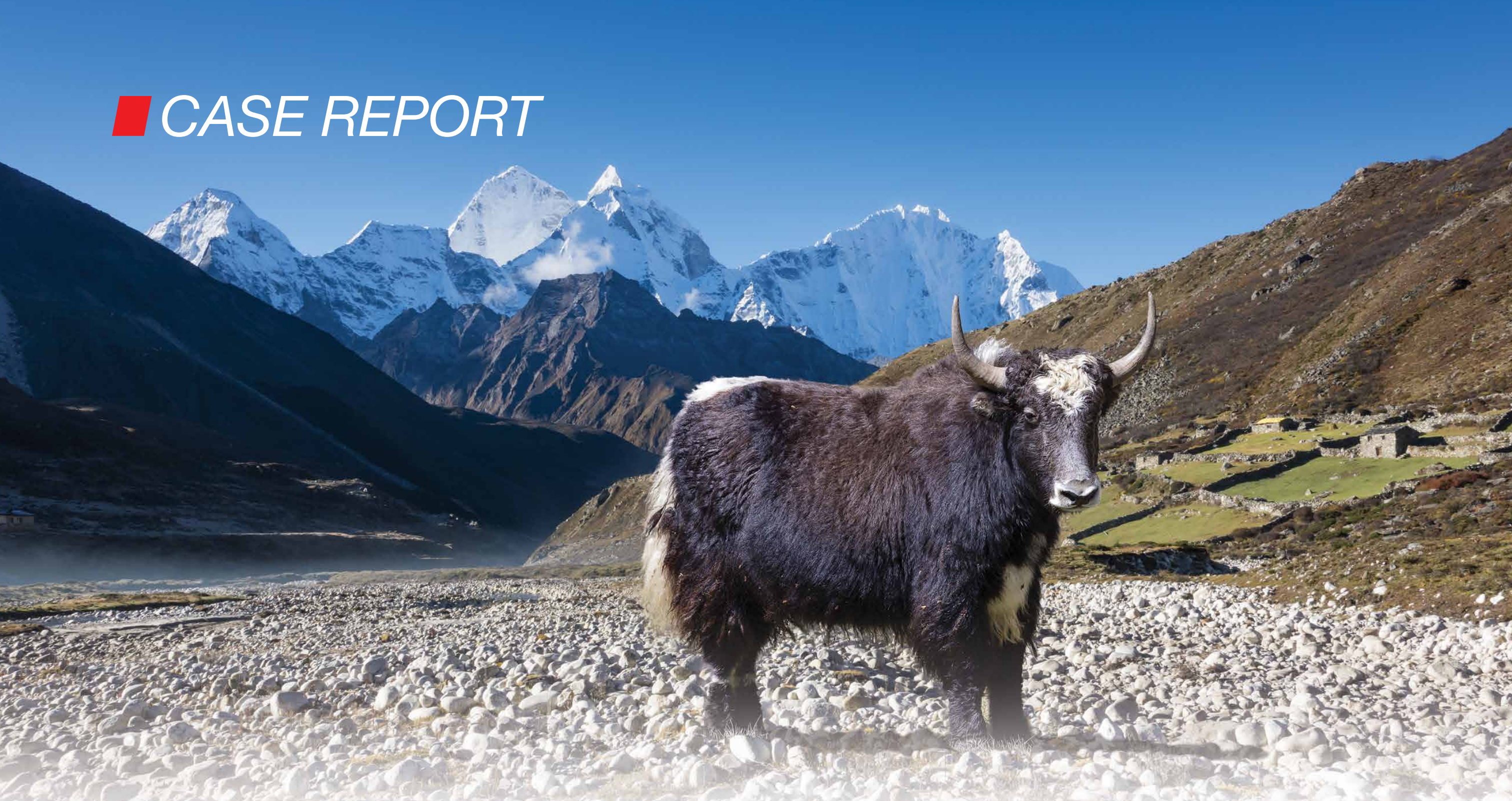
CASE REPORT



Dung Lung:
Reactive Airway Disease Syndrome From Yak-Dung Biomass Fuel Smoke

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A 30-year-old man presented with coughing, wheezing, dyspnea on exertion, and decreased exercise tolerance following an overnight exposure to biomass fuel smoke.

Case

A 30-year-old man without prior respiratory illness presented with coughing, wheezing, dyspnea on exertion, and decreased exercise tolerance after a 7-hour overnight exposure to yak-dung smoke. This episode took place at 4,240 m elevation in Pheriche village, along the Everest Base Camp trekking route within the Khumbu region of the Nepali Himalayas. Prior to going to bed that evening, the group of five cohabitants had a difficult time igniting the potbelly heating stove filled with yak-dung biomass fuel in the common room. Each time they tried to light it, the fire would smolder and go out within a few minutes, despite the group's attempts at adjusting the flue and air intake. Eventually, they abandoned

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Biomass fuels are responsible for numerous air pollutants due to incomplete combustion.

further attempts and retired to bed at approximately 9:30 PM. The patient woke up 7 hours later coughing and gasping for air. His room, which was adjacent to the common room, was clouded with smoke that had entered from the open doorway. The stove's chimney was later found to be clogged; the yak-dung fuel had reignited after everyone had gone to bed and smoldered all night long, producing copious amounts of smoke directly into the common room—and consequently into the patient's room. The patient's cohabitants slept in rooms with closed doors farther away from the common room, and did not experience significant respiratory symptoms. After awakening that morning, the patient embarked on a 2-day backpacking trip and began having spastic coughing fits, wheezing with deep inspiration, dyspnea on exertion, fatigue, and decreased exercise tolerance.

The differential diagnosis included altitude illness, airway mucociliary dysfunction (commonly known as Khumbu cough),[1] carbon monoxide (CO) poisoning, acute inhalation injury (AII) resulting in reactive airway disease syndrome (RADS), and high-altitude pulmonary edema (HAPE). Although the group hiked to Kongma La Pass (elevation, 5,545 m), and slept at 5,200 m (960 m higher than their starting point), the patient had not exhibited any symptoms of altitude illness (eg, headache, dizziness, fatigue, sleep disturbances, anorexia, nausea). Auscultation of the patient by the two physicians who accompanied him on the hike noted mild expiratory wheezing without rales or rhonchi, making HAPE unlikely in the differential diagnosis.

Although it is likely the patient had significant CO exposure, he did not display profound symptoms of CO toxicity (eg, light-headedness, headache, vertigo, nausea, or confusion). It is unclear whether the symptoms of decreased exercise tolerance and fatigue were due to CO poisoning as no co-oximeter was available to assess the patient's CO levels.[2,3] Upon return from the trip, pulse oximetry showed the patient to have an oxygen (O_2) saturation of 89% on room air, which was within appropriate range for their altitude.

One of the physicians offered the patient an albuterol metered-dose inhaler, which provided profound and immediate relief of his coughing and wheezing. The patient continued to use the albuterol inhaler every 2 to 4 hours over the next 2 days. The dyspnea on exertion and decreased exercise tolerance improved after 24 hours of treatment; the rest of his respiratory symptoms resolved after approximately 5 days at the starting elevation, and he returned to his usual baseline state of health. No follow-up chest X-rays were obtained, and the patient has had no subsequent recurrence of these symptoms despite return to higher altitude in the subsequent year.

Discussion

Nearly one-third to one-half of the world's population relies on biomass fuels for domestic heating or cooking, with developing countries accounting for 99% of its use.[4] These fuels consist of dried dung cakes or patties, agricultural products, coal, and firewood. In the Khumbu region of Nepal above timberline, yak-dung patties are used exclusively for heating and frequently for cooking. Most guesthouses in this region have potbelly-style stoves in the common dining areas, which are fueled by yak dung and ventilated with a chimney.

Pulmonary Pathophysiology of Inhaled Irritants

Biomass fuels are responsible for numerous air pollutants due to incomplete combustion. These fuels suspend particulate matter, CO, nitrogen dioxide, polycyclic aromatic hydrocarbons, and volatile organic compounds, including acetone, methyl ethyl ketone, benzene, formaldehyde, and toluene.[5] Compared to other biomass fuel sources, dung-cake combustion results in higher emissions of relatively very small particulate matter with peak concentrations ranging from 0.23 to 0.3 µm in size, which penetrate and affect the distal airway. [6] Their combustion also releases volatile organic compounds and CO.[7,8] Aside from indoor air pollution, yak-dung combustion in the Nepali Himalayan valley contributes significantly to the ambient airborne concentrations of lead, copper, aluminum, magnesium, and elemental and organic carbon.[9]

Emergency physicians (EPs) are often the first-line treating physician for patients exposed not only to biomass fuels, but also home, forest, or occupational fires resulting in smoke inhalation or AII.[10] These terms refer to the wide number of substances that may be present in the smoke and collectively affect the patient. Inhaled substances classified as irritants, such as smoke and particulate matter, can harm the epithelium of the respiratory tract, with highly water-soluble or larger particles (>10 µm) mostly affecting the upper airways. These irritants cause symptoms of progressive coughing, and wheezing; or stridor resulting in tracheitis, bronchitis, bronchiolitis, alveolitis, pulmonary edema, and/or airway obstruction. Smaller particles (<2.5 µm) can penetrate further into the lung and affect the distal airway to a greater degree. These particles are able to infiltrate the terminal bronchioles and alveoli, leading to localized inflammatory reaction and bronchospasm.[11]

Smoke may also contain chemical asphyxiants such as CO or hydrogen cyanide, which can be absorbed, leading to systemic toxicity and interfering with O_2 delivery or utilization. Importantly, high concentrations of any gas can act as an asphyxiant due to displacement of O_2.[12] Thermal injuries are also possible from fire and smoke exposure, typically affecting the upper airways. Steam inhalation can even cause irritation and burns below the vocal cords.[13]

Reactive Airway Disease Syndrome

Reactive airway disease syndrome is a constellation of symptoms presenting similar to asthma with persistent airway reactivity after an AII, and is the most common sequelae of exposure to biomass fuel combustion. This syndrome is not specifically caused by one type of particulate, irritant, or chemical component of the smoke.

Symptoms

Symptoms such as cough, dyspnea, and wheezing may begin minutes after exposure, and can persist for years due to bronchial hyperresponsiveness.[14] These chronic symptoms of RADS have been well highlighted by New York Fire Department rescue workers from the World Trade Center collapse, of whom 16% continued to show symptoms of RADS 1 year later.[15]

Treatment

Bronchodilator therapy is the mainstay of treatment for RADS. Patients who have RADS often respond well to treatment, and show improvement in symptoms and spirometry testing.

Sequelae Associated With Biomass Fuel Exposure

A cross-sectional study showed significant reductions ($P < .001$) in all pulmonary function testing parameters for cow-dung fuel users compared to those who use modern energy sources: forced expiratory volume in the first second (FEV_1), forced vital capacity (FVC), FEV_1/FVC ratio, and mid-flow rate between the first 25% and 75% of forced expiratory flow. Linear regression showed a 12.4% reduction in FVC of cow-dung users, and 36% (compared to 20% in modern energy-source users) were noted to have pulmonary infections.[16]

Due to these emissions, biomass fuel exposure causes high levels of morbidity and mortality in developing countries, with nearly 2 million attributable deaths annually.[1] Chronic exposure to biomass fuel emissions can lead to increased risk of diseases, including respiratory problems (eg, pneumonia, tuberculosis and chronic obstructive pulmonary disease, lung can-

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cer, asthma), low birthweight, cataracts, and cardiovascular events.[2,17] Women are at higher risk compared to other family members, as they typically spend approximately 3 to 4 hours longer daily in tents,[5] and perform the majoring of the cooking duties. For pregnant women, the developing fetus may also be exposed, which can lead to increased rates of fetal demise.[18]

Conclusion

Our report represents the first reported case of "dung lung" or RADS from yak-dung biomass fuel combustion exposure. In the medical literature, there has been one previous case report of dung lung by Osbern and Crapo[19] in 1981 in which the authors described three patients who died from aspiration of liquid manure in a storage facility. Our case highlights the prevalence of biomass fuel combustion in the third world, the dangerous air pollutants from their emissions, and the morbidity associated with improper ventilation of biomass fuel combustion.

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