinic, which likely represented a small proportion of all individuals traveling to Manang with symptoms of altitude sickness. Furthermore, seasonal variation in travelers to Annapurna is significant and was severely affected by natural disasters in 2014 and 2015..

Conclusions

Travel by motor vehicle to Nepal's Annapurna region became possible for the first time in 2014, and the number of patients with altitude sickness ascending rapidly to high-altitude by vehicle is increasing, especially among Nepalis. Physicians in Manang should consider travel history and ascension profile in patients presenting with symptoms compatible with altitude sickness. An educational intervention is needed to increase awareness among travelers to Annapurna, focusing on altitude sickness, its prevention, and the dangers of rapid ascent by motor vehicle. Given accelerating road construction across the China-Nepal border, new roads may contribute significantly to increases in altitude sickness in future years.

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Author Contributions:

JR conceived the original idea and wrote the first draft. DD assisted with data management and statistical analysis strategy. BB made substantial, critical changes in subsequent drafts of the manuscript. All three authors helped with the final draft and approved the manuscript.

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