MEDICAL ASPECTS OF HARSH ENVIRONMENTS
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SECTION III: MOUNTAIN ENVIRONMENTS

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Italian soldiers carrying their skis marching up snow-covered mountain trails. Some of the most ferocious mountain warfare to date occurred during World War I between Italian and Austrian armies, far outstripping mountain battles in other wars. This photograph was taken in April, when the snow had been softened by the warmer rays of the sun and the path made almost impassable by the slush. The difficulty of the march is seen in the step of the men in the rear. Photograph: Comando Supremo, Italian Army (World War I). Reproduced from Bagg EM. Letters from the Italian front. *National Geographic.* 1917;32(1):50.

Chapter 19

MOUNTAINS AND MILITARY MEDICINE: AN OVERVIEW

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INTRODUCTION

The Mountain Environments section of this textbook discusses medical concerns associated with military operations in the high mountains (Figure 20-1). Although the focus of the section is limited to military operations, the range of issues addressed is wide, reflecting the broad extent of potential consequences generated by the interaction of activities that military units engage in and the relative complexity of mountain environments. The goal of the section is to provide a comprehensive picture of this interaction that will help military medical personnel prepare to accomplish their mission to conserve the fighting force. This introductory chapter briefly describes the essential aspects of mountains and military operations, and the problems of both that shape their interaction.

Inherent in the concept that medical consequences can result from military activity in mountain terrain are the premises that

1. military operations do take place in mountain terrain, and
2. the interaction between military activity and the environment is of sufficient magnitude as to have discernible consequences.

Houston's excellent review of the history of military campaigns in mountains from ancient times to the present (Chapter 20, Selected Military Operations in Mountain Environments: Some Medical Aspects) illustrates the reality of mountain environments as a legitimate arena for military activity. As Houston points out, this arena has often bestowed considerable success on commanders who had the insight and daring to use the terrain to their tactical advantage. He also notes the large toll that was often extracted from the units involved in those campaigns by the mountain environment itself.

The lengthy border dispute between India and Pakistan at altitudes over 20,000 ft in the Karakorum region of the Himalayan range (still ongoing at the time of this writing [2002]), and the illicit-drug interdiction activities of various military forces in mountain regions of South America suggest that the mixture of soldiers and mountains is not a historical aberration. The United Nations, in designating 2002 as the "International Year of the Mountains," noted that 23 of the 27 armed conflicts ongoing in the world at the beginning of 2002 were being fought in mountain areas.[1] It is likely that as long as war remains a means of settling disputes, tacti-

Fig. 19-1. Those involved in providing medical support for military operations in high terrestrial environments are subjected to the same physical and emotional demands that combatants face. The physical rigors of traveling (often on foot) through mountain terrain, combined with the physiological challenges of hypoxia, are exacerbated and made even more dangerous by the emotional decrements (eg, on cognizance and mood state) that are part of life at high altitudes. Although problems such as acute mountain sickness can be resolved by descending to lower altitude and waiting there to acclimatize, this option is not usually available during combat. Military medical officers deployed to high terrestrial environments must therefore insist that the troops receive proper high-altitude training and be aware of the prophylactic pharmacological measures available.

Major Janet Lawrence, Medical Corps, US Army Reserve, seen here in mountain gear during a reserve hospital training exercise in Alaska, typifies the well-equipped Army arctic-mountain soldier. Having served in the Persian Gulf War (1990/91), Dr Lawrence has also experienced the environmental hazards of deserts. Photograph: Courtesy of Rhonda Richards, US Army Reserve Recruiting Command, Fort Knox, Ky.

cal considerations, whether perceived or real, will occasionally thrust military activity into the mountains. Even in the modern era of remote sensing, which lessens the possibility that large forces will use mountain terrain to gain the element of surprise, mountains remain an excellent refuge and a good

EXHIBIT 19-1

CATEGORIES OF MOUNTAIN VISITORS APPLICABLE TO HIGH-ALTITUDE MILITARY MEDICINE

Sojourners are persons living at low altitude who travel to altitude and return to low altitude. The meaning is that of a temporary resident, in this case, a temporary resident at high terrestrial altitude. For instance, Nepalese porters *from low altitude* who travel to high altitude to work as porters for a tourist trek (there is a group of low-altitude, native-born Nepalese people who do this), then return to their low-altitude homes, are altitude sojourners—as are the tourists for whom these porters carry supplies. Interestingly, these porters from low altitude are as likely as other unacclimatized individuals are to get altitude maladies.

Trekkers, in the context of mountain medicine, are persons who undertake a prolonged (ie, more than 1 day) journey in the mountains *on foot*. In general, they have a specific geographical goal to visit and then return from (ie, Mount Everest base camp), although both circuit and one-way treks are also popular. Trekkers are sojourners, but sojourners *on foot* as opposed to traveling by vehicle. (NOTE: they can use a vehicle to arrive at the start point of their trek but become "trekkers" when they dismount and walk a significant distance.) They may or may not carry their equipment with them; therefore, they may or may not also be considered "backpackers." When they do not carry their own equipment, they could be considered "hikers," except that trekkers hike for a more prolonged period (days) than do hikers (see below).

Trekkers today tend to be wealthy individuals who can afford to pay large sums of money to be guided through regions of the Himalaya Mountains on foot by commercial concerns that specialize in organizing treks. It was not always so. The word "trek" comes from the Afrikaner language in South Africa and originally referred to the migration of Dutch settlers from the coast into the interior highlands by ox cart. The "on foot" context comes from the fact that the Afrikaners walked beside the oxen to drive them. Oxen pulled the household goods and tools but not the people. In contemporary trekking, human porters carry most of the equipment and the people still walk; the trip is arduous in terms of both physical effort and the complexity of organization that it requires.

Both of these identifying characteristics are probably involved in modern commercial trekking, but the characteristic of interest to military mountain medicine is the traveling through the mountains on foot. Because military units may be required to move through mountain terrain on foot, the data collected on civilian trekkers may be used to approximate disease and nonbattle injury estimates for those military personnel.

Backpackers travel in the mountains on foot for more than 1 day but carry their equipment with them in backpacks. Hikers may or may not also carry equipment but they carry less than backpackers do. The energy requirements of backpackers may be similar to those of military personnel, given that both categories carry their own equipment, although military personnel may carry more weight per person, owing to carrying their own weapons and ammunition.

Hikers also travel on foot but for less than 1 day.

Climbers use their arms and legs to ascend a geological structure (usually a mountain but also cliffs, ice walls, pinnacles, spires, and, recently, indoor climbing walls). They must hang on to the structure to keep from falling. "Technical climbers" employ climbing equipment to keep from falling; "free climbers" do not. For purposes of mountain medicine, the constellation of diseases and injuries differs between these categories of climbers.

Depending on their mission, military personnel who deploy to mountain environments can experience activities equivalent to each of the categories described above. Consequently, military medical officers and other healthcare providers must familiarize themselves with all of them.

arena for small-unit tactical maneuvers. If the history recounted by Houston in Chapter 20 is any guide, it is probable that the mountain environment itself will remain a threat to military units operating there—one capable of causing a significant reduction in force through altitude illness, injury, and hypoxia-induced performance decrements.

Most human activity in mountain regions is not for military purposes. In addition to large indigenous populations in the mountain regions of South America and Central Asia, millions of lowlanders travel into high mountains every year for recreational or economic pursuits (Exhibit 19-1 and Figure 19-2). These civilians are subject to environmentally related medical problems, of course, but the constellation of medical problems arising out of military operations in mountain terrain differs to some extent from those related to civilian activities. The difference is due to the way in which certain inherent aspects of military activity alter the "human-to-mountain" interaction. To appreciate and, more importantly, anticipate the pattern of potential problems, we must be cognizant of the particular characteristics of mountains and military operations that can interact.

Fig. 19-2. Each year from April to July, many civilians fall victim to altitude illness, hypothermia, and freezing cold injury and are rescued from Mount McKinley, Alaska. Even experienced climbers fail to appreciate how dangerous Mount McKinley is, with its severe cold, raging storms, and avalanches. Military and civilian medical research camps at 7,300 and 14,000 ft make the mountain one of the great physiological and clinical outdoor laboratories. Photograph: Courtesy of William J. Mills, Jr, MD, Anchorage, Alaska.

CHARACTERISTICS OF MOUNTAIN ENVIRONMENTS

Mountain environments are not simple. Although the general geomorphological form known as a "mountain" is universally recognized, it encompasses a variety of actualities. To a small child, especially one with imagination, the dirt pile excavated from a small construction site is as valid a "mountain" as 8,530-m (29,028-ft) Mount Everest (called in Tibet *Chomolungma,* which means "the goddess mother of the Earth"). To someone familiar with only the East Coast of North America, "mountains" range between 150 and 1,525 m (500–5,000 ft) in height, while to someone from the central Rocky Mountains of North America, anything under 5,000 ft is a hill and not a proper mountain at all. The two more-or-less flat regions of Earth that occupy huge chunks of what should be sky from a sea-level perspective (ie, the Andean altiplano and the Tibetan plateau) bear remarkable superficial resemblance to deserts or plains, yet many of the medical problems seen in those regions are the same as those found in the surrounding snow-covered peaks. Such medical problems are not seen in the child's dirt pile or, to any great extent, in the low mountains of the North American eastern seaboard. What then is the difference? The difference is hypobaric hypoxia.

Hypobaric hypoxia (ie, the decrease in oxygen available for metabolic processes due to the progressive decrease in ambient barometric pressure that occurs with increasing elevation) is the most defining characteristic of mountain environments, because it is both unique to and ubiquitous within mountain environments. It causes a host of medical problems, which are usually classified under the general rubric of "altitude illness." It also interacts synergistically with other environmental factors to exaggerate the problems that those factors cause. Young and Reeves present an extensive discussion of hypobaric hypoxia and its physiological effects in Chapter 21, Human Adaptation to High Terrestrial Altitude. Understanding the human body's normal adaptive response to chronic hypobaric hypoxia, a process termed "altitude acclimatization," provides a framework for understanding altitude illness. In one sense, altitude illness results from either failure to acclimatize (inadequate adaptation) or from overcompensation of the acclimatization response (maladaptation).

Although hypobaric hypoxia is the most defining feature of mountain environments in terms of medical significance, it is not the only factor that can affect military personnel operating there. Mountain regions are complex in both space and time. Rugged terrain features that contain a significant

and often dangerous vertical component are a nearly constant feature of mountains, one that can present significant obstacles to military operations, including medical evacuation of wounded. Mountains can also make their own weather, in the form of ferocious storms. Although mountains are often thought of as being cold and snowy, they can also be very dry and hot. Ultraviolet (UV) light is filtered less well by the thinner atmosphere in high mountains, creating the possibility for significant UV radiation exposure.

Each of the many terrain and climatic factors that mountains have in common with other environments can constitute a threat to the health and well-being of military personnel, and the medical consequences of many of these conditions are the subjects of the first four sections of *Medical Aspects of Harsh Environments* (eg, Section I, Hot Environments, and Section II, Cold Environments, and their injuries are contained in *Volume 1*).[2] Mountain environments are unique in that hypobaric hypoxia is ubiquitous there, and other potentially harmful conditions interact with it. Depending on the degree of hypoxia, the interaction may significantly alter the effect of the other environmental factor. The alteration is virtually never in a direction that would seem favorable for the soldier deployed there. Rock and Mader discuss the problem of synergy between environmental factors in mountain environments in Chapter 26, Additional Medical Problems in Mountain Environments.

CHARACTERISTICS OF MILITARY OPERATIONS

Two characteristics of military operations are particularly important in shaping the interaction with mountain environments:

1. the wide range of activities associated with military operations, and
2. the frequent lack of choice as to when and where to participate in those activities.

Both are a consequence of the fact that the purpose of military operations is to engage in successful combat when necessary. Both of these aspects function to increase the potential for adverse consequences in the exposed personnel.

The spectrum of activities encompassed by military operations is very broad. It ranges from operation of weapons to operation of computers, from first-aid to lifesaving surgery, from preparation of field rations by individual soldiers to preparation of hot meals for hundreds of soldiers. Further, the contingencies of combat may force an individual soldier to perform multiple different tasks within a relatively short time. Each of those tasks changes the way in which the soldier interacts with the environment: sometimes subtly, often dramatically. In combat, the proficiency with which a task is performed may affect mission accomplishment and have life-and-death consequences, not only for the individual soldier but also for the rest of the unit.

The other characteristic of military operations that shapes the soldier–environment interaction is that the time and place of exposure are often dictated by tactical considerations rather than the presence of favorable or even benign environmental conditions. For soldiers in the forward echelons, virtually everything they do is associated with exposure to environmental hazards on the most basic level. When deployed in the field, they eat, sleep, train, and fight in an immediate and intimate relationship with physical and biological terrain features, hazards, and weather. Unlike the recreational climber or skier, who can choose to wait for better weather or travel a different route, a soldier may not have the option to wait. Unlike a miner who works in a high-altitude mine or an astronomer using a telescope on a high mountain peak, the soldier may not have the choice of staying home from work if the weather is bad or the route only marginally passable. The potential result of these two characteristics of military operations is an increase in the soldier's environmental exposure in the mountains.

MILITARY MEDICINE IN MOUNTAIN TERRAIN

Because mountains are complex environments, they pose a broad spectrum of potential threats to health and well-being. Add to that the potential for military operations to increase the environmental exposure, and a wide array of potential problems can be anticipated. From a military standpoint, those problems are most usefully classified in terms of their impact on unit function (ie, mission accomplishment), and it is this classification that serves to organize the material presented in the chapters in the Mountain Environment section. For a military unit operating in the mountains, environmental problems cause either a decrement in unit force or a decrement in soldier performance. Both can

jeopardize the unit's mission.

Altitude illness and other medical conditions related to the mountain environment are best viewed as causing decrement in unit force. Based on their etiology, they can be classified into three groups: (1) hypoxia-related conditions, (2) conditions that are not directly related to hypoxia, and (3) conditions that result from the interaction of hypoxia with other environmental factors.

Hypoxia-Related Conditions

The hypoxia-related conditions are unique to high-mountain environments, and they receive the most attention in this section. These conditions can be further classified into (*a*) hypoxia-induced edemas and (*b*) nonedematous conditions.

Hypoxia-Induced Edemas

Altitude edemas run the gamut from acute mountain sickness (AMS), a common and usually self-limited condition that can cause incapacitating symptoms, to high-altitude pulmonary edema (HAPE) and high-altitude cerebral edema (HACE), usually relatively rare conditions that can rapidly be fatal. AMS can cause a large, temporary decrement in fighting force because it affects large numbers of personnel. Both HAPE and HACE cause permanent decrements by their high mortality. Although HAPE and HACE are considered relatively rare in the civilian recreational setting, the limited data from military conflicts suggests that these deadly conditions may be a much bigger problem in the setting of ongoing hostilities, due either to increased incidence from the specific circumstances of exposure generated by deployment or to battle-related impediments to adequate care and evacuation. It is important to note that all hypoxia-related conditions will resolve if the casualty can be evacuated to a lower altitude in a timely fashion. AMS and HACE are discussed by Roach, Hackett, and Stepanek in Chapter 24; HAPE by Roach and Schoene in Chapter 25; and altitude-related peripheral edema by Rock and Mader in Chapter 26.

Nonedematous Conditions

While the edemas of high altitude are probably considered the quintessential altitude syndromes, other hypoxia-related but nonedematous conditions can cause significant morbidity and, thereby, impact on military operations. These include physical and cognitive performance decrements and changes in mood states, high-altitude retinal hemorrhages, sleep disturbances, and progressive physical deterioration and weight loss (known as climbers' cachexia). Hypoxia-induced physical performance decrements in mountain terrain can be profound and severely affect overall unit performance. To the affected soldier or commander, hypoxia-related decrements in cognitive function and mood state are often less apparent than physical effects, such decrements also have the potential to compromise unit function. Because hypoxia is ubiquitous, medical officers must remember that command personnel are just as susceptible as other unit personnel. Both physical and cognitive performance decrements must be anticipated so that measures can be taken to lessen their impact. Physical performance decrements are discussed by Fulco and Cymerman in Chapter 22, Physical Performance at Varying Terrestrial Altitudes, and psychological performance is discussed by Banderet and Shukitt-Hale in Chapter 23, Cognitive Performance, Mood, and Other Psychological Effects at High Altitude.

Additionally, the chronic hypoxia of high-mountain environments can also interact with preexisting medical conditions to cause significant morbidity. While this might not be thought of as a major problem for military units, which are traditionally composed of young, relatively healthy individuals without significant pathological conditions, the upper echelons of command generally comprise older individuals who may have conditions of "normal" aging (eg, coronary artery disease, emphysema) that cause them to be at increased risk from hypoxia. Additionally, conditions such as sickle cell trait, which are often unrecognized in young military personnel, can result in life-threatening pathology at high altitude. Nonedematous conditions caused by hypoxia and the interaction of hypoxia with preexisting medical conditions are discussed by Rock and Mader in Chapter 26, Additional Medical Problems in Mountain Environments.

Conditions Not Directly Related to Hypoxia

Illness or injury caused by factors other than hypoxia are not unique to mountain environments, but they can be a significant component of the constellation of medical problems seen during military operations there. Cold injury is the most obvious of these, but dehydration, malnutrition, and even heat injury are also important at high altitude. Although most of these conditions are discussed in detail in *Medical Aspects of Harsh Environments, Volume 1*,[2] they are also listed in Chapter 26, Additional

Medical Problems in Mountain Environments, along with other nonhypoxic conditions such as lightning strikes and constipation, to provide an accurate picture of the medical problems associated with deployment to high mountains. Appreciation of the complete spectrum of possible medical problems is necessary for planning adequate medical support to deploying units.

Interaction of Hypoxia and Environmental Factors

The solutions to the hypoxia-related medical problems and performance decrements experienced during military operations in the mountains fall into two broad categories: Mother Nature's and military or man-made. Nature's solution is "altitude acclimatization," a process of hypoxia-induced changes in physiological processes that regulate homeostasis around a lowered set point of blood oxygen content. Although there are limits to the altitude to which people can successfully acclimatize (eg, < 18,000 ft), the beneficial effects of acclimatization are so well recognized that the absence of altitude illness and improvement in submaximal physical performance are generally accepted to be evidence of the acclimatized state. In many ways, the acclimatization of personnel would be the ideal solution to the medical threats posed by altitude exposure for the military, but some potential problems lurk:

- The biggest problem is that time and exposure to high altitude are needed to achieve and maintain the acclimatized state. This need potentially limits the flexibility for rapid maneuver, which can offer tactical advantages.
- Reliance on acclimatization would necessitate stationing troops more or less permanently at high altitude to maintain the acclimatized state, an option that is not always available or practical. (As previously noted, the physiology of acclimatization is discussed in Chapter 21, Human Adaptation to High Terrestrial Altitude.)

If altitude acclimatization is not possible, then other (man-made) solutions to prevent altitude illness and increase military performance in the mountains must be considered. If military operations in mountain environments could be avoided, these particular problems would cease to exist. Such is not the case, however, so the military must rely on solutions that are more practical, including training and pharmacological prophylaxis against altitude illness. Various options for preventing illness and increasing performance are described in Chapters 22 through 26. Their specific applications to the military situation, and the role of the unit medical officer in implementing medical support for mountain operations is addressed in by Rock and Iwancyk in Chapter 27, Military Medical Operations in Mountain Environments.

SUMMARY

Military operations in mountain terrain can be associated with environmentally related medical problems and performance decrements that can have significant impact on mission attainment. Military personnel may be more at risk for problems than civilians, because military operations can increase exposure to harsh conditions. Hypobaric hypoxia is unique to high-mountain environments and is responsible for altitude illness and physical and cognitive performance decrements. Because hypoxia is ubiquitous, all unit personnel, including command and medical support, are equally susceptible to its effects. Altitude acclimatization can prevent altitude illness and improve performance, but the time and circumstances to achieve acclimatization may not always be available to units in a rapidly changing tactical situation.

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