Tibetan plateau earthquake: altitude challenges to medical rescue work

Tengda Xu,1 Zhenhua Wang,2 Tao Li,1 Veronica Pei,3 Liping Wen,1 Lidong Wan,2 Yuxuan Wang,4 Xuezhong Yu1

ABSTRACT

| BACKGROUND | Rescue efforts for earthquakes in remote plateau regions require large numbers of professional personnel to be transported from various lowland regions for relief work. Unacclimatised rescuers to high-altitude regions commonly suffer acute mountain sickness (AMS), which makes relief efforts inefficient and potentially dangerous. |
| METHODS | In this study, the AMS symptoms of 78 unacclimatised rescue workers for the Yushu earthquake from Beijing were recorded using the Lake Louise AMS self-report questionnaire. Heart rate and blood oxygen were recorded at rest before departure, during rest and during activity. |
| RESULTS | After ascending, resting heart rate increased from mean 75.87 bpm to 87.46 bpm and resting SpO2 decreased from an average of 98.51% to 90.35% (both p < 0.001). The mean Lake Louise AMS Score for participants was 3.1 (95% CI 2.6 to 3.6). 29 members (37.2%) met the diagnosis criteria for AMS. 16 members (20.5%) were evacuated early due to acute AMS (AMS score ≥5). Rhodiola was offered on a voluntary basis as a prophylactic measure but shown to be ineffective. |
| CONCLUSION | Given the ineffectiveness of prophylactic measures and the urgency of such disaster situations, it is unrealistic to mobilise rescue teams from lowland regions for immediate relief efforts. A local disaster plan specific to plateau earthquakes needs to be developed with local personnel for timely and efficient relief. |

| BACKGROUND | Unacclimatised travellers to high-altitude regions commonly suffer acute mountain sickness (AMS), a series of symptoms caused by the low barometric pressure and low blood oxygen.1 2 AMS is most serious among travellers who have not had adequate time to adapt to the high-altitude extreme environment. The incidence of high-altitude pulmonary oedema varies from 0.01% to 2% in most studies but has reached as high as 15.5% among soldiers flown directly to 14 500 feet without time to acclimatise.3 4 The risk of developing AMS poses a significant challenge when rescue workers of lowland are recruited to participate in relief efforts involving disasters located at high altitudes. |

| DATA COLLECTIONS AND METHODS | Study group |
| Study participants were the 78 members of the Beijing Emergency Medical Center rescue team (age: 37.1 ± 8.7 years, 73 male and five female members). Participants were mostly Han (n=76, 97.4%) with the exception of one Mongolian and one Hui (Muslim) ethnicity. The team consisted of 21 doctors, two nurses, 49 drivers and six administrators. Most team members did not have any known pre-existing medical conditions; one member had diabetes mellitus and one member had hypertension. |

| Study design | This is a prospective cohort study. |

| Inclusion and exclusion criteria | The participants of this study include all 78 members of the Beijing EMS rescue team; participation in both the team and study was voluntary. Consent was obtained before the study began. |

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ABSTRACT

Background Rescue efforts for earthquakes in remote plateau regions require large numbers of professional personnel to be transported from various lowland regions for relief work. Unacclimatised rescuers to high-altitude regions commonly suffer acute mountain sickness (AMS), which makes relief efforts inefficient and potentially dangerous.

Methods In this study, the AMS symptoms of 78 unacclimatised rescue workers for the Yushu earthquake from Beijing were recorded using the Lake Louise AMS self-report questionnaire. Heart rate and blood oxygen were recorded at rest before departure, during rest and during activity.

Results After ascending, resting heart rate increased from mean 75.87 bpm to 87.46 bpm and resting SpO2 decreased from an average of 98.51% to 90.35% (both p < 0.001). The mean Lake Louise AMS Score for participants was 3.1 (95% CI 2.6 to 3.6). 29 members (37.2%) met the diagnosis criteria for AMS. 16 members (20.5%) were evacuated early due to acute AMS (AMS score ≥5). Rhodiola was offered on a voluntary basis as a prophylactic measure but shown to be ineffective.

Conclusion Given the ineffectiveness of prophylactic measures and the urgency of such disaster situations, it is unrealistic to mobilise rescue teams from lowland regions for immediate relief efforts. A local disaster plan specific to plateau earthquakes needs to be developed with local personnel for timely and efficient relief.
Precious women, obese persons (body mass index > 25), elders (> 55 years old), those with pulmonary and cardiovascular diseases were ineligible for safety concerns.

Study protocol
Heart rate and pulse oxygen saturation were measured (Nellcor NPB-40 Handheld Pulse Oximeter) before departure in Beijing, on the second day of arrival, during rest in Yushu and after 30 min of work in Yushu, respectively. All subjects were given a questionnaire (Lake Louise AMS Self-report questionnaire) and instructed to complete it after descent to lower altitudes or before mandatory evacuation orders (the questionnaire was filled with the help of the administrators), reflecting maximal symptoms during the study period. The response rate was 100%. Symptoms were self-reported under five categories: headaches, gastrointestinal symptoms/nausea, fatigue, dizziness/light headedness and difficulty sleeping. Each category was reported on a scale of 0–3 with 0 as not suffering the symptom, 1 as mild, 2 as moderate and 3 as the symptom being incapacitating. workers who had a Lake Louise AMS Score ≥ 5 or showed an altered mental state were evacuated to Xining (Altitude 8000 feet). Further manifestations of AMS, including cerebral and pulmonary oedema, were not recorded due to the lack of medical equipment on site.

Statistical analysis
Data were entered and analysed using SPSS V.17.0 software package (SPSS Institute Inc.). All continuous variables are presented as the mean ± SD. Categorical variables were presented as frequencies or percentage. Comparisons of variables were performed using χ² test, Fisher exact test (for instances in which cell counts were < 5) and paired-sample t test. p Value < 0.05 was accepted to be statistically significant.

RESULTS
High-altitude illness related symptoms
Chest tightness, headache and dizziness are the three most common symptoms (table 1). Sudden vomiting (n = 7, 9.0%) is less common than nausea and anorexia (n = 25, 29.5%) but was the most common symptom in those who were evacuated early (57.1% vs 16.9%, p = 0.03).

Heart rate and peripheral oxygen saturation changes before and after ascent
Rescue workers demonstrated hypoxia after ascent, and SpO₂ decreased from base (98.5%) to destination (90.3% rest and 79.3% active) (p < 0.001). The change in heart rate from base (75.87 bpm) to destination (87.45 bpm rest and 112.01 bpm active) was also statistically significant (p < 0.001) (table 2).

AMS incidence and early evacuation
The mean Lake Louise AMS Score for participants was 3.1 (95% CI 2.6 to 3.6). Twenty-nine members (37.2%) met the diagnosis criteria for AMS. Sixteen members (20.5%) were evacuated early due to acute AMS (AMS score ≥ 5). Six (5.7%) of the early evacuations occurred on the day after arrival.

Of the four members who travelled by plane, one person (25%) was evacuated due to AMS. Of those travelling by train and road, 15 people (20.3%) were evacuated due to AMS. The incidence of AMS in the Rhodila-treated group and the non-prevention group was 39.1% (18/46) and 34.4% (11/32), respectively.

Follow-up
Rescue team members worked for an average of 7.0 ± 2.8 days. After 15 days of work, all members of Beijing EMS rescue team left the scene. There were no deaths or hospitalisations of participants and a 1-year follow-up did not yield any long-term effects.

DISCUSSION
The necessity of a high-altitude medical rescue plan
Altitude sickness is a major concern for rescue workers from lowland regions. Rescue workers had no time to acclimatisate and were highly active during their entire mission. AMS is common (67%) among mountain climbers who ascended rapidly (in 1–2 days) to 14 410 feet. AMS incidence among unacclimatised soldiers travelling to Tibet (11 811 feet) is 57.2% (n = 3628), with a hospitalisation rate of 12.07%. Fatigue and excessive physical activity can also increase the incidence of altitude sickness.

Many rescue workers had a pulse oxygen saturation of 60–80%, average SpO₂ was 90% during rest, decreasing to 79% with activity; some individuals had pulse oxygen of 20–40%. All 78 medical rescuers manifested some symptoms of AMS. Twenty-nine (57.2%) of the team members developed AMS and 16 personnel (39.0%) met the diagnosis criteria for moderate/severe AMS. Of those travelling by plane, one person (25%) was evacuated due to AMS. Of those travelling by train and road, 15 people (20.3%) were evacuated due to AMS. The incidence of AMS in the Rhodila-treated group and the non-prevention group was 39.1% (18/46) and 34.4% (11/32), respectively.

Prophylactic intervention for high-altitude illness requires further study
Each medical team was equipped with emergency medical resources including surgical instruments, tetanus vaccine and antibiotics. Each rescue participant was also provided with a survival pack that included emergency equipment and resources including surgical instruments, tetanus vaccine and antibiotics. After 13 days of work, all members of Beijing EMS rescue team left the scene. There were no deaths or hospitalisations of participants and a 1-year follow-up did not yield any long-term effects.

Table 1 Clinical symptoms in rescue workers

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>n (%)</th>
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</thead>
<tbody>
<tr>
<td>Chest tightness</td>
<td>53 (67.9%)</td>
</tr>
<tr>
<td>Headache</td>
<td>36 (46.2%)</td>
</tr>
<tr>
<td>Dizziness</td>
<td>33 (42.3%)</td>
</tr>
<tr>
<td>Shortness of breath</td>
<td>28 (35.9%)</td>
</tr>
<tr>
<td>Nausea/anorexia</td>
<td>23 (29.5%)</td>
</tr>
<tr>
<td>Insomnia</td>
<td>13 (16.7%)</td>
</tr>
<tr>
<td>Palpation</td>
<td>13 (16.7%)</td>
</tr>
<tr>
<td>Vomiting</td>
<td>7 (9.0%)</td>
</tr>
<tr>
<td>Cough</td>
<td>4 (5.1%)</td>
</tr>
<tr>
<td>Chest pain</td>
<td>3 (3.8%)</td>
</tr>
</tbody>
</table>

Table 2 Heart rate and peripheral oxygen saturation changes before and after ascent

<table>
<thead>
<tr>
<th></th>
<th>Before ascent (rest 150 feet)</th>
<th>Disaster region (14 000 feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rest</td>
<td>Active</td>
</tr>
<tr>
<td>HR</td>
<td>75.87 ± 8.18</td>
<td>87.45 ± 12.94*</td>
</tr>
<tr>
<td>SpO₂</td>
<td>98.51 ± 1.67</td>
<td>90.35 ± 7.60*</td>
</tr>
</tbody>
</table>

*Compared with before ascent rest, p < 0.001.
†Compared with disaster region rest, p < 0.001.
medication including dexamethasone, aminophylline, furosemide, acetaminophen and antibiotics. Additional medication for plague was included due to a plague epidemic near the quake area in 2009.10 While gradual ascent is the most effective prevention for altitude sickness, urgent situations only allow for pharmacological prophylactic measures.

*Rhodiola* is the most commonly used traditional Chinese medicine used to prevent altitude sickness and was recommended to each member of the Beijing EMS rescue team. Our data inconclusively showed that the incidence of AMS was not lower for team members who used *Rhodiola* versus those who did not take the herb. Further randomised controlled trials to assess the efficacy of herb medicine (such as *Ginkgo biloba, Rhodiola* and *Codonopsis*) are required to draw any firm conclusions.11–14 Allopathic medications such as acetazolamide and dexamethasone are used to prevent altitude sickness.14 15 Despite the availability of such prophylaxis, there is no effective means of preventing altitude sickness suitable to the rapid ascent and strenuous labour of plateau rescue work.

### High-altitude conditions adversely affect the rescue of disaster victims

In order to prevent effectively widespread trauma and secondary injuries, rescue workers need plateau-specific training before entering the field.16 Medical professionals must pay special attention to wound-management and life support specific to high-altitude regions including:

(a) Physiological parameters for locals: haemoglobin concentration is higher for inhabitants of high-altitude regions than inhabitants of lowland regions. For high-altitude inhabitants, the concentration is higher for people from lowlands living in high-altitude regions than for locals.17

(b) Procedural differences due to low oxygen: PaCO2 and PaO2 values will also be lower than normal due to the low barometric pressure of high-altitude areas. Trauma and blood loss will be poorly tolerated due to lower oxygen pressure, with traumatic shock occurring earlier than lowland regions. Patients are at an increased risk of pulmonary oedema, heart failure and multiple organ dysfunction syndrome. Tourniquets for active bleeding must be carefully used and closely monitored in order to avoid deterioration of local tissue due to hypoxia.

### Plateau disasters raised unique challenges to the ICS

Incident command system (ICS) is crucial for delivering adequate and timely aid. An effective ICS is needed to manage the enormous influx of both rescue resources and rescue personnel. The 2004 Indian Ocean tsunami exposed issues with ICS, especially with the large amounts of rescue resources unable to access the affected area. The DISASTER paradigm (table 3) for plateau areas takes into account the geographic setting, local resources and local healthcare facilities for effective disaster management.

### LIMITATION

Several limitations existed in this study design and should be considered when generalising our findings to other populations or conditions. The primary limitation of our study is its relatively small sample size. The study was carried out in a homogenous population group, and most of them were healthy adult males. The use of *Rhodiola* to prevent AMS was not randomised since use was voluntary. Finally, AMS symptoms were self-reported through a questionnaire with the possibility of recall bias.

### SUMMARY

Given the unique conditions of high-altitude plateaus, it is unrealistic to mobilise rescue teams from lowlands for the initial rescue phase. It is more practical and efficient to mobilise local personnel who do not risk developing AMS. The 2010 Yushu earthquake demonstrated the need for a disaster response plan specific to each geographic region. If emergency personnel are to be mobilised for relief in high-altitude regions, further study is required to prevent altitude sickness among relief workers.

### REFERENCES


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