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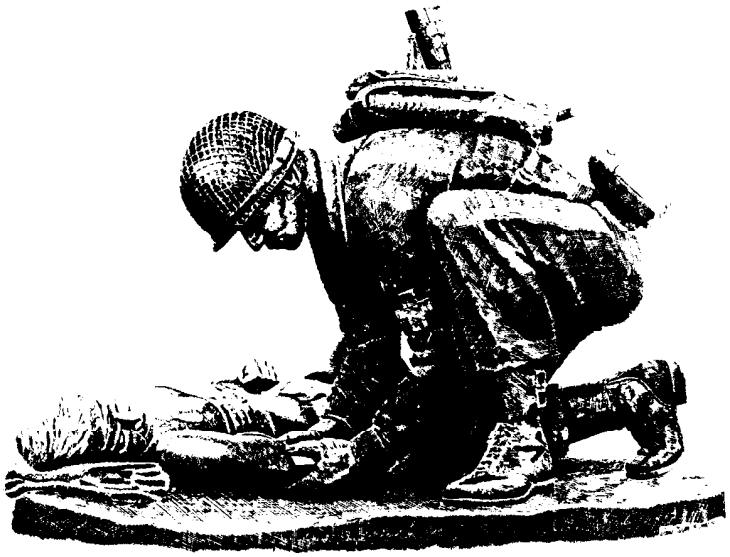

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Major General Kevin C. Kiley

AMEDD Center and School Welcomes MG Kiley

Major General Kevin C. Kiley is the new Commander, U.S. Army Medical Department Center and School and Installation Commander, Fort Sam Houston, succeeding MG James B. Peake.

He comes to the Home of Army Medicine from his positions as Assistant Surgeon General for Force Projection; Deputy Chief of Staff for Operations, Health Policy and Services, U.S. Army Medical Command; and Chief, U.S. Army Medical Corps.

A 1972 graduate of the University of Scranton, MG Kiley received his medical degree from Georgetown University School of Medicine. Following a surgical internship, he served an Obstetrics and Gynecology Residency at William Beaumont Army Medical Center, El Paso, Texas, graduating in 1980. His military career includes assignments with the 121st Evacuation Hospital, Seoul, South Korea; 10th Mountain Division, Fort Drum, NY; William Beaumont Army Medical Center; 15th Evacuation Hospital, Fort Polk, LA, and in Saudi Arabia during Operations "Desert Shield" and "Desert Storm." His other tours of duty include serving as Deputy Commander for Clinical Services, Womack Army Hospital, Fort Bragg, NC; and as Commander, Landstuhl (Germany) Regional Medical Center, with concurrent duty as Command Surgeon, U.S. Army Europe and 7th Army.

Major General Kiley's awards and decorations include the Legion of Merit (first Oak Leaf Cluster); Bronze Star Medal; Meritorious Service Medal (second Oak Leaf Cluster); Army Commendation Medal; the Order of Military Medical Merit; and the Expert Field Medical Badge.

Aviation Medicine: Professionalism and Dedication to the AMEDD

Colonel James S. McGhee
Dean, U.S. Army School of Aviation Medicine
Consultant for Aviation Medicine

Aviation medicine is a unique and diversified field in the Army Medical Department (AMEDD), and one that is sharply focused on the AMEDD's basic mission - to conserve the fighting strength. This issue of the AMEDD Journal reflects the breadth and depth of aviation-specific medical specialties, although even more space would be necessary to sample its entire spectrum. Aviation medicine requires a variety of highly trained team members in order to achieve its two primary objectives: medical support of the U.S. Army aviator and clearing of the battlefield by using air assets. It takes aviators, flight surgeons, flight medics, aeromedical physician assistants, and aviation psychologists to reach these goals. Both active and reserve component team members are at work every day, getting the job done for our Total Army. This issue salutes these professionals for doing a tough job extremely well.

Aviation medicine has a singular and proud history. It was derived from the medical requirement to reduce aviation losses during World War I and continues to be the only medical specialty directly associated with a warfighting branch. The memory of LTC (Dr) Rollie Harrison is honored each year by an award presented to the individual who most embodies the ideals of an operational flight surgeon. Other "founding fathers" such as MG (Dr) Spurgeon Neel and BG (Dr) Theodore Lyster are similarly honored.

From its beginning to the present time, aviation medicine is still about prevention. Physical standards for personnel selection and retention are developed at the U.S. Army's Aeromedical Center's Aeromedical Activity. These standards are based on analysis of the most extensive and interactive physical examination information database in the Department of Defense. Aircrew members are selected and kept flying to the maximum extent possible based on population inferences and prediction models derived from that database. The U.S. Army Safety Center Surgeon as well as the current Commander of the Center for Health Promotion and Preventive Medicine are both Aerospace Medicine Specialists. The Atlas of Injuries in the U.S. Armed Forces was co-authored by an Aerospace Medicine Specialist. Many of the projects at the U.S. Army Aeromedical Research Laboratory (USAARL) are related to aircrew protection.

The unit-level aviation medicine team makes prevention happen on the ground. The aviation commander's aviation medicine program is outlined in Army Regulation 385-95, Army Aviation Accident Prevention. This publication lists 14 program points for which the commander is accountable and the flight surgeon is responsible. Part of that responsibility is traditional clinical medicine; however, a sizeable amount of preventive medicine work is accomplished in the aviator's work environment. As with all prevention measures, it is difficult to validate the number of aviation mishaps that have been prevented thanks to the hard work of aviation medicine team members in both the tactical and installation environments.

Innovation has been a characteristic common to all aspects of this field. Certainly the USAARL has been, and continues to be, a prime mover in "thinking out of the box" in terms of aviation hardware and equipment development. Crashworthy fuel cells for helicopters, Military Anti-Shock Trousers, and lighter, safer flight helmets are just three of the many technological innovations developed at the

Laboratory. Currently, USAARL research areas include improved imaging devices and instrument displays, energy-attenuating aircraft seats, and cockpit air bags. Limits of the human element are being explored through projects dealing with laser eye surgery and rest management techniques during sustained aviation operations. These initiatives combine the special skills of flight surgeons, aviators, and civilian researchers to reach out and push the envelope of the body's endurance and capabilities in the flight environment.

Education is another hallmark of the field. The U.S. Army School of Aviation Medicine (USASAM) is where it all begins for flight surgeons, flight medical aidmen, aeromedical physician assistants, and psychologists. The School, a branch campus of the AMEDD Center and School's Academy of Health Sciences, is located at Fort Rucker, AL, the home of Army aviation. In addition to instructing AMEDD soldiers, the USASAM faculty teaches fixed and rotary wing students the aeromedical hazards of their new profession. The USASAM is dedicated to aeronautical knowledge projection. It is known for its creative methods of leveraging the latest technologies of synchronous and asynchronous training to put aeromedical information in the hands of those who need it, regardless of location. The USASAM staff is currently re-engineering all programs of instruction to reach the widest possible audience with timely and effective training products. The USASAM is also one of the few schools in the Army that employs on-site visits to validate how well its graduates are performing. The medical members (Flight Surgeons or Medical Service Corps aviators) of the Aviation Resource Management Survey teams evaluate the aviation medicine programs of active and reserve component aviation units each 18 to 24 months. This information is used by the USASAM to improve instruction and provide the AMEDD with an indication of the status of aviation medicine in the field.

Tactical medical evacuation (MEDEVAC) by fixed- or rotary-wing aircraft is one of the keys to success on any future battlefield. Skilled aviators and flight medical aidmen have proven themselves to be crucial lifesaving elements in the past and will continue to do so in the future. As warfighting doctrine and equipment evolve, MEDEVAC doctrine and equipment will keep pace. With the mission of the Army becoming increasingly diverse, the three elements of the MEDEVAC team – aviators, flight medics, and equipment will become increasingly capable. Peacemaking and peacekeeping actions present different challenges and make entirely different demands than do major theater wars; MEDEVAC assets are frequently at the forefront of these operations. Flexibility and capability are essential elements for meeting the mission in these challenging environments. New training opportunities such as the UH-60Q MEDEVAC helicopter and the new MOS 91W medic are on the horizon. Integrating these assets into future evacuation doctrine is a challenge being discussed and planned for by today's aeromedical community.

These are exciting and promising times for aviation medicine. The skills, professionalism, and enthusiasm of the men and women of this community are exemplary. The pages of this Journal issue provide a glimpse into the history, diversity, and expertise to be found there. This is a community dedicated to the values that have made the Army great; I am especially proud to be a member.

The Role of HBO Therapy in Combat Casualty Care

LTC Daniel T. Fitzpatrick, MC†

Hyperbaric oxygen (HBO) therapy is defined as treatment in which a patient breathes 100% oxygen while under a pressure greater than sea level. Limited studies involving combat casualty care have documented the effectiveness of adjunctive HBO therapy. Current technology and capability exists for all three services to provide in-theater hyperbaric treatment. Further research is needed to more clearly define the operational role of HBO therapy.

Introduction

Hyperbaric oxygen therapy is the administration of 100% oxygen to patients while at pressure greater than sea level.[1] The resultant increased pressure and hyperoxia provides a number of beneficial clinical effects. Many of the peacetime clinical indications can be applied to combat casualty care.

The Army hyperbaric medicine program began in 1986, when a hyperbaric chamber was installed at the U.S. Army Aeromedical Center, Fort Rucker, AL, to treat altitude induced decompression sickness (DCS) in aircrew members. The clinical hyperbaric medicine program was established in 1987, as part of a comprehensive Department of Defense (DOD) program. In 1993, the Army clinical program was moved to Eisenhower Army Medical Center, Fort Gordon, GA, to support the entire Southeast Region.

Clinical hyperbaric medicine can be viewed as the relatively new application of an old established technology to help resolve selected medical problems. Since 1900, HBO therapy has been accepted as the primary treatment for DCS. Over the past 25 years, animal studies, clinical trials, and extensive clinical experience have produced a set of indications for which HBO therapy may be beneficial. The following currently-approved indications are regularly reviewed by the Committee on HBO Therapy of the Undersea and Hyperbaric Medical Society which has cognizance over this field:[1]

- Air or gas embolism
- Carbon monoxide and/or cyanide poisoning; smoke inhalation
- Clostridial myonecrosis (gas gangrene)
- Crush injury, compartment syndrome, and other acute traumatic ischemias
- Decompression sickness
- Enhancement of healing in selected problem wounds
- Exceptional blood loss
- Intracranial abscess
- Necrotizing soft tissue infections
- Osteomyelitis (refractory)
- Radiation tissue damage
- Skin grafts and flaps (compromised)
- Thermal burns

Mechanisms of Action

The efficacy of hyperbaric therapy is based on two physical factors: (1) a reduction in volume of gas-filled spaces and (2) an elevation of the partial pressure of oxygen (Po_2) resulting in hyperoxygenation of perfused tissues. The volume changes are based on Boyle's Law, which states that if temperature remains constant, the volume of a gas is inversely proportional to the pressure. Therefore, as pressure increases, gas volume decreases which, in turn, reduces tissue distortion and vascular compromise. This volume reduction is of primary importance in cases of gas embolism and DCS.

The hyperoxygenation of tissues is based on Henry's Law. As the Po_2 increases during compression, the amount of oxygen dissolved directly into the plasma increases. The increased Po_2 has a negligible impact on total hemoglobin oxygen content and the oxyhemoglobin dissociation curve remains unchanged.

Unlike the hemoglobin saturation curve, the amount of oxygen dissolved in plasma is linearly related to the oxygen partial pressure. Under normal sea level conditions, there is 0.32 ml of oxygen dissolved in each 100 ml of whole blood (0.32 vol %). When breathing 100% oxygen, each additional atmosphere of pressure produces an additional 2.3 vol % oxygen dissolved in plasma. At three atmospheres absolute (the maximum pressure using 100% oxygen) plasma contains 6.8 vol % oxygen, providing an arterial Po_2 of 1900 mm Hg. This elevated oxygen pressure increases the oxygen diffusion gradient and improves oxygen delivery to relatively ischemic tissues.

The cardiovascular effects of HBO therapy include a nominal reduction in cardiac output and a generalized vasoconstriction.[2] As a result, edema formation is reduced or limited and there is preservation of the integrity of the cells lining the blood vessels. While the vasoconstrictive effect may appear to add to cellular hypoxia, the increase in plasma oxygen content results in an overall gain in delivered oxygen. The net effect of reducing edema while maintaining tissue oxygenation is very beneficial in conditions such as burns, crush injuries, and other traumatic ischemias.

Hyperbaric oxygen therapy contributes to effective immune function. Hypoxia significantly degrades the efficacy of phagocytic leukocytes to kill bacteria. Polymorphonuclear (PMN) leukocytes and macrophages use oxygen in the production of oxygen radicals, H_2O_2, and superoxide used in the killing of microorganisms.[2,3] Hyperoxygenation of blood and tissues helps to restore and maintain leukocyte function, which results in more effective bacterial killing. The HBO also has a direct toxic effect on several aerobic and anaerobic bacteria and potentiates certain antibiotic activity, all of which contribute to a more rapid elimination of infection.[4-7]

Combat Casualty Care

Although each conflict is different, a historical analysis of wartime casualties shows many injuries that would benefit from HBO therapy. Of primary importance are traumatic injuries due to bullets or shell fragments causing a large amount of crushed tissue and a compromise in blood supply. Associated problems of gas gangrene, crush injury, compartment syndrome, necrotizing infections, osteomyelitis, compromised skin grafts and flaps, and nonhealing wounds all respond to hyperbaric treatment. Other potential uses include treatment of DCS, carbon monoxide (CO) and/or cyanide poisoning, smoke inhalation, and other chemical casualties.

The efficient healing of injured soldiers not only reduces their pain and suffering, but also reduces the time investment of attending medical staff. Adjunctive HBO treatment could potentially reduce battlefield turn-around times for injured combatants, thus lessening the tremendous drain on the wartime medical care system. The net result is an increase in battlefield effectiveness, capability, and durability of our fighting force.

Acute Traumatic Ischemia. Acute traumatic ischemia is a well-known complication of severe traumatic injury to the extremities. Severe limb injury with major blood vessel damage and/or crush injury causes acute ischemia, and post-traumatic edema further reduces oxygen availability to tissues. Although vascular repair may successfully restore peripheral blood flow, ischemia may actually increase postoperatively.[8] Ischemic damage makes it difficult to distinguish between necrotic tissue, partially damaged tissue, and healthy tissue.

Following repair of major blood vessels, HBO therapy maintains oxygen delivery via plasma flow and reduces edema secondary to vasoconstriction.[1] In areas where the microcirculation is compromised, HBO therapy improves tissue oxygenation and interrupts the chain of events leading to ischemia and tissue necrosis. As a result, partially damaged tissue may be salvaged and it is easier for the surgeon to distinguish between viable and necrotic tissue.

Several reports have documented the effectiveness of HBO therapy as adjunctive treatment for war injuries to the vascular system. Schramek and Hashmonai described treatment of vascular injuries in a series of 51 wounded soldiers during the Yom Kippur War of 1973.[9] Seven soldiers showed severe peripheral ischemia with imminent gangrene following vascular repair, and all were successfully treated with hyperbaric oxygen. Radonic et al reported treatment of 28 patients with combat-related vascular injuries in Croatia.[10] Thirteen patients who presented with a long period of ischemia and more extensive tissue destruction received HBO therapy following surgery. Despite long delays to surgery, the amputation rate was 8% in the hyperbaric treated group versus 33% on the nonhyperbaric group. Shupak et al published a report on 13 casualties with persistent post-traumatic ischemia following vascular repair.[11] Clinical impression before hyperbaric treatment was that amputation was unavoidable in all cases. In eight patients (61.5%) there was total limb salvage, and the remaining patients received amputations at a lower than expected level.

Problem Wounds. The use of HBO therapy has been recognized worldwide by military physicians as an effective method for treating wounds that fail to respond to standard surgical and antibiotic treatment. Wound healing can be significantly compromised following a severe traumatic injury. The common underlying problem, regardless of etiology, is tissue hypoxia, and its sequale. The HBO therapy intermittently increases tissue oxygen tension in hypoxic wounds causing an increase in fibroblast proliferation, collagen production, and capillary angiogenesis; as well as enhancing leukocyte bacterial killing.[1,3,12] Although HBO may be a useful adjunct, a successful outcome also requires daily aggressive wound care and meticulous dressing changes. The Vietnam experience has shown that delayed wound closure combined with antibiotics and surgical debridement is the most effective way to achieve wound healing and prevent infection. Addition of HBO therapy to the regimen will further improve clinical outcomes and reduce recovery time of injured soldiers, contributing to increased military effectiveness.

Clostridial Myonecrosis. The risk of infection in battlefield injuries can be high due to extensive injury to tissue and blood supply and wound contamination with dirt and debris. Gas gangrene, a serious battlefield complication, is most commonly caused by Clostridium Perfringens. In hypoxic tissue, the organism proliferates and produces exotoxins that rapidly cause tissue necrosis, hemolysis, and inhibit local host defenses. The major lethal toxin produced is alpha-toxin. A tissue oxygen tension of 250 mm Hg inhibits alpha-toxin production.[1]

Improved wound care methods combined with antibiotics reduced the incidence of gas gangrene from 0.3% to 0.8% in World War II, to 0.08% in the Korean War, to a total of only 22 cases reported during Vietnam.[13-15] A review of the literature shows mortality rates of 45% to 50% with standard surgery and antibiotics. By adding HBO therapy to the treatment regimen, mortality is reduced to 15%; if treated within 24 hours of symptom onset, mortality falls to 5%.[2,16] Shupak et al reported treating four casualties during the Lebanon War using a combination of HBO therapy, surgery and antibiotics, all initiated within 24 hours of diagnosis.[17] All four patients recovered with no amputations. The advantages of early HBO treatment include arresting alpha-toxin production, which is essential to reversing the infection; reducing systemic toxic reactions so that the patient is a much better surgical risk; and obtaining a better demarcation between viable and necrotic tissue, resulting in smaller areas of resection.

Necrotizing Soft Tissue Infections. Necrotizing soft tissue infections usually occur in traumatic or surgical wounds or around foreign bodies. The flora found in most necrotizing infections includes facultative and anaerobic organisms. Infections typically cause local tissue hypoxia, which impairs PMN function, and allows for proliferation of bacteria.[2,3] The rationale for using HBO therapy is to reverse the depressed PMN function at the progressing ischemic margin of infected tissue.

The principal treatment is surgical debridement and systemic antibiotics. The HBO therapy is recommended as an adjunct only in cases where mortality and morbidity are expected to be high despite aggressive standard treatment.[1] Although most reports of HBO use have been anecdotal, Riseman et al compared outcomes with and without adjunctive HBO therapy in 29 patients with necrotizing fasciitis.[18] Mortality was 23% in the HBO group

versus 66% in the non-HBO group ($P<0.02$), with an average of 1.2 versus 3.3 debridements in the HBO versus non-HBO group ($P<0.03$).

Skin Grafts and Flaps. Hyperbaric oxygen therapy is not recommended for the support of normal or uncompromised grafts and flaps. The HBO seems to be of great benefit in patients who require grafts or flaps over areas of compromised microcirculation or where hypoxia may threaten transplanted tissue viability.[1] In these cases, HBO enhances flap and graft survival through hyperoxygenation of tissues, stimulation of fibroblasts, and enhancement of collagen synthesis and neovascularity.[3] Although no randomized study has been performed, a number of clinical reports describe the beneficial effect of HBO therapy.[1] In one study, Bowersox et al reviewed 105 patients with ischemic skin flaps or grafts and found that 89% of the flaps and 91% of the threatened skin grafts were salvaged with HBO therapy.[19] Other studies that excluded HBO therapy have reported success rates of 35% in compromised tissue. In our limited wartime experience, two soldiers with lower extremity blast injuries received during Desert Storm were evacuated to Fort Rucker, AL, with failing tissue flaps. Both patients were successfully treated with HBO therapy, eliminating the need for further surgery or amputation.

Toxic Inhalation. In a battlefield environment, the atmosphere may contain CO, cyanide, carbon dioxide, or other dangerous chemicals which are toxic to the respiratory system. The HBO therapy has been shown to be an effective treatment for such exposures. During the Persian Gulf War, the Israeli government instructed all civilians to remain in their homes and use sealed rooms in case of a chemical attack. This resulted in six cases of acute CO poisoning, all of which were treated successfully with HBO therapy.[20]

The pathophysiology of CO poisoning appears to be a complex interaction between tissue hypoxia and cellular toxic effects.[3,21] Toxic exposures most frequently affect the cardiac and central nervous system resulting in cardiac arrhythmias and encephalopathy. The HBO therapy is the most rapid way of displacing CO bound to hemoglobin, myoglobin, and intracellular enzymes. Patients treated with HBO have a more rapid improvement in cardiovascular status, lower mortality, and a lower incidence of neurological sequale.[3,21]

Air Embolism. The two main causes of air embolism (AGE) are pulmonary overpressurization and iatrogenic accidents.[1,3] Overpressure injuries may occur during an uncontrolled ascent in divers, as a result of blast injury, or as a complication of positive pressure ventilation, especially when there is damage to the lung parenchyma as in a penetrating chest wound. Iatrogenic causes include surgery, biopsy procedures, hemodialysis, and central line placement. Circulating emboli may obstruct the micro-circulation, resulting in varying degrees of ischemia in the affected area. The vascular endothelium may also be damaged causing increased permeability and rapid local accumulation of leukocytes and platelets, with a further reduction in microvascular flow.[3]

The most frequently noted and most severe complications involve embolization of cerebral or coronary vessels, producing either severe neurologic symptoms or lethal arrhythmias.[3] Regardless of etiology, immediate recompression in a hyperbaric chamber is the primary treatment of choice. The HBO oxygen therapy reduces the volume of the embolism and the resultant edema, and increases oxygenation of the involved ischemic tissue.

Decompression Sickness. This refers to the disease that may occur after a reduction in ambient pressure. This disease is seen most often in divers and occasionally in aviators. The cause of DCS is the release of dissolved gases, usually nitrogen, from solution in the tissues and blood of the body and the resultant formation of gas bubbles. Symptoms occur when gas bubbles distort tissue and obstruct blood flow. The blood-bubble interface also acts as a foreign surface and activates the coagulation, complement, and kinen systems.[22]

The most common manifestation of DCS is localized joint pain that generally develops within 6 hours of exposure. Symptoms range from mild discomfort to very severe pain, which may gradually increase during the following 24 to 36 hours. More serious cases can present as paraplegia, respiratory distress, or cardiovascular collapse due to gas emboli in the spinal cord, lungs, or cardiac system.[22]

Hyperbaric oxygen therapy is accepted worldwide as the primary treatment for DCS. Treatment with HBO

mechanically decreases the size of the bubbles and increases the nitrogen pressure gradient, accelerating bubble absorption. This therapy also increases oxygenation of hypoxic tissue and decreases associated edema.

HBO Administration

Hyperbaric oxygen therapy should be initiated early, preferably within 4 to 6 hours for optimal benefit in the treatment of CO poisoning, DCS, AGE, crush injuries, and other acute traumatic ischemias.[1] Delay in treating combat casualties could adversely affect clinical outcome. Portable lightweight hyperbaric chambers are currently available which could be used to provide in-theater treatment. In addition, host nation fixed facilities and hyperbaric chambers on board Navy ships in theater could also be used. Providing in-theater HBO capability would ensure expedient treatment of combat casualties to achieve maximum potential benefit. A DOD-level joint service plan is needed to establish protocols to reduce the time from injury to initiation of HBO therapy.

Following initial stabilization, casualties could be evacuated to one of the five military hyperbaric facilities in continental United States for additional treatment. The Army clinical chamber, located at Eisenhower Army Medical Center, Fort Gordon, GA, is a multiplace chamber (see figure) capable of treating up to 12 patients simultaneously. The chamber is pressurized with compressed air, and the patients breathe 100% oxygen through a face mask, head tent, or endotracheal tube. Medical equipment, including monitors, ventilators, and defibrillators can be used in the chamber to support critically ill patients. Similar chambers are located at Brooks AFB, TX, Travis AFB, CA, Wright-Patterson AFB, OH, and Portsmouth Naval Hospital, VA.

Future Considerations

The high risk of exposure to chemical warfare agents on the battlefield requires identifying treatment modalities that will quickly and effectively deal with their toxic effects. The HBO therapy has been shown to be an effective adjunct in the treatment of cyanide poisoning.[21] At the 7th International Congress on Hyperbaric Medicine in Moscow, the extensive use of and experience with mobile field hyperbaric units in Russia was described.[23] These portable hyperbaric chambers were used regularly in the treatment of combat and chemical warfare casualties. To date, scientific efforts to validate these reports have been inconclusive. A critical need exists for further research to better determine the role of HBO in treating chemical casualties.

Treatment of eye injury due to laser exposure is

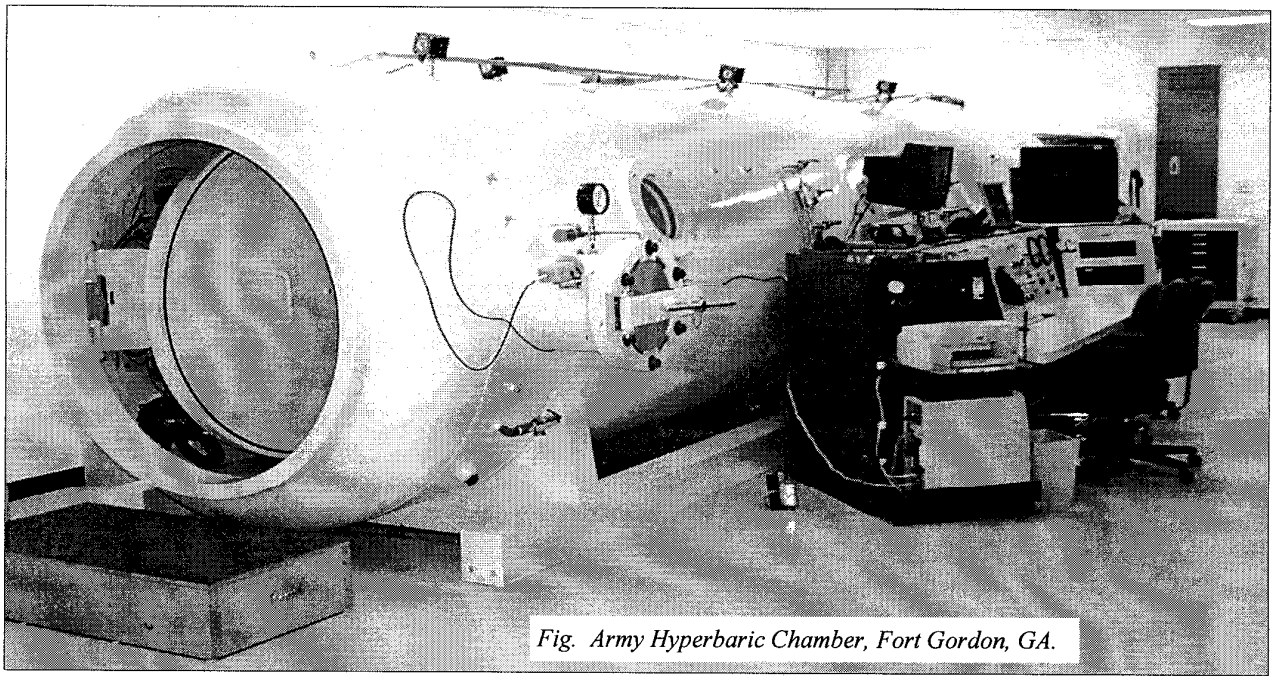

Fig. Army Hyperbaric Chamber, Fort Gordon, GA.

another potential use for HBO therapy.[24] Exposure causes thermal and mechanical damage to retinal cells and microvasculature, with the formation of large amounts of free radicals, causing structural protein damage, lipid peroxidation, and cell death. These biochemical processes are similar to burn and reperfusion injuries, both of which are treated effectively with HBO. The hyperbaric facility at Brooks AFB is coordinating initial research in this area.

Conclusion

Hyperbaric oxygen therapy is an effective treatment when administered in accordance with established protocols. Sporadic studies involving combat casualty care have documented improved patient outcomes with HBO therapy. Additional clinical and basic research is needed to better define the operational role of HBO therapy. Developing scientific support for the use of HBO in the treatment of injured soldiers should be a firm goal of all services to enhance our medical readiness posture during war.

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Hypoxia and Altitude Training in the U.S. Army

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This article examines the origins of hypoxia exploration and the subsequent impacts that military warfare has had on the study of altitude physiology. An overview of the physiologic manifestations of hypoxia, and the United States Army School of Aviation Medicine (USASAM) hyperbaric chamber, safety, and training is presented.

Introduction

"They leap up and death seizes them, without a struggle, without suffering, as a prey fallen to it on those icy regions where an eternal silence reigns. Yes, our unhappy friends have had this strange privilege, this fatal honor, of being the first to die in the heavens." This was part of Paul Bert's (Professor of Physiology at Paris) eulogy at the funeral of M. Croce-Spinelli and M. Sivel, two early altitude explorers. The date was 15 April 1875. The brave balloonists had trained for the ascent in an altitude chamber, and routinely reached altitudes in excess of 24,000 ft using oxygen enriched air intermittently to maintain their sensibility during their altitude explorations. However, tragedy struck during an attempt to reach 26,200 ft. During this flight, they took a third person, M. Gaston Tissandier, on board without increasing their already inadequate oxygen stores, despite the warning from Professor Bert advising them to take much more oxygen than they had planned. The balloonists achieved their goal, climbing to 28,200 ft, but all three lost consciousness due to hypoxia: Tissandier was the only one to waken upon descent.[1] Post accident inquiries revealed that they were too weak to reach out for the oxygen tubes only a few feet away from them.

These two men died of altitude induced hypoxia, despite their knowledge of the risks and possessing equipment, albeit rudimentary, adequate to treat the consequences of the disorder. Today, despite tremendous advancements in technology and aviation medicine education, mountain climbers, trekkers, and aviators, both professionals and novices, continue to succumb to the hazard of hypoxia. Although not a conclusive finding by the National Transportation Safety Board, preliminary indications implicate hypoxia as the most likely cause of the bizarre crash of the Learjet carrying golf champion Payne Stewart, on 25 Oct 99. The end came for Stewart and his aircrew within 4 hours and 1400 miles after takeoff when his chartered jet, with iced over windows (and no apparent visible damage or communication from the aircrew), plunged into a South Dakota field killing everyone inside.[2]

Physiology of Hypoxia

Hypoxia can be defined as any condition in which there is a decreased supply of oxygen to peripheral tissues, short of anoxia. Clearly, hypoxia can be a threat in the aviation environment, as the resultant decrement in mentation could adversely affect an aviator's ability to pilot an aircraft.

Hypoxia is typically divided into four classes, depending on the root causes. *Anemic* hypoxia is caused by a decreased oxygen carrying capacity despite normal partial pressure of oxygen (Po_2) and blood flow. An example of anemic hypoxia is carbon monoxide (CO) poisoning. The CO has approximately 245 times the affinity for the ferrous heme binding sites of the red blood

cell, displacing molecular oxygen.[3] This adversely affects the ability of the red blood cell to carry oxygen. The CO is significant in the aviation community, as it may accumulate in cabin air, and smokers are known to have carboxyhemoglobin levels 7 times higher than non-smokers, which puts them at additional risk.[4] Stagnant, or *hypokinetic* hypoxia is caused by a decreased rate of blood flow to end organs and peripheral tissues. It can be caused by abnormal physiologic conditions, such as heart failure or inappropriate vasodilatation, and in those with normal physiology (such as aviators) sustaining high G-forces in certain aerobatic flight maneuvers.[5] Sudden incapacitation due to stagnant hypoxia can result from decreased cerebral perfusion. This is known as G-Induced Loss of Consciousness ("G-LOC") and has been well documented in the fighter pilot community since World War I. Histotoxic hypoxia is caused by a defect in the blood's ability to utilize the molecular oxygen, despite normal or even elevated P_{O_2}. Poisoning of the cytochrome oxidase enzyme by cyanide or hydrogen sulfide inhibits oxidative phosphorylation and compromises aerobic metabolism. As a result, oxygen utilization is diminished and oxidative metabolism slows to the point where it cannot meet metabolic demands. Death can occur rapidly.[6]

The final subtype of hypoxia is known as arterial, *anoxic* or *hypoxic* hypoxia, and is caused by lower than normal P_{O_2} in arterial blood, which has a normal oxygen carrying capacity. *Hypoxic* hypoxia can be also be caused by abnormal physiologic processes such as Adult Respiratory Distress Syndrome, exacerbation of asthma and emphysema, as well as normal physiology in an abnormal environment, such as exposure to low barometric pressure (P_B). This latter condition is sometimes termed "altitude hypoxia," and can result in various high-altitude illnesses, including acute mountain sickness, high-altitude pulmonary edema, high-altitude cerebral edema, incapacitation, and death.[7] In military medicine, altitude hypoxia is a risk to special operations forces operating in mountainous terrain, and aviators flying above 10,000 ft mean sea level (MSL). The symptoms can be acute and dramatic, but are more often insidious, resulting in incapacitation if not remedied in a timely fashion.

At sea level, the atmospheric pressure is 760 mm Hg. This total atmospheric pressure decreases logarithmically with increased altitude. At 18,000 ft MSL atmospheric pressure is one half that at sea level, and at 28,000 ft MSL it is one third as great. Atmospheric density also decreases with altitude. The P_{O_2} in the atmosphere also decreases as the altitude rises, but it remains at a constant 20.93% of the P_B.[8] The solubility of gas in water (as at the alveolar membrane) depends on its partial pressure at the air/water interface. Thus, the decreased P_{O_2} found in ambient air at altitude results in decreased arterial P_{O_2}. The interaction of these properties are described by the gas laws (Boyle's, Charles', Henry's, and Dalton's).

The alveolar oxygen pressure equation:

$$P_{aO_2} = (P_B - P_{H_2O})\, FIO_2 - (P_{CO_2}/R)$$

accounts for the ambient oxygen available for transmembrane exchange and the partial pressures of the physiologic derived gases: CO_2 and water vapor (H_2O). The P_{O_2} in alveolar air is determined by multiplying the fractional composition of oxygen in inspired air (FIO_2) by the P_B, after the opposing vapor pressure of water (P_{H_2O}, 47 mm Hg) has been subtracted. P_{CO_2}/R accounts for metabolically derived carbon dioxide where P_{CO_2} is arterial P_{CO_2} and R is the respiratory quotient (approximately 0.83). The P_{aO_2} directly affects the plasma oxygen tension and the degree of oxygen saturation of hemoglobin. Arterial P_{O_2} (P_{aO_2}) is usually within 10 to 15 mm Hg of the P_{aO_2}. To a limited degree, increasing the respiratory rate can compensate for increasing altitude; hyperventilation is an early symptom of hypoxia. But soon the P_{aO_2} will fall below 60% and hemoglobin will desaturate.[9]

Hypoxia as a Clinical Syndrome

Hypoxia is particularly dangerous in the aviation environment because of its insidious onset and because the first signs and symptoms affect the central nervous system. Factors that affect these symptoms are predictably those that affect available oxygen and tissue oxygen demand. Rate of ascent, altitude reached, time at altitude, physical workload, cabin pressurization, temperature, fatigue, individual fitness, alcohol, smoking, and certain medications all affect the onset of symptoms.[10] Symptom constellations vary from individual to individual, although they tend to remain predictably constant for each person, allowing for valuable feedback and obvious benefit to the aviator when producing those symptoms in a training environment.

The human eye is particularly sensitive to decreases in arterial oxygenation. Dark adaptation is affected as low as 5,000 ft, an important factor for night operations. At 10,000 ft MSL, visual sensitivity is reduced by 28% and performance of novel mental tasks slows. At this point, there is an increase in pulse and ventilation rate. For these reasons, AR 95-1, paragraph 8-7, requires Army aviators to use supplemental oxygen at and above this altitude.[11] If allowed to progress, the compromised judgement can result in the pilot's inability to recognize that anything is wrong. Task fixation, clouded memory, and impaired judgement are common initial signs. Even if the situation is correctly diagnosed, aviators may not have the mental agility to correctly find or correct the cause quickly enough. Some have speculated that this may have been what happened on the Payne Stewart flight.

Depending on the altitude, hypoxic effects can have a slow or rapid onset. The time of useful consciousness (TUC) refers to how long from exposure to unconsciousness an individual has. The TUC varies with individual fitness, experience, workload, and stress. In a rapid decompression (RD) situation above 33,000 ft MSL (such as might occur with a window blowout), the arterial/alveolar oxygen gradient actually favors oxygen moving from the blood (high concentration) to the atmosphere (low concentration). This can reduce the resting TUC of 2 minutes at that altitude to 1. Exercise, such as one would expect from a pilot wrestling the controls of a damaged aircraft, may also cut the resting TUC in half.[12]

The ultimate defense against hypoxic hypoxia is to recognize its signs and symptoms and reverse the process as quickly as possible. As has been stated, a pilot's ability to function in novel situations is one of the first faculties to be lost. One focus of hypoxia training in the Army is to train aviators to recognize these signs and symptoms in themselves so that they may detect them as early as possible. Symptoms and signs of hypoxia are listed in Tables 1 and 2 respectively.[13]

Flight Physiology Training and the USASAM

Today's U.S. military aircrew members and Special Operations personnel have incurred a global mission to conduct sustained operations in virtually every environmental extreme, to include high-altitude operations. The aircraft are technologically superior to those of yesteryear and most are capable of prolonged operations at or above 10,000 ft MSL. Now, more then ever, aviators are routinely exposed to the hazards of altitude ranging from the austere regions of South Eastern Europe (average elevation about 8,000 ft MSL) to South America (Andes Mountains, maximum elevation of 22,834 ft MSL).

- Air hunger or breathlessness
- Apprehension
- Fatigue
- Nausea
- Headache
- Dizziness
- Tingling
- Hot and cold flashes
- Numbness
- Blurred vision
- Tunnel vision
- Volatile mood
- Euphoria
- Denial of any symptoms

Table 1. Symptoms of Hypoxic Hypoxia in Aviators

- Increased rate and depth of breathing
- Cyanosis of lips and fingernail beds
- Confusion
- Poor judgement
- Loss of muscle coordination
- Unconsciousness

Table 2. Signs of Hypoxic Hypoxia in Aviators

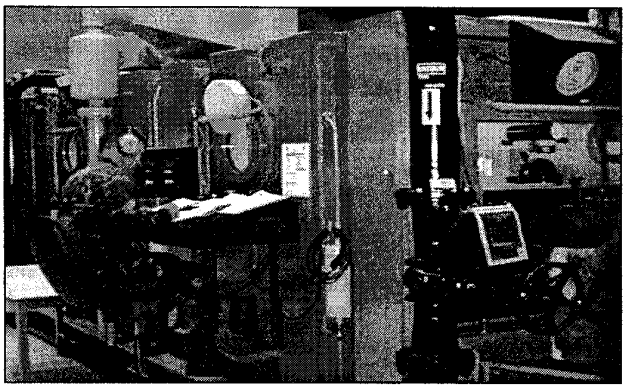
High-altitude illness has hampered the activities of military forces, aviators, and explorers for centuries. As recently as 1996, six climbers died in a single morning on Mount Everest.[14] We have repeatedly learned the lessons demonstrating the significance of hypoxia and some of the means of prevention, but how can leaders train their forces in altitude physiology at a minimal resource cost and without ever leaving the safety of the ground?

The Hyperbaric ("Altitude") Chamber

The Army's only Hyperbaric ("altitude") chamber is

located at the USASAM at Fort Rucker, AL. It was first installed at Fort Rucker in 1971 at Hanchey Army Heliport, but then later moved into its current location at the USASAM schoolhouse in 1985. Chamber training provides over 1,100 students annually with the opportunity to experience, first-hand, the physiologic effects of altitude. Such training validates the student's academic instruction, their learned in-flight hypoxia management techniques, and the regulations set forth AR 95-1, all focused to benefit safety of flight operations in the aviation profession.

The chamber is affectionately referred to, by the "Chamber Rats" (instructors), as the "Blue Beast" because of its immense size. Constructed of welded reinforced steel plates, the device weighs approximately 42,000 lbs and measures 8'x9'x24'. Specially designed windows allow for observation from the chamber operating crew to ensure safe operation. The chamber itself consists of two compartments, the main compartment and the inside lock. A door separates them. The main compartment is the primary training area, with stations to accommodate up to 16 students and two inside observer crewmembers. Each position is equipped with oxygen and intercom consoles. This is where the students are seated throughout the flight while participating in hypoxia and night vision demonstrations. The lock portion of the chamber is designed much the same as the main compartment, except there are only eight seats available. An additional inside observer occupies a position in the lock on operational flights. The lock compartment serves a dual purpose. Its primary purpose is to conduct RD training, but it is also useful to remove chamber students suffering from minor medical conditions such as ear/sinus blocks from the main chamber without disrupting the flight.



The USASAM Altitude Chamber, Fort Rucker 1999

Hypoxia Training Requirements

Hypoxia training (academic and hyperbaric chamber) is integrated into the aeromedical training requirements as required by AR 95-1, paragraph 4-14. Currently, all U.S. Army initial flight training students receive didactic aeromedical training, minus the hyperbaric chamber. Aeromedical training is also provided for specific aviators during refresher training courses. Refresher training is required once every 3 years for aviators flying in pressurized aircraft, aircraft that routinely exceed 10,000 ft MSL, and high altitude parachutists. There are several different types of chamber profiles. Each is specifically designed to effectively train for a specific mission. The current chamber flight profiles trained by USASAM are listed below in Table 3.

- Type II 35,000' USAF Original
- Type IV 25,000' USAF Refresher
- Type IV 25,000' USA Profile
- Type V 35,000' USAF/USA High Altitude Parachutist (HAP)
- Type VI 25,000' FAA
- Rapid Decompression

Table 3. Chamber Flight Profiles

Chamber Training and Flight Profiles

Chamber training is conducted in two venues, classroom instruction and the all important hyperbaric flight demonstration. During a typical training session, the students receive altitude academic refresher training, chamber orientation training, oxygen mask fitting, and then move into the chamber to experience hyperbaric flight. Safety is of the utmost concern during chamber operations. The chamber has an excellent safety record with only two confirmed decompression sickness (DCS) and 21,230 students trained since 1989, a rate of less than 1 in 10,000. No matter what the student load, the flight requires a training crew of nine "Chamber Rats," all highly skilled and credentialed in altitude physiology and related risk management IAW regulations and policies. A physiology training officer manages the flight and a flight surgeon is immediately available for medical advice.

Training inside the USASAM Altitude Chamber, Fort Rucker 1999

Training flights conducted inside the hyperbaric chamber are called "profiles." The purpose of conducting these profiles in the altitude chamber is to demonstrate to the aircrew members the limitations associated with hypoxia at altitude. The training objectives are listed below in Table 4.

- Demonstrate crewmember limitations associated with hypoxia at altitude
- Demonstrate the effects of trapped gas problems on the ear, sinuses, intestinal tract, and the procedures for their prevention
- Demonstrate the effects of hypoxia on night visual acuity
- Demonstrate the capabilities of oxygen equipment
- Demonstrate the effectiveness of denitrogenation in eliminating evolved gas problems

Table 4. Training Goals of Hyperbaric Flight Profiles.

The chamber profile begins when all students are masked and breathing 100% oxygen. This is the beginning of the 30-minute denitrogenation period. When 100% oxygen is breathed using a tightly fitted mask, an alveolar nitrogen pressure of nearly zero is established and a marked pressure differential between the alveoli and body tissues results. Nitrogen rapidly diffuses from the tissues into the blood, where it is transported to the lungs and is exhaled. Pre-breathing 100% oxygen for 30 minutes eliminates between 30% - 40% of dissolved nitrogen out of the body, greatly reducing the risk of DCS.[15] The DCS is a physiological effect produced by the evolvement of nitrogen or the expansion of trapped gases when the ambient pressure is decreased, as in ascent to altitude. In general, DCS does not occur until pressure altitudes above 18,000 ft MSL are reached. During this denitrogenation period, the chamber ambient pressure is decreased to the equivalent of 5,000 ft MSL then returns back to ground level for the ear and sinus check. This check is conducted to identify any students encountering pressure difficulty with their ears or sinuses. Since the greatest atmospheric pressure change occurs between sea level and 5,000 ft MSL, students successfully completing this check will most likely encounter no problems with the rest of the profile.

At the completion of the denitrogenation time, the chamber is depressurized to its maximum profile altitude. At this altitude, the first hypoxia demonstration is conducted. The students take turns removing their masks and begin conducting various tasks that challenge their coordination and decision-making skills. During this demonstration, the students are required to identify three symptoms of hypoxia prior to remasking.

Upon completion of the hypoxia demonstration, the chamber is pressurized to an equivalent altitude of 18,000 ft MSL for the night visual acuity demonstration. At 18,000 ft MSL, the chamber lights are dimmed to simulate night conditions. The students then unmask and receive a card with various colors and shapes. After 4 minutes in simulated night conditions, the students are asked to pick up the card and focus on obtaining as much information from it as possible. The still diminished Pao_2 in the chamber causes a state of *hypoxic* (altitude) hypoxia in the students. The color perception of the macula is greatly compromised by the relative oxygen deprivation and the students' abilities to read fine print or discern colors are significantly diminished. Only shades of gray are visible on the cards. While still focusing on the card in dimly lit conditions, they remask. As the 100% oxygen enters their bodies, the colors begin to come alive and objects become much clearer. This demonstrates the profound effect hypoxia has on night visual acuity. During the subsequent descent to ground level, the lecturer facilitates a discussion of the

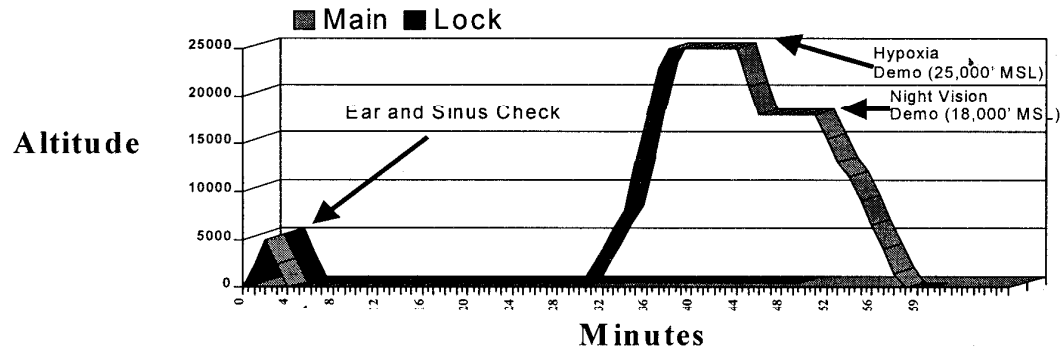


Fig 1. (Type IV 25, 000) Fixed-Wing Initial and Refresher Profile.

hypoxia symptoms experienced by the students during the profile. Figure 1 represent the U.S. Army Type IV Fixed-Wing Initial and Refresher Profile.

Upon successful completion of the profile, each student will be issued a chamber card (valid for 3 years) signifying that they are fully trained on how to manage the effects of altitude.

Rapid Decompression Training

Since many aircraft can fly at higher altitudes than aircrew members can physiologically tolerate, cabin pressurization was developed to ensure the safety and comfort of the crewmembers and passengers. However, a failure of the pressurization system results in a decompression, which produces significant physiological problems for crewmembers and passengers. This has been hypothesized as the cause of the Payne Stewart mishap, and was depicted by Hollywood in the movie "Airport 1975." In the cinema dramatization, a Boeing 747 collides with a smaller civilian aircraft and the inside cabin of the 747 fills with a rush of air and flying debris. Without supplemental oxygen, the aircrew and passengers would be incapacitated within 1½ -2½ minutes at an altitude of 25,000 ft MSL.

During RD training (see Figure 2), the sequence is conducted by using the main chamber as an accumulator. The unoccupied main chamber is depressurized to an equivalent altitude of 33,000 ft MSL. The lock, with students inside, is then depressurized to an equivalent altitude of 8,000 ft MSL, simulating the common pressure of an airliner at altitude. A switch is activated to create

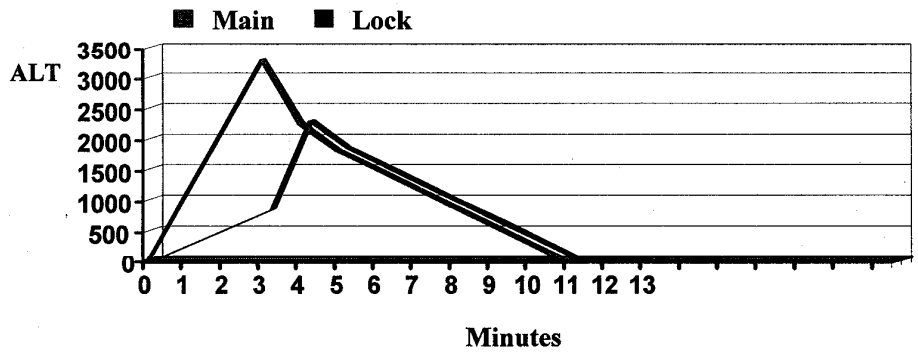


Fig 2. Rapid Decompression.

an opening between the main chamber and lock compartment. The result is an instantaneous decompression of the lock compartment from 8,000 ft MSL to 22,500 ft MSL, an experience the student will never forget! This training provides the aircrew members a safe and controlled first-hand look at the effects of a RD, while enhancing their confidence to take corrective actions.

Conclusion

Years of aviation medical research have shown that the principles of altitude physiology are based on the immutable laws of nature. Without supplemental oxygen, aircrews will become symptomatically hypoxic after 1 hour above 10,000 ft. Even though our understanding of hypoxia has progressed considerably from the time of balloonists Croce-Spinelli and Sivel, the aviation community has no alternative but to continue researching technological means to minimize the associated hazards, train in hypoxia countermeasures, and institute policies in risk management. The foreseeable future holds numerous challenges for those involved in aviation medicine, especially in the military. The military will continue to press the envelope of sustained operations above 10,000 ft MSL in support of worldwide national security contingency operations; USASAM will continue to train future aircrew members against the effects of hypoxia in the aviation environment.

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Coronary Artery Disease and In-Flight Incapacitation

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Introduction

Coronary artery disease (CAD) is a major public health problem, representing a significant cost in death and disability for the military services. It has a bearing on readiness, and must be viewed as a major risk factor from the standpoint of aviation safety.[1] The CAD is the single largest killer of American males and females, and the leading cause of permanent suspension from flying duties and nonaccidental premature death in aircrew members, even though it is less common among aviators than in the general population.[2-6]

The first signs and symptoms of CAD are often dramatic, incapacitating, or even fatal.[7] In 57% of men and 64% of women who died suddenly from CAD, there were no previous symptoms of the disease.[2] The major risk to flight safety is sudden in-flight incapacitation as a result of sudden death, altered consciousness, or incapacitating angina. Civil and military aviation researchers have ascribed numerous incidents of in-flight incapacitation to CAD; these will be reviewed later.

The CAD is present in many asymptomatic aircrew. Pettyjohn and McMeekin found that 87% of autopsied military pilots aged 20-34 had some evidence of CAD, with 17% being classed as moderate or severe.[8] This generally confirmed previous studies but refuted the claim that CAD incidence was decreasing in military pilots. From 1975-77, the prevalence of CAD among pilots autopsied after fatal general aviation accidents was 50.9%.[9] Severe CAD was found in 4.9% – around 11 cases per year in U.S. general aviation mishaps. The largest rise in prevalence was from age intervals 30-39 to 40-49, where an approximate three-fold increase was seen. From 1980-82, the rate of severe CAD had decreased (see figure).[10] The prevalence of severe CAD increased with age from 5.8 per 1000 for ages <40 years, to 73.9 for ages 50 years and above, higher than in the 75-77 study. Masters and Kohn showed that although the incidence of CAD is lower in young aircrew than the general (age-matched) U.S. population, the rate is almost identical by ages 55-59.[11]

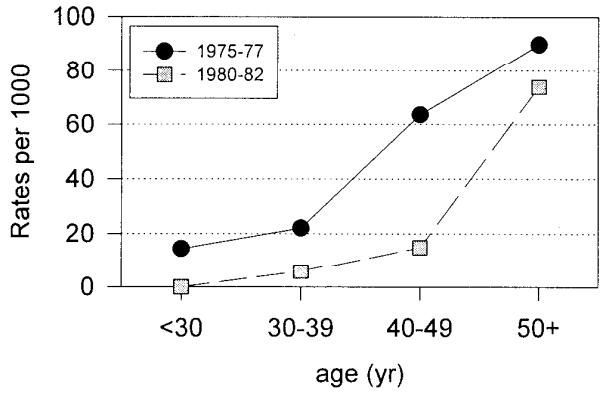

Fig. Age-specific rates of severe CAD among 1975-77 and 1980-82 fatal general aviation accident pilots.[10]

Those supporting cardiovascular screening programs for aircrew point out that "there is really no desirable aeromedical presentation for silent CAD."[12] The U.S. Air Force (USAF) and U.S. Army have taken the position that safety and ethical imperatives require the pursuit of asymptomatic CAD, and have instituted CAD screening programs. On the other hand, the Federal Aviation Administration (FAA) has not instituted specific cardiovascular screening, except to require a resting

electrocardiogram (EKG) for first class airline pilot certification and annual blood pressure measurement (for all classes of flight medical examination).

In-flight Incapacitation

The term "incapacitation" has various meanings, especially in the aeromedical context. Incapacitation can be partial or complete, acute or chronic, psychological or physiological, etc.[13] Evans and Rainford cite the International Civil Aviation Organization definition of incapacitation:[3]

> "any condition which affects the health of the license holder during the performance of his duties associated with the privileges of his license and renders him incapable of performing his duties."

The result of an in-flight incapacitating event depends on its specific characteristics. A slow-onset partially incapacitating event in a multi-crew aircraft would almost certainly have a lesser effect on flight safety than a near-instantaneous event in a single-pilot aircraft that renders the pilot unconscious. A sudden event during nap-of-the-earth helicopter operations using night vision goggles with a student at the other set of controls could have a catastrophic outcome.

Raboutet and Raboutet stated that four conditions must be met before an accident occurs due to in-flight incapacitation:[14] (1) the incapacity must affect the pilot at the controls; (2) must be sudden; (3) must be total (such as follows a severe infarction or an unpredictable epileptic attack); and (4) the incapacity must take place during the critical time of take-off or final approach. At those phases of flight, surprises may delay the reaction of the second pilot so that he is unable to take over control in the few seconds available.[14]

These conditions seem too restrictive, however. It is easy to conceive cockpit scenarios that only affect the copilot or are gradual in onset, but manage to disrupt cockpit order to the point that an accident could occur. Several catastrophic airline accidents have occurred because of inattention or errors in cruise flight.[15,16] Also, these criteria were not intended for the military helicopter environment, single pilot operations, or an instructor-student situation, but apply mainly to the multi-crew air transport fixed wing environment.

Incapacitation is particularly likely to have an adverse outcome in helicopters, where "obstacles in the landing areas are often present and takeover by the copilot is less certain."[13] Even in the peacetime rotary-wing flight environment, recovery from uncontrolled flight can be very difficult for other crewmembers, should a pilot become incapacitated.

CAD as an Accident Cause

Studies characterizing the variety and incidence of in-flight incapacitations have shown that these events are uncommon, and when they occur rarely result in aircraft accidents.[17] Other authors have targeted the cause of in-flight incapacitation that is most notorious and dramatic (and the subject of this report) - myocardial infarction (MI) or heart attack.

Attributing an aircraft accident to MI-related in-flight incapacitation is frequently speculative. Many un-witnessed general aviation mishaps have been judged secondary to CAD when the only evidence is narrowing of the coronary arteries on autopsy. However, even healthy males over 50 years of age who die for noncardiac reasons have about a 10% incidence of at least one coronary artery with a high-grade stenotic lesion.[18] It is certainly possible that a decades-old coronary artery stenosis, for example, can cause symptoms at just the wrong time resulting in a crashed airplane, but there should be other corroborating evidence.

Sometimes historical clues are present, such as witness statements describing pre-flight chest pain, etc, but these are not diagnostic. Witnessed in-flight deaths when supported by autopsy findings can be more convincing, but even then, the laboratory data usually needed to make the definitive diagnosis in a living patient (for example, enzyme and EKG changes) are still lacking. Jokl and McClellan reported a typical case:[19]

> "while flying at an altitude of 5,500 ft over Kentucky, (the 50-year-old pilot) complained of shortness of breath and asked that the windows of the plane be opened. A few minutes later, he

slumped over, dead. One of the passengers came to to the rescue and landed the plane...autopsy revealed complete blockage of three coronary arteries, and extensive infarctions of the apex and interventricular septum."

Davies described autopsy data that are needed to assess probability of causative MI: the presence of thrombi, presence and distribution of old and recent MI, and the number of coronary arterial segments with a pinpoint lumen (<1 mm) equivalent to at least 75% diameter stenosis.[18] Thrombus seen by naked-eye examination in a coronary artery provides good evidence of acute myocardial ischemia, even if the artery is not completely occluded.

Cardiac incapacitation is a controversial area in aeromedical circles, and the reports of CAD-related in-flight incapacitation reported below should be interpreted in the context of the many diagnostic uncertainties. Note that it is possible that some cases may be reported by more than one author as the accident data are analyzed and reanalyzed over time. Where this is obvious, the cases are counted only once in this article, but since most identifying data are removed for publication, this is not always possible.

Incapacitation in Military Aviation

There have been no published reviews of U.S. Army in-flight incapacitation statistics. For this article, we queried the U.S. Army Safety Center (USASC) Risk Management Information System for cases involving medical factors from 1992-98. There were no mishaps attributed to in-flight incapacitation during the study period, but there were 17 reports of in-flight incapacitation (Table 1). One case was found in which the pilot complained of chest pain and was dropped off at a local emergency room by his copilot, but no follow-up is available (USASC, unpublished data). A search of prior data failed to find any cases since 1972.[20] Voge reported no case of in-flight MI in her review of U.S. Navy mishaps.[21]

During the 10-year period 1962-71, Rayman found two confirmed and five suspected cases of in-flight MI in the USAF.[22] In both confirmed cases, the aircraft was landed safely by the afflicted pilot or his copilot and the diagnosis was made subsequently by EKG and serial enzyme changes.[22] McCormick and Lyons reviewed the 1978-87 USAF accident history for cases of in-flight incapacitation and found 5 of 23 in-flight incapacitating events were of cardiac origin.[23] Three of these were MI. The relatively low cardiac in-flight event rate (0.03 per million flying hours) was attributed to a young flying population compared to the civilian sector. Adaval et al found one case in the Indian Air Force between 1962-78 that could be attributed to sudden cardiac death.[24] They also reported that helicopter pilots in their autopsy series had lower rates of CAD than other military pilots.

Condition	# incidents	% of total
Nausea/vomiting	5	29.5
Ear pain	2	11.7
Sinus pain	2	11.7
Hypoxia (fixed wing)	2	11.7
Knee pain	1	5.9
"Illness"	1	5.9
Chest pain	1	5.9
Stomach cramps	1	5.9
Syncope	1	5.9
Corneal abrasion	1	5.9
Total	17	100

Table 1. In-Flight Incapacitation Cases in the U.S. Army from 1992-1998

Incapacitation in Civil Aviation

In-flight cardiac incapacitation occurred about 6 times per year in U.S. general aviation during the 1960s.[25] During 1974-75 alone, National Transportation Safety Board (NTSB) reports revealed 13 U.S. general aviation pilots died of cardiovascular incapacitation in-flight.[26] Eighteen deaths resulted, and in nine cases, the pilots were flying alone. Five cases had fresh occlusions seen on autopsy, and an additional four showed evidence of old MI. Mohler and Booze noted that this comprised only 0.93% of the total fatal general aviation accidents (1,404) during that period.[26]

Booze reported that 36 general aviation accidents from 1975 to 1985 were caused by cardiac events (4 per year).[27] He also noted that older age groups were over-represented in the annual cardiovascular incapacitations in aviation.

To arrive at a general idea of the number of fatal cases occurring in U.S. general aviation since 1985, we queried the on-line NTSB aviation accident/incident database and the FAA Incident Data System for cases including the word "heart" (**http://nasdac.faa.gov/asp/fw_ntsb.asp**). The NTSB accident/incident database is the official repository of aviation accident data and causal factors. The FAA Incident Data System contains a much more extensive collection of incidents. We found 35 cases that appeared to be attributed to CAD from 1986 to 1999-approximately 3.2 events per year. These should be regarded as rough estimates, as these search criteria were incomplete and very little corroborating information was given.

There have been two major incapacitation surveys of professional airline pilots. The first was reported by Buley in 1969.[28] Of 25,000 questionnaires distributed, 5000 were returned (20% response rate). Approximately 27% of respondents stated that they had been incapacitated in-flight at least once. Many of the gastrointestinal symptoms were attributed to food poisoning. There were no cardiac symptoms or events reported. Overall, 45% of respondents said the event had affected flight safety.

The second survey was conducted by James and Green in 1991, and also studied members of the International Federation of Air Line Pilots Association.[29] In decreasing numbers, the U.S., United Kingdom, Canada, Netherlands, Switzerland, and other countries were represented in the dataset. Although the number of surveys distributed was not known, 4,325 aircrew responded (Table 2). Incapacitation had been experienced at least once by 29% of respondents. The authors were impressed with the similarity between the 1967 and 1991 studies, and concluded that the etiology of in-flight incapacitation had changed very little in the 21-year interim period.

While these two surveys are valuable indicators of the nature of incapacitating events, they do not provide actual incidence rates. Further, since only active members of the pilot organizations are surveyed, there is a bias toward mild causes of incapacitation (those that did not result in an accident and did not permanently disqualify the pilot).

Rank	Condition	Reported incidents	
		#	%
1	Uncontrolled bowel action	334	15.2
2	Nausea or desire to vomit	327	14.9
3	Vomiting	317	14.4
4	Severe indigestion/stomach cramp	306	13.9
5	Earache / blocked ear	186	8.5
6	Faintness, general weakness	124	5.6
7	Headache, including migraine	109	4.9
8	Vertigo, disorientation	63	2.9
9	Back, loin, or kidney pain	60	2.7
10	Dizziness, double vision	41	1.9
10	Nosebleed	41	1.9
12	Toothache	36	1.6
13	Eye injury	16	0.73
14	Chest pain	15	0.68
14	Coughing attack	15	0.68
14	Sneezing attack	15	0.68
17	Leg or foot cramps	9	0.41

Table 2. Reported In-Flight Incapacitating Events in Airline Pilots[29]

Raboutet and Raboutet reviewed the records of French airmen declared "unfit" (permanently grounded) from 1948 to 1972.[14] The source of these data was the archives of the Medical Council for Civil Aviation in France. They found 17 cases of in-flight incapacitation, of which two constituted a "total" incapacity. There were no accidents or deaths related to the incapacitating events, but 52.9% were of cardiac etiology (Table 3). The authors cautioned that they were unable to count minor causes of temporary incapacity, as the database contained only aircrew who had been permanently grounded.

Rank	Condition	Reported incidents	
		#	%
1	Angina	5	29.4
2	Myocardial infarction	4	23.5
3	Epileptic seizure	2	11.7
4	Cerebrovascular accident	1	5.9
5	Hypoxia with secondary MI	1	5.9
6	Loss of vision in one eye	1	5.9
7	Pulmonary embolism	1	5.9
8	Cerebral vascular malformation	1	5.9
9	Gastrointestinal bleeding	1	5.9

Table 3. Causes of In-Flight Incapacitation in French Civilian Pilots from1948-1972[14]

A second study of French civil aviation was reported by Martin-Saint-Laurent.[30] These authors reviewed the records of Air France from 1968-88 for cases of incapacitation. They found 10 cases reported in 21,600,000 flying hours, for a rate of 0.44 events per 1 million flying hours. The lack of CAD cases was attributed to "careful medical supervision in the domain of coronary insufficiency."

Cullen et al recently described 1,000 fatal aircraft accidents investigated by the Royal Air Force Dept of Aviation Pathology.[31] This organization has responsibility for investigating civil and military aviation mishaps, and so the dataset is mixed. Pre-existing disease was found in 13.7%; CAD was the most common finding (54 cases). Pre-existing disease was the cause or contributed to the cause in 34 cases (22 related to cardiac pathology, seven to central nervous system etiologies). They noted lower levels of disease in commercial and military pilots, while the less stringent private pilot medical standard produced a rate of 15.7%, and glider pilots (who have no medical examination requirement) had a rate of 30.1%. This trend was attributed to regular aircrew medical examinations and higher standards in the military/commercial groups. Note that this analysis would have missed less severe incapacitation cases, as only fatalities were included.

The FAA Civil Aeromedical Institute (CAMI), in Oklahoma City, has constructed a database of in-flight incapacitation events in U.S. civil aviation. As of 1 Dec 99, the database contained detailed medical and incident information on 147 accidents and incidents in which aircrew incapacitation was strongly suspected. All 147 cases were reviewed for this article, and the cardiac cases were subjected to more detailed analysis. This database provided a great deal of medical information, as each case is individually researched by CAMI investigators. Of the 147 cases in the database, 19 were found in which an incident/accident was caused by CAD. Six incapacitations occurred in airliner-type aircraft, but none resulted in an accident.

Finally, Shkrum et al reviewed civil aviation crashes occurring in Ontario, Canada, between 1985-89, and found two of the 47 crashes involving pilot incapacitation from CAD.[32]

Discussion

As described above, there have been no confirmed instances of in-flight incapacitation of a U.S. Army aviator. This can be taken as evidence of a successful CAD screening program, but must also be considered in terms of exposure (incidence rate). Earlier, we presented an analysis of the FAA/NTSB on-line accident database from 1986-97, in which we found 35 cases of CAD-related incapacitation occurring in 310,670,000 general aviation flying hours (**http://www.ntsb.gov/aviation/Table10.htm**). Expressed as a rate, there were 0.11 CAD-related mishaps per million flying hours. If the same rate of CAD-related mishaps prevailed in the U.S. Army, we would only expect 1.02 cases during the period 1992-99. As discussed previously, there have been no confirmed U.S. Army aviation mishaps due to CAD, and only one documented case of in-flight chest pain (of unknown etiology) in the last 28 years (although these are certainly underestimates). It should be emphasized that these calculations are based on the U.S. general aviation CAD-related mishap rate (FAA third class medical examinations).

Conclusions

In-flight incapacitation events are uncommon in aviation, but do occur. Such an event has never caused a U.S. Army helicopter accident. However, in-flight sudden cardiac death is a well-known phenomenon in general aviation, and usually results in a fatal accident.

Short of ceasing flight operations entirely, there is no way to completely eliminate airplane crashes; short of grounding all aviators, there is no way to completely prevent all in-flight incapacitation events. The continued application of risk management principles and aero-medical standards by Army flight surgeons will ensure that in-flight incapacitation events remain rare in Army aviation.

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Behavioral Health Applications in Army Aviation

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Introduction

Aviation psychology has been described as "the optimization of the relation between aviation machines in the air and on the ground and the people who operate them."[1] Its theory and practice also extend beyond the cockpit to include air traffic controllers, maintenance crew, regulatory authorities, and other support personnel and institutions that impact on aviation operations. Aviation psychology in the U.S. Army is directed at supporting the Army aviation combat mission by enhancing aircrew performance, monitoring and controlling aviation and combat stress, educating aviation personnel in the management of stress/fatigue, and providing psychological evaluation and treatment. These objectives are accomplished through a variety of educational, clinical, and consultation activities conducted by doctoral level clinical and counseling psychologists world-wide throughout the Army. This article reviews current Army aviation psychology programs and discusses future directions for this expanding subspecialty of Army clinical psychology.

Flight Stress and Fatigue

Flight operations and aviation combat operations involve unique physical, environmental, social, and psychological stressors that must be identified and controlled to insure flight safety and mission completion.[2] As noted by Bowles, military aircrews operate at "the leading edge of human capability" and are continuously challenged in an environment characterized by advanced technology, complex human and mechanical systems, and the need to accomplish tasks and operate under conditions of high stress and fatigue.[3] Tough, realistic training in combat flight operations is perhaps the most effective strategy for controlling the effects of aviation stress and fatigue.[4] Overlearning flight procedures and maneuvers and encountering simulated battle conditions in a controlled training environment provide invaluable experience that prepares the aircrew member to function adequately in an actual combat environment.

Beyond tough, realistic aviation training, Army psychologists recognize that aircrew must also *understand* the threat that unidentified, uncontrolled stress poses to mission completion and flight safety and *implement* efficient and appropriate stress coping strategies in their flight operations and personal lives. Effective communication, assertiveness, problem solving, time management, relaxation, physical fitness, and good sleep hygiene are all essential skills for Army aircrew. To ensure aviators acquire and practice good stress coping skills, Army psychology has devised a comprehensive psychoeducational program, providing primary prevention education on stress and fatigue to student aviators during Initial Entry Rotary Wing Training at the U.S. Army Aviation School (as part of the basic aeromedical training provided at the U.S. Army School of Aviation Medicine [USASAM]). As they advance in their careers, aviators receive stress and fatigue refresher training at the unit level and follow-up training at USASAM. Recently, distance learning blocks of instruction on stress and fatigue have also been made available on the USASAM Web Site Aeromedical Psychology Page at **http://usasam.amedd.army.mil**.

Army psychologists also strive to maintain a regular presence in the aviation community and act as consultants and subject matter experts in stress and fatigue for aviation commanders, safety officers, flight surgeons, and aircrew in general. Part of this presence involves accruing actual flight time. This increases psychologists' accessibility, diagnostic acumen, and the quality of their services, as it

augments their understanding of the aviation work environment and its associated stressors.

Aeromedical Psychology Training Course (APTC) (6HF27)

In order to ensure the quality and standardization of psychological support to the aviation community, Army clinical and counseling psychologists receive 3 weeks of specialized training at the APTC, a postgraduate numbered short course sponsored by the Office of The Surgeon General and the USASAM. The APTC was first implemented in 1992 and has graduated over 100 psychologists to date. The present goal is for all clinical and counseling psychologists coming onto active duty from the Army Clinical Psychology Internship Program to complete the APTC prior to beginning their first assignment.

The APTC focuses on aviation stress and fatigue, psychological assessment and treatment of aircrew, the medical waiver and review process, and safety psychology. Specialists in clinical aviation psychology and psychiatry present small group workshops and seminars to review aviator personality profiles and assessment of fitness for flying. A foundation is also provided in basic aviation medicine and related topics of aerodynamics, noise, toxic hazards, spatial disorientation, and night vision. Through actual time in rotary-wing aircraft (UH-1H, UH-60, and CH-47) and time in the synthetic flight simulator, psychologists learn to appreciate the cognitive, physical, and behavioral demands placed on Army aircrew. Extensive use of guest faculty from the Army, Navy, and Air Force broadens the scope of the training program and incorporates a wealth of practical experience from pioneers in clinical aviation psychology and psychiatry.

The APTC is open to licensed, doctoral level clinical and counseling psychologists of the Department of Defense. It is the only course among the U.S. uniformed services to concentrate on aviation psychology practice, as opposed to research psychology. Although a small number of nonpsychology mental health professionals (psychiatry and social work) have participated in the course, it is primarily focused on the unique perspective that professional psychology brings to aviation medicine and flight safety. There are no courses in the U.S. military at this time devoted specifically to the application of psychiatry or social work to aviation medicine.

Mental Health Specialist (91X) Training via Distance Learning

Recently, USASAM began offering a 1 hour block of instruction on Army aviation psychology via telemedicine to the 91X Mental Health Specialist Course held at the AMEDDC&S at Fort Sam Houston, TX. The goal of this training is to equip 91X's with the knowledge needed to effectively assist aeromedically trained psychologists in providing support to the aviation community. Topics of instruction include aeromedical policy and mental health fitness standards, the limits of confidentiality of mental health information in aviation medicine, and aviation stress/fatigue.

The first 91X distance learning class was conducted in Mar 00 from Fort Rucker, AL, with approximately 60 specialists trained. Senior 91X's in the field will receive the same block of instruction in Aug 00 via telemedicine as part of an annual short course sponsored by the AMEDDC&S. It is anticipated that approximately 500 personnel will participate in the August training.

Psychology Training in the U.S. Army Flight Surgeon Primary Course

In addition to training psychologists and mental health specialists in aviation psychology, a significant effort has been made to educate Army flight surgeons in the use of psychologists as expert consultants. Training in aeromedical mental health policy, the capabilities and scope of practice of aeromedically trained psychologists, and combat stress in aviation are integrated into the 6-week-long Flight Surgeon Primary Course held at USASAM. The instruction serves not only as didactic training but also as an opportunity for the USASAM clinical psychologist to begin a consulting relationship with the flight surgeon students that will continue after the students' graduation. Flight surgeons are strongly encouraged to make use of USASAM psychology consultation support as well as support from aeromedically trained psychologists in their area of operations. The USASAM clinical psychologist is the school's subject

matter expert in stress/fatigue and provides consultation to Army flight surgeons and mental health professionals world-wide, coordinating resources in Army aviation psychology and assisting flight surgeons in locating and making optimal use of aviation psychology resources in their geographical area.

Safety Psychology and Accident Investigations

Aviation safety culture and behavior are an important focus of both the civilian and military aviation psychology literature.[3,5,6] As experts in the analysis and modification of human behavior, clinical and counseling psychologists can play an important role in promoting aviation safety and examining the role of human factors in aviation mishaps.[7] Safety as an area of primary prevention in aviation psychology is a developing field in the U.S. Army, with ample opportunities for creative applications of theory, research, and practice.

Within the past 5 years, a growing number of clinical and counseling psychologists have become involved in the U.S. Army Safety Center's accident investigation process. Psychologists serve as members of the accident investigation board, assisting the board's flight surgeon in the analysis and classification of human factors that contribute to aviation mishaps. Aeromedically trained psychologists have also been active in providing consultation and education to aviation safety officers and other personnel in the effects of psychosocial factors on aviation safety.

In addition to investigating aviation accidents, psychologists also play an important role in providing post-trauma support to individuals and families in the form of critical incident stress debriefings (CISD).[3,8] These debriefings are focused group discussions by trauma survivors about the thoughts, feelings, and behaviors involved in the accident experience. The groups are led by a psychologist, but are not considered psychotherapy. According to the founders of the CISD technique, CISD is a structured group process integrating crisis intervention strategies with education in the effects and management of traumatic stress.[8] It is an opportunity for survivors to cognitively and emotionally process the trauma and reinforce coping strategies. It is also an opportunity for the psychologist to identify personnel who are experiencing overwhelming stress and may benefit from psychological evaluation and support.

International Exchange Initiatives

Recently, USASAM has initiated a series of international subject matter expert exchanges in the area of aviation psychology. The first of these involved the participation of the USASAM psychologist, CPT (Dr) John Leso, in a 1 week conference on human behavior sponsored by the Colombian Armed Forces. Topics of exchange included psychological evaluation, profiling, education, and treatment in military aviation. This mission was a joint effort with social worker CPT Steve Lewis of the Mental Health Specialist Branch, Department of Preventive Health Services, Academy of Health Sciences. One of the outcomes of the conference was the discovery of a shared interest on the part of the Colombian and U.S. aviation psychologists in the neuropsychological screening and profiling of Army aviators. Further exchange of information in this area is being discussed and may eventually lead to cooperative investigation of the cross-cultural validity of neuropsychological testing in military aviation.

Future Directions

Army aviation psychology is an exciting, expanding operational subspecialty of Army clinical psychology. As experts in human behavior and cognition, psychologists are uniquely equipped to support and enhance aircrew readiness and performance. To date, psychology programs in aviation have focused mainly on education, evaluation, and treatment, with very little emphasis on psychological profiling or screening. Nevertheless, psychology has much to offer in this area, as the technology of personality and neuropsychological testing has reached high levels of efficacy in describing and predicting human performance.

Development of a neuropsychological testing protocol for initial entry rotary-wing aviators would assist to screen out learning disorders and other neuropsychological problems that may interfere with training and ultimately lead to training failure. Presently, only a basic assessment of mental status is conducted during the flying duty medical examination of student pilots. This level of assessment is sometimes not adequate

to capture more subtle functional deficits in attention, visuo-spatial processing, and cognitive processing speed. An initial neuropsychological screening protocol would have the added value of providing baseline comparison data for use by flight surgeons in making waiver decisions when aircrew suffer head trauma or other neurologic problems.

Another important direction for Army aviation psychology involves the integration of nonpsychology mental health providers into aviation medicine practice. Although social work and psychiatry have special, unique contributions to make to the health and performance of Army aircrew and their families, very little has been accomplished so far to ensure these personnel are adequately trained in aeromedical policy and procedures. The most effective behavioral health support for Army aviation will involve a team model, coordinating the contributions of psychology, social work, and psychiatry. Detailed discussion of models and training for such cooperation is an important goal for the future.

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U.S. Army Residency in Aerospace Medicine

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Introduction

The Army Medical Department (AMEDD) exists to protect the health and maximize the performance of our most precious asset: the soldier. The cost of training the men and women who fly, coupled with the multi-million dollar aircraft they operate, require that we maximize their physical and mental performance, while expediting the return to the cockpit of those who become sick or injured. The resource intensity of aviation required the development of a field dedicated to husbanding those resources.

Aviation medicine was developed out of necessity to prevent loss of life and equipment in the aviation environment. During the first year of World War I, only 2% of British aviator casualties were due to hostile fire, 8% from aircraft materiel failures, and 90% from human factors (physical defects, physiologic limitations, carelessness, or neglect). Early researchers soon realized that as many as two-thirds of the losses attributed to human factors were secondary to inadequate aeromedical selection criteria. The British military established a special service for the selection, care, and disposition of their aviators and the results were dramatic. By the end of the third year of the war, deaths attributed to a pilot's medical condition or physical defect were down to only 12%.[1]

The analysis of illness and injury in various work groups contributes to a better understanding of occupational illness. Population-based medicine has provided a more complete understanding of human physiologic responses to hazardous conditions such as those encountered in the aviation, space, and undersea environments. The application of population-based medicine to the specific population at risk, the aviator, is the domain of aerospace medicine physicians who: assess risk; monitor performance; refine medical standards and develop the requisite aeromedical programs and equipment to enhance the safety and performance of aviators and astronauts.

Aerospace medicine is one of the 24 specialties recognized by the American Board of Medical Specialties, falling under the auspices of the American Board of Preventive Medicine (ABPM), along with Occupational Medicine and General Preventive Medicine. While its American roots are in the AMEDD, the Army does not offer a residency in aerospace medicine. The Army uses the residencies of its sister services to train its aeromedical specialists. In 1998, the Army began to send the majority of its residents to the U.S. Navy program at the Naval Operational Medicine Institute (NOMI) in Pensacola, FL. There were several reasons for this shift. NOMI's proximity to the home of Army Aviation at Fort Rucker, AL, the program's strong clinical focus, flexibility in program design, rotary-wing flight training, and deployment medicine orientation weighed heavily in the decision. This article provides an overview of the U.S. Naval Residency in Aerospace Medicine. It also describes how the program prepares career flight surgeons to meet the exciting challenges and opportunities of this most interesting medical career field.

Residency in Aerospace Medicine

The U.S. Naval Residency in Aerospace Medicine is an American College of Graduate Medical Education (ACGME) approved program of 3 or 4 years duration depending on the qualifications of the entering resident. It includes a primary care internship, a Master of Public Health (MPH) degree, and 1 or 2 years of aerospace

medicine specific studies. This allows the resident to combine clinical and population-based medicine in order to comprehensively serve a defined community: military aviation. The success of the residency can be measured in part by the excellent performance of residents on the Aerospace Medicine Certification exam sponsored by the ABPM.

Successful completion of the aerospace medicine residency is a pre-requisite for assignment as the Senior Medical Officer (SMO) of a nuclear aircraft carrier battle group. Being a SMO is the toughest and most rewarding operational assignment for a Navy flight surgeon. The SMO is responsible for the health and medical readiness of over 7,000 sailors and marines deployed with the carrier battle group. In addition to practicing clinical medicine, the SMO is directly responsible for the delivery of the broadest spectrum of preventive and occupational medicine – from travel medicine to radiation safety. The clinical, wellness, and leadership skills that so effectively prepare the SMO for leadership in the nuclear carrier battle group also uniquely prepare the Army aerospace medicine residency graduate for success as an Aviation Brigade or Division Surgeon.

Medical Corps officers interested in an aerospace medicine career should apply through the same Graduate Medicine Education (GME) Selection Board process as for any other Army residency. The application form and other useful information are available on the AMEDD Directorate of Medical Education Web Site (see Table 1).

The Naval Operational Medicine Institute

- **www.nomi.navy.mil**

AMEDD Directorate of Medical Education

- **www.army.medicine.army.mil/medcom/meded/**

Association of Schools of Public Health

- **www.asph.org**

Society of U.S. Army Flight Surgeons

- **www.army-aviation-med.org**

Society of U.S. Naval Flight Surgeons

- **www.aerospacemed.org**

Table 1. Internet Information on the Aerospace Medicine Residency Program and Application Instructions

Aerospace Medicine Specialty Competencies and Board Eligibility

The American College of Preventive Medicine (ACPM) has been on the cutting edge of developing an outcome-oriented competency-based approach to resident training since 1989. In June 1998, the ACPM revised the list of core competencies for all preventive medicine residents. These competencies were organized in the basic skill categories of biostatistics/epidemiology, management and administration, clinical preventive medicine, occupational and environmental health, and medical management competencies and performance indicators.[2]

In 1998, the U.S. aerospace medicine residency directors developed an additional set of aerospace medicine competencies that augment the ACPM core competencies (see Table 2). The ACPM core competencies and the aerospace medicine competencies are not meant to be all-inclusive, but give a prospective resident a broad overview of the goals and objectives of the residency and the specialty of aerospace medicine. Residents in the Naval aerospace medicine program are eligible to sit for the ABPM certification exam upon successful completion of an accredited internship year (PGY-1), the MPH degree (PGY-2), and the practicum year (PGY-3).

PGY-1 Year

The PGY-1 focuses on amplifying the physician's clinical skills. Aside from providing population-based healthcare recommendations, flight surgeons must also provide primary care to a sizable active duty population (and family members in many locations). Aeromedical primary care is often delivered in austere deployed conditions, so a broad clinical foundation is important. Additionally, aviation medicine requires a keen understanding of how man relates to his environment. Because of these unique requirements, the prospective Resident in Aerospace Medicine (RAM) is encouraged to complete PGY-1 rotations in ophthalmology, otolaryngology, psychiatry, obstetrics-gynecology, emergency medicine, and primary care.

Currently there are no aerospace medicine internships; however, transitional, internal medicine,

emergency medicine, or family practice internships provide the appropriate clinical experience. In addition, in the summer of 2000, Dwight David Eisenhower Army Medical Center will begin offering an aerospace medicine specific transitional internship position that incorporates aviation medicine rotations at the U.S. Army Aeromedical Center, Fort Rucker, during the year.

receives a well-rounded graduate education based upon the five core areas of study in public health: health services administration, biostatistics, epidemiology, behavioral sciences/health education, and environmental health sciences. The programs at Johns Hopkins, Harvard, and the University of Texas at Houston's San Antonio campus have been historical favorites. An Army GME

- Manage the health status of individuals working in all aspects of the aerospace environment.
  - Develop, apply, or grant exceptions to aerospace medical standards.
  - Detect, investigate, and recommend remediation for health hazards to aerospace workers.
  - Facilitate early diagnosis of conditions resulting from, or impacting performance in the aerospace environment.
- Promote aerospace passenger health, safety, and comfort.
  - Serve as passenger advocates to regulatory bodies, carriers, and other concerned agencies.
  - Educate passengers and their physicians regarding the stresses of aerospace travel and associated aeromedical issues.
- Facilitate optimum care of patients transported in the aerospace environment.
  - Identify appropriate candidates for aeromedical transportation.
  - Provide guidance on aeromedical transport
- Applying human factors/ergonomic concepts in the aerospace environment.
  - Advise in the design of bearer and space equipment and vehicles.
  - Enhance performance.
  - Facilitate crew resource management.
- Promote aerospace operational safety and mishap prevention.
  - Conduct medical aspects of mishap investigation.
  - Provide aerospace safety information.
- Interpret, integrate, and/or perform aeromedical research.

Table 2. Aerospace Medicine Resident Competencies[3]

PGY-2 Year

The RAM enters the PGY-2 year either from internship or, more often, after a successful tour as a flight surgeon. The PGY-2 year consists of earning an MPH degree. This is an important year because the population-based analytical tools (biostatistics, epidemiology, etc) that will later be applied to the aviation population are acquired here. An excellent starting point for determining which MPH program to choose is the Association of Schools of Public Health's Web Site listed in Table 1. Any of the 29 accredited schools of public health will assure the resident requirement is that the MPH must be completed prior to the start of the PGY-3 year.

The MPH student may concentrate in any area of personal interest as long as the year fulfills all of the basic ACGME requirements for aerospace medicine. Sample areas of concentration include: general preventive medicine, occupational medicine, healthcare administration, international health, tropical medicine, and nutrition. Certain areas of concentration are more closely aligned with aerospace medicine than others. Recently, the University of Texas Medical Branch at Galveston

introduced a new masters program designed specifically for aerospace medicine residents. The Uniformed Services University for the Health Sciences also offers a highly regarded MPH program with a general military focus.

During the PGY-2 year, the resident will receive the same pay and allowances of other military residents with comparable rank and time in service. In addition, residents who are flight surgeons and geographically close to a military air base may be able to continue their flight status and continue to draw Aviation Career Incentive Pay (flight pay).

PGY-3 and PGY-4 Years

The next phase consists of 1 or 2 years at the NOMI in Pensacola, FL. The PGY-3 year, known as the aerospace medicine PGY-3 year, emphasizes the aerospace medicine application of clinical and population management tools in the aeromedical settings. During this year, the resident will hone skills in applying preventive medicine principles toward such aviation issues as medical standards and certification, crew health issues, biomedical protective equipment, radiation safety, and aviation related ophthalmology, psychiatry, and internal medicine topics.

Clinical rotations are done locally at the Pensacola Naval Regional Medical Center and the flight medicine clinic at Naval Air Station - Whiting Field. Experiences not available locally are provided through away rotations. These include attending professional conferences such as Aerospace Medicine Association (AsMA) scientific meeting, the USAF Global Medicine course, the Undersea Medicine Course, the Naval Aviation Safety Officer Course, and the Federal Aviation Administration (FAA) Aeromedical Examiner course. The weeklong rotation covering space medicine at the Johnson Manned Space Flight Center, Houston, is always a favorite required rotation. An overview of the required PGY-3 rotations is listed in Table 3.

During PGY-3, the resident teaches students in the primary flight surgeon course, provides on-call coverage for hyperbaric medicine, and completes assigned academic requirements relevant to the practice of aerospace medicine. Traditional didactic coursework is also part of the curriculum. Army residents who have previously completed a primary care residency are graduated from the program at the end of this year and are eligible to sit for the qualifying board exam.

- Accident Investigation
- Aerospace Ophthalmology
- Aerospace Psychiatry
- Aerospace Internal Medicine
- Aerospace Otolaryngology
- Aviation Safety
- Physical Examinations and Qualifications
- Clinical Aerospace Medicine – Outpatient
- Instructor Training
- Hyperbaric Medicine
- Conferences: AsMA, ACPM, Aeromedical Problems Courses
- Aviation Preflight Indoctrination and Flight Training
- Travel Medicine or Global Medicine

Table 3. Required Training for PGY-3

The advanced clinical year (PGY-4) prepares the resident for the special needs of military operational medicine. The program for this year varies from resident to resident and is developed with the physician's particular needs and interests in mind. The NOMI has established inter-institutional agreements with many civilian and military organizations to insure the broadest possible training opportunities are available. Electives include radiation health, travel medicine, critical care medicine, and others. Some institutions include:

- Baptist Hospital of Pensacola (emergency medicine)
- Naval Aerospace Medical Research Laboratory (various research topics)
- U.S. Army Institute of Surgical Research (burn unit), San Antonio, TX
- MLK – Charles Drew Medical Center (shock – trauma unit), Los Angeles, CA
- U.S. Army Aeromedical Center (various clinical rotations), Fort Rucker, AL
- Escambia County Public Health Department (public health rotations)

Flight Training

The benefits of actual flying experience to

practitioners of aviation medicine have been understood since The Great War. "Actual flying is of great value as an additional aid in rendering the flight surgeon better able to realize and cope with the peculiar conditions and ills incidental to aviation."[4] As it was in the early days of the specialty, it is still crucial for the aviation medicine specialist to have a working knowledge of the patient population and workplace hazards. Without a first-hand understanding of the fundamental concepts of aerodynamics, aircraft systems, emergency procedures, psychological stresses, and unusual physiologic phenomena (such as vestibular and visual illusions, G-induced loss of consciousness, and barotrauma) the aerospace medicine specialist would be ill equipped to make prudent aeromedical recommendations.

The NOMI realizes the importance of the flight experience. A basic flight-training syllabus is included which exposes the resident to nearly 20 hours of day/night flights. The flight training encompasses all aspects of fixed-wing and rotary-wing aviation through the use of the TH-67 helicopter and T-34 Turbo Mentor airplane. Ground school incorporates an optimal mix of classroom and simulator periods and prepares the student-pilot for taking control of the aircraft. The residents participate in the same classroom instruction and training flights as the student naval aviators.

After Military Service

The practice of aviation medicine in the Army is the most diverse of the preventive medicine specialties. The same is true after one leaves the service. The ABPM has certified 1,241 specialists in this field since the specialty was established in 1953. Aerospace medicine residency trained physicians have myriad career opportunities in clinical, administrative, academic, preventive, and occupational medicine.

Aviation medicine specialists are well qualified to enter the field of policy and medical standards development. Government and industry both require this service. Since the repeal of "double dipper rules," government agencies such as the FAA and National Aeronautics and Space Administration hire many retired military flight surgeons. Additionally, many large governmental contractors are particularly interested in former military physicians with strong operational backgrounds to help them interface with the governmental agencies that they support. These include software developers, equipment suppliers, systems developers, and education developers in particular.

Probably the largest number of aerospace medicine positions is found in the clinical practice of the specialty. Aircrews of all types require regular flight physicals. But the practice is much broader than simply performing flight physicals. As in the Army, the physical provides the cornerstone of a comprehensive employee health program. Three of the major airlines have their own aviation medicine departments. Airlines without aviation medicine departments contract with firms to handle this aspect of their employee benefits program. The large international aircraft manufacturers, like Boeing and McDonald-Douglas, practically have their own air force and require extensive aeromedical support. Many occupational medicine group practices list aerospace medicine as a service.

Many specialists discover a love of teaching during their military career. There is opportunity to continue this after leaving the service as well. There are two civilian residency programs (Wright State University and University of Texas Medical Branch) that train aerospace medicine specialists. Research opportunities often are coupled with academic positions at major universities. As equipment capabilities exceed human tolerance limits, human factors is becoming an increasingly challenging field. Ergonomics, cockpit information and man/machine interface development, laser/night vision optical systems, and survival equipment are a few areas of current research interest.

Conclusion

Aviation medicine is an unusually interesting, challenging, and professionally rewarding medical practice of particular military relevance. It is the science and art of clinical and preventive medicine as applied to those who serve in the aviation environment. Its goal is to mitigate the harsh physiologic stressors and hazards of flight in order to promote the aviator's safety and maximize effectiveness. A flight surgeon must have basic clinical and specialized skills in order to provide medical support to this singular

population which constantly tests the boundaries of human capability. The Navy Residency in Aerospace Medicine is an exciting, intense operational medicine training experience completely unlike any other. It successfully equips the Army's aviation medicine specialist, the Army RAM, to meet the unique challenges of this field.

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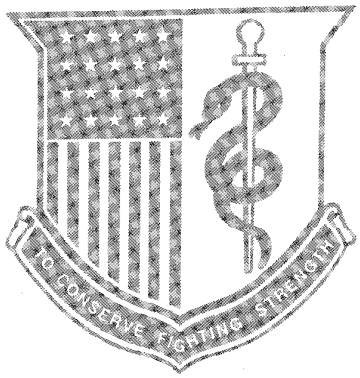

Hereditary Hemochromatosis Among U.S. Army Aviators

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From 1988 to 1995, there were five reported cases of hemochromatosis among U.S. Army aviators. Three of the five are presented and discussed. The cases of hereditary hemochromatosis were discovered during unrelated work-ups or from investigation of a positive family history, and not by routine flying duty medical examinations. Recent studies show a prevalence of 5 per 1000 in the general population. This study shows the incidence among Army aviators is 0.296 per 1000 aviator-years of observation. It is possible that there are cases presently undiagnosed in the Army aviation community. Without screening measures in place, the Army Aviation Branch has greater difficulty diagnosing and treating hereditary hemochromatosis. Heightened awareness and a high clinical index of suspicion are necessary to identify affected patients. Early detection and treatment is essential to prevent long-term end organ damage from iron deposition.

Hereditary hemochromatosis is a common autosomal recessive disease of excessive intestinal iron absorption leading to overload and subsequent pathologic tissue deposition. In the U.S., hemochromatosis is estimated to occur in 5 per 1000 individuals with a higher prevalence in males (1.8:1).[1,2] Symptoms from iron overload usually present at 40 to 50 years of age. Early treatment is crucial in preventing the permanent effects of end organ damage secondary to iron deposition. The liver is always the principal recipient of the excess iron and is involved in hereditary hemochromatosis.[3] End organ damage from hemochromatosis is irreversible, but diagnosis and treatment before cirrhotic liver changes occur place the patient at no increased risk for hepatic abnormalities. Other end organ complications are diabetes, hypothyroidism, cardiomyopathy, atrial and ventricular dysrhythmias, congestive heart failure, joint space narrowing and swelling, and a bronzing or graying of the skin. Complications are avoided with early detection and treatment.[3] From 1988 to 1995, there were five new cases of hemochromatosis among U.S. Army aviators with an overall incidence rate of 0.296 per 1,000 aviator-years of observation. These cases were extracted from the medical database at the United States Army School of Aviation Medicine. This database is designed and maintained to assess and monitor the health status of this select population. Three cases of hemochromatosis are discussed in reference to screening and aviation duty performance.

Case Reports

Case 1. A 47-year-old male aviator presented with an elevated serum iron during a physical examination in Jul 88. This was an incidental finding, since serum iron is not part of the routine examination. His serum ferritin was 700 $\mu g \cdot L^{-1}$ (normal 15-250 $\mu g \cdot L^{-1}$). He had a transferrin saturation of 80% (normal 20% to 50%). A liver biopsy indicated minimal periportal fibrosis with chronic inflammation. The iron stains were positive for iron accumulation, consistent with the diagnosis of

hemochromatosis. He underwent phlebotomy treatments and was granted a waiver for this condition in 1991. He performed his duties in the desert environment of Operation Desert Storm without complications from this condition.

Case 2. A 35-year-old male aviator presented with a serum iron level of 234 $\mu g \cdot dL^{-1}$ (normal 38-180 $\mu g \cdot dL^{-1}$) and a serum ferritin level of 882 $\mu g \cdot L^{-1}$ during evaluation for allergic reactive airway disease in Mar 92. A liver computed tomography showed diffusely increased hepatic attenuation and liver biopsy demonstrated increased iron stores of 19,573 $\mu g \cdot L^{-1}$ of dry weight (normal 530-900 $\mu g \cdot L^{-1}$). The diagnosis of hemochromatosis was made. Treatment consisted of periodic phlebotomies. He was granted a waiver in Sep 93 without limitations.

Case 3. A 41-year-old male aviator with a recently discovered positive family history for hemochromatosis requested testing at his annual physical in Sep 96. His laboratory values were serum iron level 217 $\mu g \cdot dL^{-1}$, transferrin saturation of 83%, and a serum ferritin level greater than 1000 $\mu g \cdot L^{-1}$. A liver biopsy showed periportal hepatocellular hemosiderosis without evidence of fibrosis. His cardiology evaluation showed no evidence of cardiac involvement. He was treated with weekly phlebotomies until his iron levels normalized and then intermittently as required. A waiver was recommended to continue flying duties without limitations.

Discussion

There were five cases of hemochromatosis identified among U.S. Army aviators in 8 years of observation. The two cases not presented contained insufficient archived data to present in this article. There were multiple similarities in all cases. These aviators were diagnosed either during a routine work-up for another condition or from a positive family history. In the general population, this same pattern of incidental findings from routine iron panels and family history work-ups comprise up to 80% of patients.[3] When hemochromatosis is suspected, a fasting serum iron, total iron binding capacity, transferrin saturation, and a serum ferritin should be obtained.[3,4] A liver biopsy is recommended following detection of abnormal iron studies. Although invasive, the biopsy provides a means for definitive diagnosis and assessment of liver involvement.

Routine phlebotomy is an effective and inexpensive means of treating hemochromatosis. The removal of excessive iron stores early in the disease process is essential to prevent the detrimental and irreversible effects of tissue iron deposition.[5] The duration and amount of phlebotomy is variable and may require removal of as much as 1.5 to 2.0 units of blood per week for the initial therapy. The phlebotomies are done quarterly when iron studies indicate improvement. The laboratory values indicative of successful treatment are a serum iron of 60-180 $\mu g \cdot dL^{-1}$, a serum ferritin level below 50 $\mu g \cdot L^{-1}$ and a transferrin saturation below 50%.[2-5]

During 9 years of observation, only five cases of hemochromatosis were detected in Army aviators. Since this is such a common disease in the general population, some laboratories are beginning to include iron studies in their routine screening.[3] The common nature of this disease in the general population raises concerns of underdiagnosis in the Army aviation population. It is necessary for healthcare professionals to have a heightened awareness of this problem and be able to recognize the associated laboratory findings. Numerous studies have been done to assess the benefits of screening either through iron studies or through genetic testing.[1,6-8] Their results conclude that genetic testing would not be prudent as a screening tool at this time because a high rate of patients who are positive for the gene do not demonstrate the disease. Some authors advocate using iron studies for routine screening of Caucasians of Northern European descent. Currently the U.S. Army, U.S. Navy, and U.S. Air Force do not screen for hemochromatosis during flight physicals.

Conclusions

It is likely that there are other aviators with hemochromatosis that are unaware of their condition. As the studies are conducted to determine the benefits of genetic or laboratory screening in the general population, it would be prudent to investigate the value of this in the Army aviation community. Early detection and treatment allow not only for the curtailing of end organ damage, but also allow the aviator to remain functional in his or her

aviation duties without limitation. A possible solution to this issue would be to include iron studies in the panel of blood work performed at the initial and over-40 flight physical examinations. Additional guidelines need to be in effect to ensure an exceptional standard of care is upheld during evaluation, treatment, and return to duty criteria.

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U.S. Army MEDEVAC in the New Millennium: A Medical Perspective

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Introduction

The new millennium has brought significant challenges to the AMEDD, both on the battlefield and on the home front. New operations, including peace enforcement and humanitarian missions, require new approaches to providing effective medical care. The shift to managed care (TRICARE) and the ever-increasing expectations of beneficiaries, soldiers, and their commanders for improved standards of care add to the challenges. The Army aeromedical community is not immune to these issues.

Despite significant progress made both in technology and patient-care capability in the civilian sector, our Army Medical Evacuation (MEDEVAC) units continue to closely resemble their Vietnam-era forebearers with regard to medical care provision. Now is an appropriate time for the AMEDD to re-examine the current capabilities, doctrine, and mission environment of our air ambulance fleet. Further, we should address a fundamental question: does MEDEVAC exist primarily or solely as a transport tool to clear the battlefield in the event of a major regional conflict (MRC), or should it truly be an "air medical transport" (AMT) asset with a crew that is trained to a recognized standard and equipped to provide in-flight medical care?

The Air Ambulance "System" at a Glance

The Total Army currently operates over 20 independent air ambulance units worldwide. The typical Army air ambulance unit is a freestanding company or platoon-sized element commanded by a Medical Service Corps aviation officer (pilot). The standard company is composed of 15 air ambulances and their concomitant aircrew members. These units are resourced to train all aviators to a high degree of proficiency with regard to their respective aviation tasks, and are held to rigorous training and skills standards.[1] These standards encompass not only requirements for total flight hours, but specify flight training and experience operating in marginal conditions, use of night vision equipment, and instrument flight rules navigation. A system of specific and rigorous performance standards is utilized, as well as a cadre of instructor pilots who confirm that these standards are met.

The medical aircrew component of the standard air ambulance company consists of 17 flight medical aidmen ([FMA] flight medics), who are responsible for providing patient assessment and in-flight medical care. Constituent FMAs are approved individually by each unit's commander through the use of subjective and highly variable methods. There is rarely any professional medical input. A FMA training course is offered by the U.S. Army School of Aviation Medicine (USASAM); however, attendance at this course is not a requirement for assignment as an FMA. Course attendance does not necessarily result in a follow-on assignment as a FMA.

Unit level FMA training is performed by the unit Flight Instructors and supervised by Standardization

Instructors. These are senior FMAs designated by their unit commanders based on rank and experience level. A check in the system is a thorough inspection by the Aviation Branch's Directorate of Evaluations and Standardization. These inspections occur every 18-24 months and include oral, written, and flight evaluations by senior FMA inspectors. However, the training standards are only those which are set forth in TC 1-211 for UH-1s and TC 1-212 for UH-60s.

This potentially-thorough system is flawed by the lack of rigor in the training standards contained in the Aircraft Training Manuals cited. As an example, the current training standards for flight medics flying UH-60s are contained in TC 1-212, and are summarized in Table 1.[1] These standards are broadly written and lack coherence. They fail to provide an organized framework around which a medical training program can be designed. Of specific note is the standard "provide treatment for a patient," which instructs the FMA to "use procedures per the unit standard operating procedure (SOP) and treatment protocol," and identifies each unit's commander (an aviator) as the individual who is responsible for identifying required medical tasks, "based on his combat and local missions in cooperation with the senior flight medic and flight surgeon." In accordance with these performance standards, there exist currently no uniform treatment protocols, SOPs, or other guidance from which local commanders or flight surgeons might form the basis of local policies.

- Prepare patient for hoist recovery and departure
- Relay patient information to medical control
- Load, secure and unload litter and ambulatory patients
- Identify and treat adverse effects of altitude on a patient with chest and/or head injuries
- Perform a preflight inspection of medical equipment
- Restrain a patient during flight
- Provide treatment for a patient

Reproduced from TC 1-212, ATM: Utility Helicopter UH-60/ EH-60, U.S. Army, 1996.

Table 1. Current Flight Medic Performance Standards

Medical officers are not assigned to air ambulance companies. Professional medical oversight for Army air ambulance units rests primarily with a flight surgeon assigned to the unit's parent organization, if one exists. The flight surgeon, who is often an aeromedical physician assistant or general medical officer (GMO) (possessing 1 year of post-graduate medical training and the 6-week Army Flight Surgeon Primary Course), provides medical clearance to the flight crew and advises the unit on medical matters. This includes development of the unit medical SOPs and treatment protocols as noted above. Although the Office of The Surgeon General (OTSG) has launched an initiative to assign residency trained medical officers as brigade and division surgeons, as many as 50% of flight surgeon positions will continue to be occupied by GMOs for the near future. Even when these positions are all filled by residency-trained physicians, only a small fraction of these doctors will have received any specific in-residency training on the provision of pre-hospital/aeromedical patient transport and management.

Current Civilian AMT Systems

The AMT is defined as the actual provision of medical care to a patient or patients while in-flight. This contrasts with Casualty Evacuation (CASEVAC), which denotes the transportation of patients from the injury scene to a location where medical care may be delivered, either employing nonmedical transport platforms or with no substantive medical care rendered en route.

Both governmental and private civilian air medical services have become an important component of emergency medical service (EMS) systems throughout the U.S. and in many developed countries. Like many other medical advances, the concept of AMT was envisioned and first developed by the military during wartime.[2,3] The civilian arena has been the scene of further refinement of these services toward the model of an "airmobile intensive care" configuration, providing advanced patient assessment, definitive airway management, and other advanced life support procedures.[4] In several studies, the provision of such advanced interventions as endotracheal intubation, cricothyroidotomy, pulse oximetry, and needle thoracostomy by medical aircrews has been directly linked to enhanced quality of care for AMT patients.[5-8] In addition to the ability to provide these interventions, civilian AMT

crews bring to their practice a greater knowledge base and clinical acumen than the average EMS provider. Most AMT crews are composed of two advanced EMT-Paramedics (EMT-P) or an EMT-P and flight nurse. The effect of this "smart combination" is, to some degree, intangible, but it generally translates into an improved outcome for critically injured patients, as well as for some subsets of critical medical (nontrauma) patients such as those who have initially survived cardiac arrest.[9-12]

Civilian AMT systems are most often supervised by physician medical directors trained predominantly in emergency medicine. These experts in pre-hospital care develop SOPs, treatment protocols, continuing education (CE) programs, and conduct process improvement review.[13] Additionally, they may augment the medical aircrew, during personnel shortages, when complicated interfacility transfers are expected, or when long flight times for critical patients are anticipated.

The MEDEVAC Mission – Doctrine versus Reality

In military operations other than war, unlike conventional warfare in a developed theater, casualty numbers may be small but evacuation distances from point of injury to surgery are likely to be substantial. These longer transport times mean that unstable patients may need to have a variety of medical interventions performed in-flight if they are to survive. The traditional evacuation chain that routes casualties from point of injury, through a battalion aid station to a Forward Support Medical Company, and on to a Combat Support Hospital is adequate and appropriate for the majority of patients but, as was demonstrated in Vietnam, there is a subset of the wounded for whom the delay in surgery that is caused by this routing is fatal. It is this group of casualties who benefited from the decision that was often made by MEDEVAC pilots to over-fly these intermediate military treatment facilities (MTFs) and to transport casualties directly from point of injury to a surgical treatment facility. The efficacy of this practice has been validated by a recently published study conducted in a civilian trauma system with an available AMT service. In this study, it was found that transport from injury scene to an intermediate level hospital for the purpose of "stabilization" prior to transport to a trauma center produced a delay in definitive surgical intervention that was, on average, 6 times (196 minutes) longer than the time it would have taken to have directly transported the patient to the trauma center (34 minutes). In this group receiving delayed surgery, both morbidity and mortality were increased as compared to the group that was transported directly without intermediate "stabilization." The AMT teams evacuating these "unstabilized" trauma victims, often over long distances, need the knowledge and skills necessary to keep such patients alive. Furthermore, they need the knowledge and experience to know which patients require such direct transport, which would not receive any benefit, and which might actually benefit from intermediate stabilization.

Finally, the development of Forward Surgical Team doctrine has made basic resuscitative surgery available at, or near, the first echelon of care. These far forward surgical units have a very limited casualty holding capability and no "beds" in the traditional sense. This means that immediately, postoperative casualties who have traditionally been deemed unstable, will need to be transported to a higher level facility. Historically, it has been contrary to policy to evacuate such postoperative patients because of the increased morbidity and mortality that was associated with such evacuations. Only by providing skilled in-flight medical care will we avoid re-learning such lessons of the past.

The aforementioned scenario predicts an operational environment for MEDEVAC crews that includes longer transport distances and greater patient acuity during missions. The current lack of a workable contingency plan for medical or skilled nursing "aircrew" augmentation makes it incumbent upon MEDEVAC units themselves to anticipate this deficit, or to be prepared to answer for the consequences.

Discussion

It is a fundamental tenet of good management that before you can correct a deficiency, you must recognize that one exists. The U.S. Army MEDEVAC community possesses an unequalled aviation component; the quality of the medical component should be equally excellent. It is our contention that appropriate and modern standards of care, initial training, documentation, and medical knowledge and skills maintenance are no less necessary for

our medical aircrews than pilot training and sustainment is for pilots. This point is further reinforced by the advent of the UH-60Q "Dustoff" air ambulance, which will represent the state-of-the-art in military AMT airframes worldwide. It seems both ironic and illogical that the U.S. Army already possesses the best aviators, and will soon possess the best platform for AMT, yet our ability to provide the "medical" component on that platform on a system-wide scale is significantly limited when compared to the civilian standard.[14] In terms of our own definitions, official doctrine, and training standards, we are in fact providing a service that is closer to CASEVAC, rather than MEDEVAC. We must also face the fact that despite an often predicted overload of our evacuation and health services support systems in the setting of MRC, it is evident that as a nation we are less willing today, than in the past, to tolerate substandard care simply because that care is being provided in a combat zone.

In the search for a workable solution to this situation, we believe that several points must be kept in mind. First, individual MEDEVAC commanders cannot and should not be expected to independently recognize and fill the medical training and skills gaps that exist currently. In order to effect a successful change, the Army and the AMEDD must recognize the existing deficiencies in doctrine, training, and oversight. Leadership must make the tough decision to provide the resources to correct them. Otherwise, the Army and the AMEDD will be accepting a standard of care below that of our civilian counterparts.

Second, the commitment to improving the medical component of MEDEVAC does not necessarily translate into a requirement for this maximal level of care in all circumstances. Combat is perhaps the ultimate mass casualty incident. As such, medical care in such an environment is conducted under an "emergency preparedness plan" in which standard care is suspended, triage guidelines are instituted, and minimal stabilization is performed, followed by expeditious evacuation. In other words, if we institute higher training standards and medical oversight, we could still revert to a "scoop and run" mode, but we currently do not have the ability to do the reverse. It is easier for a trained EMT-P to operate at the level of an EMT-Basic than it is for an EMT-B to operate as an EMT-P.

Third, precedence exists for the proposals made herein. Army Special Operations Aviation units have instituted policies of advanced FMA training and medical oversight[15] In addition, the U.S. Air Force has expended significant resources in developing and fielding their Critical Care Air Transport (CCAT) teams, which are designed, in theory, to provide far-forward stabilization and AMT to combat casualties. In short, the MEDEVAC mission can be performed better. This is not "a bridge too far."

Recommendations

Our specific recommendations for improving the MEDEVAC system constitute a single vision with four supporting points (see figure). Namely, MEDEVAC should be a system composed of constituent air ambulance units, and it should be optimized by relevant standards, sufficient training resources, an emphasis on sustainment and competent medical oversight.

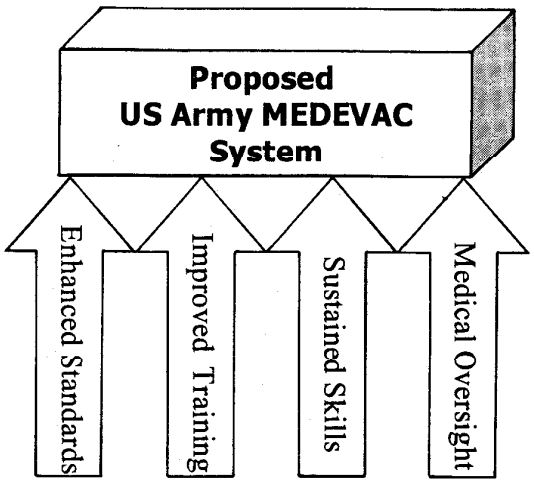

Fig. Proposed system approach to Army AMT.

Viewing medical aircrew and MEDEVAC units as part of a system is a first integral step toward establishing civilian-comparable AMT care. MEDEVAC units should adhere to a common core standard of patient care, rather than heterogeneous SOPs and protocols based upon local perceptions or "mission requirements." While each unit will doubtless encounter unique missions and situations, their constituent medical treatment capabilities and standards should remain essentially the same.

The first step in establishing a MEDEVAC system is the establishment of standards. We propose to enhance medical treatment standards outlined in Aircraft Training Manuals with the goal of eventually approximating civilian standards for AMT. Specific proposals appear in Table 2. In addition to specific cognitive and skills performance requirements, the standards build-in national certification, which provides a reliable, portable, and comparable credential to civilian EMS providers. While in their present form they would not provide complete equivalency to civilian CCAT, these modest enhancements, if enacted, enforced, and sustained, would approximate the skill level of providers holding National Registry of Emergency Medical Technicians (NREMT) Basic certification with some enhanced skills.

Substantive changes in FMA standards must be supported by adequate initial training. Soldiers assigned to MEDEVAC units as FMAs should be *required* to attend the Flight Medical Aidman's Course (FMAC) conducted at the USASAM, Fort Rucker, AL. This course currently is undergoing redesign with the goal of decreasing the duration of the resident phase while increasing the actual didactic and hands-on medical training components. It is anticipated that after the redesign, prospective students will complete a distance learning phase which will encompass flight physiology didactics and some administrative tasks, and they will be required to complete the American Heart

- Prepare a patient for hoist recovery and departure.
- Relay patient information to medical control.
- Load, secure, and unload litter and ambulatory patients.
- Identify, and suggest flight parameters to avoid, or treat adverse effects of altitude on a patient with chest, head, and diving injuries.
- Perform a preflight inspection of medical equipment.
- Restrain a patient during flight.
- Assess airway for patency.
- Know indications, contraindications, and demonstrate proper placement/technique ("mannequin" or actual patient) of the following airway and ventilation adjuncts:
  - nasopharyngeal (NPA) airway and oropharyngeal (OPA) airway
  - bag-valve-mask (BVM) apparatus for assisted ventilation
  - laryngoscopic orotracheal intubation
  - manual or electronic powered suction device for airway clearance
  - supplemental oxygen using nasal cannula and nonrebreather mask
- Using a stethoscope and basic physical examination techniques, demonstrate the clinical assessment for tension pneumothorax, and demonstrate treatment with needle decompression.
- Identify and treat shock.
- Control active bleeding using direct pressure, elevation, and application of a pressure dressing.
- Correctly obtain vital signs (pulse, blood pressure, respiratory rate, and temperature), and know the range of normal and abnormal vital signs in adults.
- Properly apply and interpret the results of a transcutaneous pulse oximeter.
- Know indications, contraindications, and demonstrate proper technique for establishment and maintenance of intravenous access via a peripheral vein.
- Know the indications, contraindications, and demonstrate proper use of a standard Automated External Defibrillator (AED) device.
- Demonstrate maintenance of professional certifications:
  - NREMT
  - AHA ACLS; or in lieu, Basic Life Support (BLS)/Cardiopulmonary resuscitation (CPR) with AED
  - AHA Pediatric Advanced Life Support
  - ACS PHTLS or American College of Emergency Physicians Basic Trauma Life Support (BTLS)

Table 2. Proposed Enhanced Flight Medic Performance

Association (AHA) Advanced Cardiac Life Support (ACLS), Pediatric Advanced Life Support (PALS), and American College of Surgeons Pre-Hospital Trauma Life Support (PHTLS) provider courses at their local military MTF or other local provider. The actual FMAC resident phase is projected to be 2 to 3 weeks in duration, and will focus upon advanced patient assessment and airway management skills, use of new technologies (such as pulse oximeters and oxygen-powered ventilator systems) and a greater proportion of in-flight patient assessment and interventional training. Critical nonmedical aircrew tasks and hoist operations training would still be conducted during the resident phase, as well. If this course becomes compulsory, it would satisfy the initial training requirements of new FMAs, setting them up for success in meeting our proposed enhanced standards.

Once FMAs are trained to standard, their knowledge and skills must be maintained. Cost, mission requirements and quality of the educational experience are all important considerations. In addition, any such initiative must be designed with sufficient flexibility to fit around the high operational tempo of MEDEVAC units. While there are several potential approaches to CE sustainment, we propose a structured program based upon the guidelines for EMT-B recertification published by NREMT.[16] These requirements, which must be satisfied at 2-year intervals, are displayed in Table 3. It is worth noting that NREMT designates no specific minimum requirements for the skill maintenance component beyond certification by the respective candidate's physician medical director that the skills have been demonstrated. Normally, this occurs as a result of patient treatment record review. While details of this component require further definition, our initial proposal would include documented patient contacts either with the FMA's respective MEDEVAC unit, at an AMEDD approved Level I or II trauma center or ALS ambulance service. Direct observation would be provided by the MEDEVAC unit's senior FMA, the MTF's emergency physician on duty, or the EMS service's shift supervisor. Rather than specifying a number of contact hours for clinical skills confirmation, we would suggest a minimum number of patient contacts documented by a brief narrative of presenting complaint, assessment,

- 24 contact hours of formal didactic coursework:
  - Attendance at FMA CE program conducted at AMEC/JSS OR
  - Attendance at a local MTF or civilian approved EMT refresher course
- Maintain AHA BLS/CPR with AED certification.
- 48 contact hours additional in-service training (certified by local flight surgeon or AMEDD):
  - EMT-related in-services conducted at local MTF or fire departments
  - Attendance at additional formal refresher courses (see one above)
  - Recertification in ACLS, PALS, BTLS / PHTLS (16 hours credit each)
  - Distance learning programs developed by AMEDD or USASAM
- EMT Skills Maintenance:*
  - Patient assessment and management: Medical & Trauma
  - Ventilatory management cognitive and skills: OPA, NPA, oxygen delivery, BVM
  - Cardiac arrest management (BLS/CPR skills demonstration on actual patients)
  - Hemorrhage control and splinting
  - Spinal immobilization
  - Management of gynecologic bleeding and childbirth-related complications/delivery
  - Radio communications
  - Documentation and report writing

* See discussion for further details

Table 3. Proposed Flight Medical Aidman Continuing Education Requirements (To be Completed at 2-year Intervals)

interventions performed and outcome during transport. We would initially suggest 40 such patient contacts during each 2-year period as a starting point.

In addition to clinical skills experience and maintenance of national certifications, we propose to offer on an annual basis the opportunity to attend a 2-day CE program conducted in conjunction with the biannual Army Medical Evacuation Conference (AMEC) or the annual Joint Services Symposium (JSS) on Emergency Medicine. Both conferences, which occur in proximity to the Academy of Health Sciences, would provide an excellent venue for a combination of lectures and skill laboratories which could be conducted primarily with existing resources. In combination with attendance at portions of the standard AMEC or JSS curriculum, it would be possible to approximate the biannual NREMT-mandated 24-hour CE course. Thus, the cost for such a program would likely be limited to TDY funds.

The fourth, and perhaps most complex component of our proposal, involves the establishment of professional medical oversight for the care rendered by the MEDEVAC system. While the technology and resources do not currently exist to support on-line direct medical control, it is possible to improve significantly on the current system by focusing on the standardization of medical SOPs, treatment protocols, oversight of CE and professional credentials maintenance, and the development of a mechanism for at least incremental medical review of MEDEVAC treatment records (commonly referred to as "trip sheets"). We propose to establish some form of "MEDEVAC medical direction board," to be coordinated among the Medical Evacuation Proponency Directorate, USASAM, and OTSG Consultant for Emergency Medicine. This office would disseminate templates of medical SOPs, treatment protocols, and a uniform patient treatment report form, track FMA credentials, and perhaps coordinate the identification and support of local flight surgeons with emergency medicine or family medicine specialty training who might serve as local medical advisors under respective MEDEVAC commanders. In addition, if the aforementioned sustainment program were to be adopted, this board could provide retrospective review of at least the stipulated patient care narratives generated during MEDEVAC duties, both as a quality assurance tool as well as to provide the required physician medical director certification of skill maintenance for NREMT recertification. Finally, this office would coordinate with sister services to insure compatibility of platforms, equipment, methods and standards, as well as coordinate joint training.

Conclusion

This initiative proposes sizable changes in both our perception and conduct of the MEDEVAC mission. While quantitative in-flight treatment data from the Vietnam and Persian Gulf Wars is limited, it is evident from recent studies conducted in both the civilian and military settings that the medical care we are rendering in-flight is not equivalent to the civilian standard unless the existing crew is augmented.[15] With this issue in mind, we offer our approach toward closing this gap. It is possible that if adopted, recent Department of Defense Health Affairs initiatives may mandate the provision of civilian-equivalent care. If this is mandated, our proposal offers a path toward meeting such a mandate. Absent such a directive, however, the strongest argument for adopting this approach is that it will lead to improved care of our wounded and critically-ill soldiers and other beneficiaries – a not unworthy endeavor.

In summation, the U.S. Army MEDEVAC community has established a tradition of excellence to be both treasured and maintained. There also exists an unwritten bond of trust between the AMEDD and the troops we send into Harm's way, that we will provide them with the best and most modern care that we can provide. To wit: "...Medicine has an indirect influence on war which is not negligible. There seems little doubt that some of the reckless courage of American troops is stimulated by the knowledge that in front of them is only the enemy, but behind them are the assembled surgeons of America, with sleeves rolled up."[17]

We believe that our proposed enhancement of the MEDEVAC force, when coupled with our new MEDEVAC airframe and other initiatives aimed at improving combat and other deployment casualty care, will allow the AMEDD to honor and maintain that bond.

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Rollie Harrison: An Aviation Medicine Pioneer

Jim Williams, PhD†

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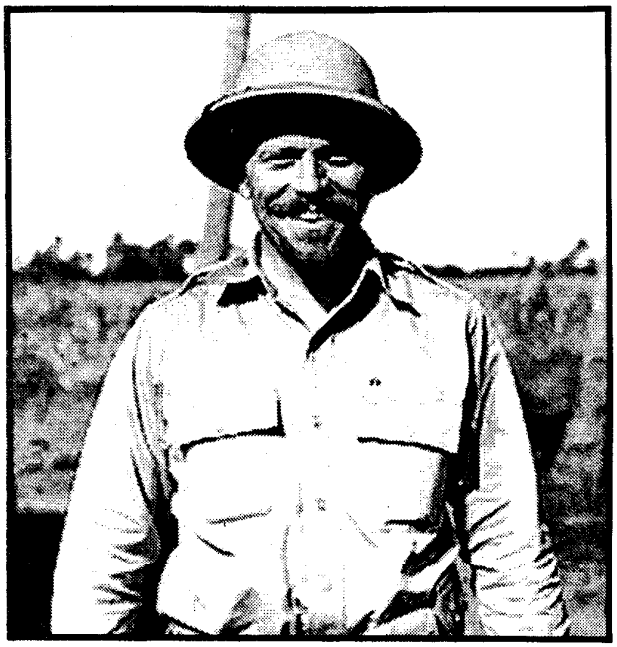
On 2 March 1976, Doctor Rollie M. Harrison died. At that time Harrison, a retired reserve lieutenant colonel, was an examining physician at the armed forces entrance examining station at Fort Worth, TX. His death closed a career that, with several twists and turns, let Harrison claim the title as Army Aviation's first flight surgeon. That claim and the contributions that lay behind it led ultimately to his being memorialized in a dispensary at Fort Sill and a street at Fort Rucker. Harrison's career and his contributions illustrate several broad themes in the history of Army Aviation. These themes include the struggle for organizational maturity and independence, Army Aviation's core mission to support ground commanders, the Army Value of Duty, and the importance of the Total Army. Harrison also illustrates the key role that individual interest and initiative have in capturing and preserving the history and heritage of the Army.



Captain Rollie Harrison
Pacific, 1942

In some ways, Harrison seemed like an odd person to pioneer aviation medicine. He was born in Ramon, SD, on 22 October 1900. After graduating from the University of Illinois with a bachelor's degree in biology in 1929, he attended medical school at Northwestern University. In 1934, he received his medical degree. After finishing his internship at Wesley Memorial Hospital in Chicago, he opened a private practice in a suburb. Harrison's involvement with the Army began on 21 January 1936, when he entered the Reserves as a first lieutenant. On 23 July 1937, he entered active duty as a general medical officer at Fort Sheridan, IL, near Chicago. Sometime later he went to a similar assignment at Fort Custer, MI.

Exactly when Harrison first developed an interest in aviation medicine is uncertain, but his interest was clearly incidental to his assignments after the U.S. entered World War II (WWII). Possibly his interest began while he was assigned to Scott Field, IL. It may have begun with his first overseas assignment with the Army Air Corps. That assignment took him to the Southwest Pacific. In 1943, the Army returned Harrison to Randolph Field, TX, to take the Basic Aviation Medicine Course. He graduated in August 1943. After 2 months at West Palm Beach, FL, he went to Walter Reed Army Medical Center, where he took a course in tropical medicine – a major concern for all the armed forces in the Pacific. Disease killed about half as many American soldiers in the Pacific as the enemy killed in battle. He then returned to the Pacific as a flight surgeon.

He remained in that area until May 1947. Then, with the war over, he returned home to private practice in Illinois. After his return to private practice, Harrison retained a reserve commission. It is not clear from the available records that he did anything with aviation at the time. In fact, some facts suggest that he did not. When the rest of the flight surgeons in the Army transferred to the newly-created U.S. Air Force in September 1947, Harrison alone did not shift to the new service. In summer, 1949, when he served a 30-day period of active duty for training, he was working as a general medical officer.

In fact, Harrison's start as Army Aviation's first flight surgeon may have been accidental. His start clearly reflected a set of difficulties that the Army inherited as a result of the reorganization that created a separate Air Force. When the new service went its own way, the rest of aviation left in the Army faced several challenges to support the ground commander. The Army was dependent on the new Air Force in several areas. Most visible to most people were conflicts that arose over the acquisition of new aircraft. The Army could not buy aircraft directly but had to go through the Air Force. As part of defining the missions of the newly separated services, the Army inherited a number of handicapping restrictions on the size and other characteristics of aircraft it was allowed to buy.

The training of flight surgeons, though far less obvious to most people, was a similar handicap. During WWII, the scattered nature of aviation assets to support the ground commander had already prevented the Army from having flight surgeons located with ground units. The loss of all but one person with a background in aviation medicine left the Army overwhelmingly dependent on the Air Force to support its medical needs. By the time North Korean forces attacked across the 38th Parallel into South Korea, starting the Korean Conflict on 25 June 1950, the growing importance of aviation to the Army was already evident. The number of aircraft in a division had grown from 10 per division in WWII to 18. In November 1950, the first Army helicopter company activated at Fort Sill, OK. To meet the increased needs, the Army immediately began to expand flight training there. In conjunction with this expansion, Harrison returned to extended active duty. After a refresher course at the Air Force School of Aviation Medicine, Harrison became the sole flight surgeon at the Fort Sill dispensary. He continued in that role until the school moved to then-Camp Rucker in 1954.

Harrison became something of a legend in his own time for his zeal in promoting aviation medicine. A photograph in Harrison's papers from Colonel I. B. Washburn, the assistant commandant at Fort Sill, had the greeting, "To the most militant of missionaries for aviation medicine in the Army." Harrison held the view that a real flight surgeon had to be more than a doctor; he had to be a friend to the pilots. In practice, that meant being present everywhere and aware of everything that affected the pilots. Harrison was well-known among pilots as "a crusty old aristocrat," "a perfectionist," "yet fair and honest." The handlebar mustache and goatee beard he adopted while in the Pacific, as well as his raising and showing champion terrier dogs, help feed his aristocratic aura. He enjoyed joking with the younger pilots, but they feared him when he flew with them on their final check rides. He was quick to act when someone was in danger and equally quick to correct the cause of the danger as soon as it was past. On one occasion, flying a helicopter above a highway in Germany, Harrison saw an auto accident. As they radioed for help, Harrison and the pilot landed and gave aid. On another occasion, following an aircraft accident, the pilot was brought in for medical evaluation. After determining that the pilot was all right, Harrison launched into a lengthy lecture about wearing a wristwatch. The accident apparently stemmed from the pilot's failure to wear a watch on that particular flight.

Harrison made it a point to know not only the pilots, but also their families and what was happening with them. He was highly direct and personal in his approach to ensuring physical fitness. He would walk into the club bar and grab a pilot's sides through the shirt to see how much flab the man was carrying. He would greet a returning flight with a set of scales to check the crewmembers' weights as they landed. One aviator recalled him hiding behind a food counter at the snack bar to catch overweight pilots sneaking a piece of pie or ice cream. Harrison was particularly strong in stressing the need for physical fitness in aviators over the age of 30. Harrison taught in the Department of Air Training at Fort Sill, which became the Aviation School on 1 January 1953. There, he taught pilots about the need to enforce pilot rest programs and to avoid excessive alcohol. He formed the foundation for training in aviation medicine within the Army. He developed the

first Army Aviation orientation course for Army medical officers graduating from the Air Force School of Aviation Medicine.

When the Aviation School moved from Fort Sill to Fort Rucker, Harrison went to Germany. There he commanded the 31st Surgical Hospital. He briefly served at the 97th General Hospital before returning to the U.S. From 1958 to 1960, Harrison was the chief of the Medical Examination and Aviation Medicine Division, as well as the Aviation Medicine Advisor at Fort Rucker. During this last tour, Harrison worked to prove the value of having flight surgeons participate in investigations of aircraft accidents. He also worked to develop the techniques for such participation. Partly as a result of his efforts, this role of flight surgeons is accepted in both aviation medicine and safety.

Harrison was a character and perhaps cultivated the image of an eccentric. Both his appearance and manners fed this image. An illustration was inconsistencies between what he practiced and what he preached, such as smoking. It was ironic, though not necessarily surprising, that this vocal opponent of smoking among aviators died of respiratory conditions probably related to his own use of tobacco. His dedication to duty, though, was unquestioned; he was renowned for working 7 days a week. While at Fort Sill, Harrison lived in quarters just a block from the dispensary. He frequently interrupted or set aside hunting, fishing, or golf to meet and treat a sick aviator.

When the time came for Harrison to depart his duties at Fort Rucker, some who were present at the time recall that it was clearly a difficult transition. Harrison relished the close, personal ownership of his role and the service he gave. Moreover, the function of the Army flight surgeon, which Harrison began with a total of one in 1950, reflected the growing pains that came with the split of the Army into two separate aviation organizations with very different views of the proper role of aviation and relationships to the ground commander. Harrison, his staying as part of the ground forces, and his close and personal methods of relating to soldiers reflected the nature of the Army as an organization, as distinct from the newer Air Force. Finally, Harrison's entry into the Army and his return for a second career when new needs arose, reflected the great importance of the reserve components to the Army. In 1937 and 1950, much as today, the Army could meet its needs only by drawing on pools of specialized talent that exist mainly in the civilian world. It is recognition of that need that underlies the concept of the Total Army.

Harrison's legacy continues in several ways in Army Aviation, particularly at Fort Rucker. Flight surgeons everywhere and the Army School of Aviation Medicine at Fort Rucker that trains them are essential elements in the welfare, safety, and combat effectiveness of Army Aviators. The School of Aviation Medicine has for many years been the home of Harrison's personal effects, including his original flight wings and photo albums. Now-Colonel Kevin Mason, one of the medical staff at Fort Rucker, had learned a bit about Harrison's pioneering role while Mason was a student medical officer. Mason researched more about Harrison's background and then took it upon himself to discover what had happened to Harrison's personal effects after he died. Mason found them abandoned in the hands of a lawyer who handled Harrison's estate. Mason undertook to give these items a proper home, first at Fort Sill and later at Fort Rucker. He also initiated action that led to naming Harrison Street in front of the hospital.

Today, more than 20 years after Rollie Harrison died, his personal items, a street name, and the name of a clinic remain a tribute to a man who, in quiet but important ways, helped Army Aviation rise to become the force that dominates the battlefield and that promises to remain "Above the Best."

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Helmet-Mounted Systems Use and Spinal Conditions in Army Aviators

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This study determined the association of spinal symptoms with use of helmet-mounted systems such as night vision goggles and helmet-mounted head up displays in rotary-wing aviators. A voluntary, anonymous questionnaire was used to survey the prevalence of spinal symptoms in 231 U.S. Army rotary-wing aviators from three U.S. Army Posts in Texas. The prevalence of ever having spinal symptoms while on flight status was found to be 78%: 86% for those individuals using helmet-mounted systems frequently and 73% for those with low use of these systems. For the subgroup of aviators who reported having spinal symptoms regularly, the high-time users of helmet-mounted systems had a significantly higher prevalence of spinal symptoms than those in the comparable low-time helmet-mounted systems users after appropriate age adjustment, resulting in a P<.04 with an odds ratio of 1.24 (95% confidence interval of 1.016-1.517) using the chi-square test. In this study population, approximately 32% of the aviators reported spinal symptoms to their flight surgeon in the prior year, and 15% consulted chiropractors and massage therapists for symptom relief. Of those individuals reporting spinal pain, 26% reported ergonomics, 29% flight sortie time length, and 40% helmet-mounted systems use as the source of their spinal symptoms.

Introduction

The prevalence of spinal symptoms (back and neck pain) in rotary-wing aviators is well doumented.[1-4] Several studies have noted that the prevalence of spinal symptoms range from 21% to 95%.[1,2] The etiology of these symptoms has been attributed to a number of factors in the flight environment of the modern helicopter. Several studies suggest that the seat design and resulting posture of the rotary-wing pilot during flight are causal factors.[5-8] Other studies have noted that the symptoms are associated with the constant total body vibration that crewmembers are exposed to in the flight environment.[1,9,10] Furthermore, some researchers have noted that there is an increase in the incidence of spondylolisthesis in helicopter pilots, which may be associated with the vibration inherent in this flight environment.[10,11]

Regardless of the etiology, spinal pain has been found to adversely affect military operational readiness and mission completion secondary to pilots being grounded for treatment with rest, physical therapy, and medications.[7] Approximately 9% of medical discharges in the first 180 days of active service and approximately 20% of all medical discharges in the U.S. Army are due to spinal symptoms or pathology.[4,12] Army flight surgeons have noted the complaints of their aviators for years. However, with the recent development and deployment of more complex and heavier helmet-mounted systems (such as night vision goggles and helmet-mounted displays), the author has noted increased spinal symptom complaints from the aviator population. These symptoms range from traditional low back pain to torticollis and paresthesias in the extremities. Traditional plain film radiographs rarely reveal pathology, nor do most modern scanning techiques.[12] Recent studies investigated the affects of helmet-mounted systems use in the high + Gz (gravitational forces along axis of the spine) environment. The authors concluded that there is increased spinal symptomatology in aviators using these systems.[13-15]

To my knowledge, no affects of the study has addressed the relatively low G environment of the rotary-wing aviator on spinal pain.

Current modern Army helicopter pilots wear one of several helmets while engaged in flight. The SPH-4 (Sound Protection Helmet) weighs approximately 3.6 pounds (1.63 kg), the SPH-4B weighs approximately 3.1 pounds (1.41 kg), and the Integrated Helmet and Display Sighting System (IHADDS), which is used on all Apache helicopters (AH-64), weighs approximately 3 pounds (1.36 kg). A new helmet being deployed, Helmet Gear Unit No. 56P (HGU-56P), is designed to replace all current helmets and weighs approximately 2.5 pounds (1.14 kg). An aviator using the current generation of night vision goggles (ANVIS 6) adds an additional 29 ounces (0.82 kg) to his helmet ([19 ounces (0.54 kg) for the goggles and 10 ounces (0.28 kg) for the battery pack]). Additional weight in the form of the Aviators Night Vision Imaging System Head Up Display, Aviator Night Vision Imaging System Optical Display Assembly, lip lights, and chemical protective mask can also be added to the helmet (6 ounces (0.17 kg), 2.4 ounces (0.07 kg), 2.5 ounces (0.07 kg) and 2 pounds (0.01 kg) respectively). Additionally, most aviators add a counterweight to the back of their helmet to improve the center of gravity of the helmet since night-vision-goggles tend to shift the center of gravity some 30 mm forward without a counterweight.[16] These counterweights range from 10 to 20 ounces (0.28 - 0.57 kg). Thus, a typical rotary-wing aviator flying with helmet-mounted systems could be increasing his spinal weight bearing load by almost 7 pounds (3.18 kg). This would increase to almost 9 pounds (4.08 kg) of increased spinal load in the chemical weapons threat environment.

This study was designed to compare spinal complaints in two groups of rotary-wing aviators who use helmet-mounted systems: (1) those with relatively high flight time hours and (2) those with relatively low flight time hours but comparable *total* flight time hours. The rotary wing mission profile continues to evolve towards a primary night mission with its inherent requirement for helmet-mounted systems. Also, new prototype helicopters such as the Comanche (RAH-66) may have two helmet-mounted systems per aviator and the possibility of obtaining moderate G forces during flight. Therefore, the question addressed by this study becomes more important to the areas of operational readiness, mission completion, aviator health, and flight safety.

Materials and Methods

- *The Study Design.*

The study was a retrospective case control study designed to determine whether there is an association between frequent or high-time use of helmet-mounted systems and the incidence of spinal symptoms in aviators. Frequent use was defined as greater than 300 hours of helmet-mounted system use. Spinal symptoms were defined as neck pain, back pain, or extremity numbness (paraesthesia) with a severity scale from never (0) through regularly.[11] The null hypothesis stated that there was no statistically significant difference (P=0.05) between spinal complaints in high-time users of helmet-mounted systems when compared with low-time users of helmet-mounted systems having comparable total flight hours. The alternate hypothesis stated that there was a significant difference between these two groups ($P \leq 0.05$).

- *The Population.*

The 231 participants in this study were all active duty U.S. Army rated rotary-wing aviators who volunteered to complete an anonymous survey questionnaire. All subjects were in good health and based in Texas (Fort Hood, Conroe, and San Antonio). The group consisted of 77 regular commissioned officers (from Second Lieutenant through Colonel) and 144 warrant officers (WO1 through CW5) on active flight status. The group consisted of 224 males and seven females. The participants age ranged from 23 to 52 years.

- *The Survey Instrument.*

The survey instrument consisted of a 40 item questionnaire that allowed for approximately 100 data fields to be answered by each participant. The questionnaire received approval by the Institutional Review Board for Human Use Studies at Brooks Air Force Base, TX, prior to being distributed to the participants. The questions were used to identify demographics, aviation history, frequency and severity of spinal symptoms, previous spinal injury, treatment for spinal conditions, related medical waivers, and personal preventive measures or exercises that the participants may

have utilized for spinal symptoms reduction. Participants were also asked to attribute their symptoms to lifestyle and activities. The author explained and distributed the questionnaire to company size units over several days during routine unit safety briefings. Participants were given ample time to complete the questionnaires which were then collected by the company safety officers and returned to the author in a sealed envelope. The participants reported that the questionnaire took between 15 and 20 minutes on average to complete. A total of 250 questionnaires were distributed and 231 completed forms were returned. The surveys were then entered by a noninterested party into a relational database at the Aeromedical Consult Service at Brooks Air Force Base prior to statistical analysis.

• *Statistical Methods.*

Descriptive statistics were derived using the number of participants that answered a particular question affirmatively as the numerator and using the total number of questionnaires that were returned as the denominator (231). These statistical values were calculated as percentages. Each participant's age, flight hours, helmet-mounted system use hours, and spinal symptoms frequency were analyzed by calculating the mean, median, mode, standard deviation and range of each variable.

Analytical statistics were derived using the total number of aviators who admitted to at least monthly, or at least weekly spinal symptoms as numerators. The denominator was the total number of questionnaire respondents. Ten participants that had reported prior spinal injury and medical waivers were removed from the database before analysis. The data were analyzed using SAS, version 6.08. Prior to data analysis, an operationally significant level of high-time helmet-mounted system use was designated at 300 hours or greater. This resulted in identifying 81 aviators with high-time helmet-mounted system use and 140 aviators with low-time helmet-mounted systems use but comparable total flight hours. Additionally, two medically and operationally significant levels of spinal symptoms were designated as (1) monthly or more frequently and as (2) weekly or more frequently. The former group contained 111 individuals and the latter group contained 64 individuals who reported spinal symptoms. Differences in reported spinal symptoms of high-time helmet-mounted systems users versus low-time helmet-mounted systems users were calculated using the Cochran-Mantel-Haenszel chi-squared test with one degree of freedom. The significance level was set at 0.05 ($P \leq 0.05$).

A total of 250 aviators were eligible to participate in the study. Two hundred thirty-one aviators returned the survey completed for a 92.4% return rate. Ten participants reported a prior history of spinal injury or a medical waiver for spinal pathology and were not used in the final calculations. The total number of questionnaires used in the study was therefore 221 or 88.4% of the total originally distributed.

Results

• *Descriptive Statistics.*

The group of participants consisted of 224 males (97%) and seven females (3%). There were 155 WOs and 76 commissioned officers. The distribution of officers is noted in Table 1. Two commissioned officers and three WOs were removed from the low systems use group and five WOs were removed from the high systems use group due to prior spinal pathology in the analytic phase of analysis. Participants age ranged from 23 to 52 years with a mean of 33.7 years (Table 2). The average total military flying hours was 1596 with a range of 180 to 7200 hours and the flying hours using helmet-mounted systems averaged 285 with a range of 0 to 2000 hours (Table 3).

In addition, the average age for the high-time helmet-mounted systems use group was 37.3 years (range 25 - 52) versus the low-time helmet-mounted systems use group age average of 31.4 years (range 23 - 49) (Table 2). The average total military flying hours for the high-time helmet-mounted systems use group was 2498 hours (range 515 to 7200) versus the low-time helmet-mounted systems use group average of 1031 hours (range 180 – 5124). Finally, the average helmet-mounted systems flight hours in the high-time systems use group was 572 hours (range 300 - 2000) versus the low-time systems use group average of 121 hours (range 0 - 280) (Table 3).

Rank	2LT	1LT	CPT	MAJ	LTC	COL	WO1	CW2	CW3	CW4	CW5
Total	7	12	35	15	5	2	3	83	43	15	11
Percent	3	5	15	6	2	1	1	36	19	6	5
High	0	3	3	6	1	2	0	23	33***	7****	8
Low	7	9	32	9*	4	0	3	60**	10	8	3

Secondary to prior history of spinal pathology, the following participants were deleted from the study:
* Two Majors, ** Three CW2s, ***Two CW3s, and ****Three CW4s.

Table 1. Rank Structure of the Population (N=231)

Variable in Years	Age of Total Population (N=221)	Age of High-Time Systems Use Group (N=81)	Age of Low-Time Systems Use Group (N=140)
Average	33.68	37.27	31.36
Mode	31	39	31
Median	32	36	30
Standard Dev	6.63	6.30	5.85
Max	52	52	49
Min	23	25	23

Table 2. Age Distribution of the Population (N=221)

Variable in Hours	Total Flight Time (N=221)	System Flight Time (N=221)	High Use System Total Time (N=81)	High Use System time (N=81)	Low Use System Total Time (N=140)	Low Use System Time (N=140)
Average	1596	286	2498	572	1031	121
Mode	1200	150	1700	300	500	150
Median	1100	200	1985	450	750	100
St Dev	1417	320	1640	370	928	04
Max	7200	2000	7200	2000	5124	280
Min	180	0	515	300	180	0

Table 3. Flight Time Distribution of the Population (N=221)

The distribution of helmet types as well as the primary aircraft of the aviators at the time of the study are noted in Tables 4 and 5 respectively.

HELMET*	SPH-4	SPH-4B	HGU-56P	IHADDS
Total	61	27	57	85
Percent	26%	12%	25%	37%
High **	13	4	14	46
Low***	48	23	43	39

* One participant did not enter helmet type on survey.
** Two SPH-4 and three IHADDS deleted secondary to prior spinal pathology.
*** Three SPH-4 and two IHADDS deleted secondary to prior spinal pathology.

Table 4. Helmet Distribution of the Population (N=231)

TYPE	AH-1	AH-64	UH-1	UH-60	OH-58C	OH-58D	CH-47	SIM
Total	3	80	17	57	7	37	1	29
Percent	1	35	7	25	3	16	1	12
High*	0	46	2	16	2	15	1	4
Low**	3	34	15	41	5	22	0	25

* Three AH-64, one OH-58C, and one OH-58D deleted secondary to prior spinal pathology.
** Two AH-64, two UH-60, and one UH-1 deleted secondary to spinal pathology.

Table 5. Primary Aircraft Distribution of the Population (N=231)

All 81 individuals in the high-time flight group were male; 19% were commissioned officers, 81% were WOs. The low flight time group consisted of 140 participants, including six females (4%) and 134 males (96%). Forty-two percent of the low flight time group were commissioned officers and the remainder were WOs. The high-time system use group had an average age of 37 years, an average total flight time of 2498 hours, and an average helmet-mounted systems total flight time of 572 hours. The low-time systems use group had an average age of 31 years, an average total flight time of 1031 hours, and an average helmet-mounted systems total flight time of 121 hours. There was not a statistically significant difference between these two groups regarding age at the $P<0.05$ level.

The prevalence of total spinal symptoms in this group of 221 aviators was calculated at 78% which is consistent with the literature.[3,6-8] The high-time systems use group reported an 86% prevalence versus a 73% prevalence reported by the low-time systems group. Thirty-two percent of the entire population reported to have seen their flight surgeon in the past year regarding spinal symptoms, including 37% of the high-time systems use group and 29% of the low-time systems use group. The population noted that 31% of the fellow aviators in their unit experienced spinal symptoms with the high-time systems use group reporting 35% and the low-time systems use group reporting 29%. When asked as to a possible source for spinal symptoms, 26% (33% high-time system use group versus 22% low-time systems use group) reported helicopter ergonomics (seat design, instrument placement, etc). An additional 29% (40% high-time systems use group versus group versus 23% low-time systems use group) reported total flight sortie length as the primary factor causing their symptoms. Another 40% (53% high-time systems use group versus 32% low-time systems group) reported helmet-mounted systems as the source of spinal symptoms. Finally, 15% of the aviators reported using alternative medicine (chiropractors, massage therapy, and hydrotherapy) to treat their spinal symptoms. The high-time systems use group preferred chiropractors 3:1 over the low-time systems, while the low-time systems use group favored massage therapy by the same ratio.

• *Analytic Statistics.*

The 221 aviators in the population were analyzed for the association of spinal symptoms and high-time helmet-

mounted systems use at two frequencies of reported spinal symptoms either monthly or more frequently or weekly and more frequently. Thus, the monthly or more frequently level includes the weekly or more frequently level. The resultant data was analyzed using the Cochran-Mantel-Haenszel chi-squared test with one degree of freedom. The significance level was set at $P< 0.05$. The results for the monthly or more frequently study are noted in Table 6, while those of the weekly or more frequently are found in Table 7.

X	Spinal Symptoms Present	Spinal Symptoms Not Present	Total
High HMS Use	51	30	81
Low HMS Use	60	80	140
Total	111	110	221

Table 6. Chi-square Test (Mantel-Haenszel) for Aviators Reporting Spinal Symptoms Monthly or More Frequently

X	Spinal Symptoms Present	Spinal Symptoms Not Present	Total
High HMS Use	35	46	81
Low HMS Use	29	111	140
Total	64	157	221

Table 7. Chi-square Test (Mantel-Haenszel) for Aviators Reporting Spinal Symptoms Weekly or More Frequently

The results for those individuals experiencing spinal symptoms at least monthly showed a significance level at $P<0.005$ with an odds ratio of 2.37 prior to age adjustment. Stratification for age decreased the P value to 0.128 with an odds ratio of 1.288 (95% confidence interval of 0.930 - 1.784). When age adjustment was carried out using logistic regression where age was treated as a continuous variable, the P value again was decreased to 0.1097 and again failed to meet the preset significance level of this study. Thus, although the data do not appear to be statistically significant at a level of $P<0.05$, the incidence of spinal symptoms remains higher in the group of individuals with high-time helmet-mounted system use.

The results for those individuals experiencing spinal symptoms at least weekly showed a significance level at $P<0.0004$ with an odds ratio of 2.91 prior to age adjustment. Stratification for age decreased the P value to 0.035 with an odds ratio of 1.241 (95% confidence interval of 1.016 – 1.517). When age adjustment was carried out using logistic regression where age was treated as a continuous variable, the P value again was decreased to 0.0397 with an odds ratio of 2.014, which met the preset significance level of this study. Thus, the group of aviators that have high-time helmet-mounted system use have a higher incidence of spinal symptoms than do those aviators with comparable total flight hours but relatively low-time use of helmet-mounted systems. This was significant at the $P<0.05$ level.

Discussion

This study was undertaken to determine if there was an association of increased spinal symptoms in U.S. Army rotary-wing aviators who have high helmet-mounted systems flight time as compared to those aviators with comparable total flight hours with low helmet-mounted systems use. Several studies have documented the increased risk of spinal symptoms in rotary-wing pilots due to vibration or poor ergonomic design.[1,4-10] This study revealed two major findings in reference to spinal symptoms in this population. First, the overall prevalence of spinal symptoms was 78% which is consistent with the finding of previous studies.[4] Secondly, the study showed a statistical association between the frequent use of helmet-mounted systems and an increased incidence of spinal symptoms.

The overall incidence of spinal symptoms was noted to be higher in those helmet-mounted system users suffering symptoms at least once a month. One other study has noted the correlation between age, total flight time, and increased spinal symptoms in aviators.[9] Most

aviators require several years to obtain a significant amount of helmet-mounted systems hours. In the present study, the average age difference between the two groups was 6 years. This systemic confounder in the study was addressed by age adjustment as previously noted. However, it is possible that the age adjustment eliminated part of the true statistical significance of the association between increased use of helmet-mounted systems and increased spinal symptoms. Certainly, if the population was larger, this problem may have been avoided.

In addition to the systemic confounder of age difference in this study, there are other possible areas of bias that merit discussion. The first is that of selection bias. The study was voluntary and thus, the population self selected to fill out a questionnaire. However, since the return rate was so high (92%), this bias had marginal impact. The second possible source of bias is that of recall. Certainly an individual is more likely to recall spinal symptoms in relation to flying and report them when asked, but significant recall bias is unlikely in this study. Many individuals, when asked, did not report spinal symptoms and many of those that did report spinal symptoms did not associate them with the flight environment.

The operational significance of the association between increased spinal symptoms and increased use of helmet-mounted systems is important. Overall mission completion and flight safety could be strongly affected by aviators who are either distracted or incapacitated by spinal symptoms. Furthermore, given (1) the current tempo of Army operations; (2) the development and deployment of even more helmet-mounted systems (as in the Commanche which is capable of experiencing significant G forces); and (3) current battle doctrine in which the vast majority of missions are flown at night with helmet-mounted systems, this finding could potentially impact the total Army rotary wing population. More studies are needed to address the affects of increased spinal load bearing and center of mass changes due to helmet-mounted systems and their effects on spinal symptoms. These studies could use a similar survey instrument or be designed possibly as cohort studies.

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The History of Aerospace Pathology

COL Warner D. Farr, MC†

Following a mishap, the first dare devil aviator picked himself up, dusted himself off, and sat back down to consider what had gone wrong, the first aviation accident investigation began. Investigations evolved slowly, beginning with untrained personnel and no medical assistance. Contemporary literature from the early days of pioneering aviation contains speculation on the causes of early accidents. Modern authors have looked back at some famous, and not so famous, early accidents (both true and fictional) and, in many cases, have come to different conclusions than those past investigators. One of the earliest episodes of an in-flight medical problem involved Jean-Pierre Blanchard on his 60th balloon ascent in 1808. Contemporary writers believed he experienced a fit of apoplexy, while modern day medical authors believe it was a heart attack.[1,2] Published in wry satire in today's literature is the account of the Headquarters Ancient Greek Air Force accident board that investigated the flight and accident of CPT Daedalus and LTC Icarus when they ventured too close to the sun.[3] The American Civil War also produced accounts of balloon mishaps involving Federal civilian contract aviators, and at least one mishap involving a Confederate Army officer.[4,5]

The first documented fatal aviation accident took place in France and involved the balloon flight of Croce-Spinelli, Sivel, and Tissandier in 1887. Croce-Spinelli and Sivel died of hypoxia and Tissandier became unconscious.[6] In 1903, a nonfatal accident damaged the front rudder of the Wright's Flyer, cutting short one of the early flights at Kitty Hawk, NC. On 17 September 1908, the first reported aircraft fatality in America occurred when the Wright brothers were demonstrating their Type A Flyer to the U.S. Army Signal Corps at Fort Myer, VA. A crack developed in the starboard propeller, causing violent vibration. Orville, who was at the controls, was unable to prevent the nose-dive and resulting crash. First Lieutenant Thomas E. Selfridge, U.S. Army, aboard as an nonpilot observer, died. Captain H. H. Bailey, Medical Corps, U.S. Army, performed the autopsy and determined the cause of death to be a compound, comminuted fracture of the base of the skull suffered during the crash. An aeronautical board investigated the cause of the crash.[7] An observer on the ground, LTC Hap Arnold, U.S. Army, later dusted off his old West Point football helmet to gain some measure of head protection when he became an Army aviator.[8]

On 7 September 1909, Eugene LeFebre became the first pilot accidentally killed in the U.S. when he crashed his Wright Flyer. By 1910, accidents had cost 38 lives. The first accident to be attributed to a medical cause was listed in *The Aeronautical Journal* in 1911.[9] A recent look back at two aviation deaths in 1911, one attributed by contemporaries to heart failure and the other to vertigo or an epileptic seizure, are now felt by modern day authors to both be pilot error. Many early accidents blamed on medical causes were actually human error.[10] The first attempt to relate structural damage to impact forces was after the 1910 crash of Jorge Chavez in the Andes. Investigators concluded that a 4-G force had been applied to the airframe of Chavez' aircraft. In 1917, Hugh DeHaven was the sole survivor of four in a midair collision. People said he was just lucky, but, after studying the wreckage, DeHaven found he had been the only occupant with occupiable space in his part of the cockpit throughout the entire accident sequence.[8] In the United Kingdom, formal military accident investigations started in 1911 with Boards of Inquiry consisting of a board president pilot, three officers, with at least one of the other members being an engineer. Early board conclusions included "what goes up, must come down," to which the military higher headquarters duly added "concur."[11]

Army Air Service pilots provided early airmail service in the U.S. This resulted in 17 deaths, and ultimately forced the passing of the Kelly Bill in 1925, the

first Air Mail Act. It contracted out the airmail service and also started the government regulation of commercial aviation in the U.S. Regularly scheduled commercial passenger service began shortly thereafter. The number of passengers flown in 1926 was 5,782 but by 1934, this number had grown to 461,743, an 80 fold increase over only 8 years. By 1942, it had increased to 4,060,545. A 1981 article enumerated a list, admittedly imprecise, of 259 fatal commercial air transport crashes between 1924 and 1981.[12] In 1931, a Transworld Airlines Fokker F-10 carrying Notre Dame football coach Knute Rockne and seven others crashed and was investigated by the Aeronautical Branch of the Department of Commerce. No attempt was made to secure the scene. By the time the investigators arrived on the scene the following day, only the two wings and propeller-less engines remained. The local coroner, a physician, examined the bodies and identified them by an external examination and by personal effects.

The team of investigators did not use his autopsies, which contained noteworthy data for modern day aerospace pathologists. The team's account, which blamed the accident on ice accumulation on the wings, was the first accident report made public by the Commerce Department. The report also grounded 35 recently built Fokkers for inspection of wing structures. This was a precedent setting action in American aviation history. Inspection of the grounded aircraft showed glue deterioration of the wooden wings, and the remaining Fokker fleet was grounded and inspected. This case and its management helped develop public confidence in and regulation of air travel. It also started the trend toward metal construction of aircraft.[13]

Transcontinental and Western Air Flight 6 from Los Angeles to New York crashed in the dense fog of Missouri on 6 May 1935. Few would have taken notice of this crash, which killed five, save that Senator Bronson M. Cutting (R-New Mexico) was among the dead. The U.S. Senate quickly authorized the Committee on Commerce:

> To investigate (the crash) and any other accidents or wrecks of airplanes engaged in interstate commerce in which lives have been lost; and to investigate interstate air commerce, the precautions and safeguards provided therein, both by those engaged in such interstate air transportation and by official or department of the U.S. Government; and to investigate the activities of those entrusted by the Government with the protection of property and life by [*sic*] air transportation, and the degree, adequacy, and efficiency of supervision by any agency of Government including inspection and frequency thereof.[14]

This solidified federal interest in aircraft accident investigations, and exploration into mechanical causes of crashes progressed.

The first published accident report in the United Kingdom was in 1939. On 21 January, an Imperial Airways flying boat was lost over the Atlantic Ocean suffering from carburetor icing. Ten of 13 survived for 10 hours in the sea before being rescued. After public pressure forced release of the report, the ministry directed action to improve hot air control of carburetors. Other board recommendations for life rafts and pre-flight briefings for passengers were ignored.[15]

It was not until the 1950s, with several mysterious crashes of British Comets (new pressurized jet-powered aircraft), that the value of medical input to mishap investigation gained recognition. The first Comet crashed on 10 January 1954, with 35 persons on board 25 minutes after leaving Rome, Italy, en route to London, England. A second crashed en route to Cairo, Egypt, from Rome on 8 April with 21 persons on board. Both aircraft crashed into the sea leaving no apparent indications why. Postmortem examinations of the passengers and crew who floated to the surface enabled pathologists to speculate that an explosive decompression had occurred.[16] These findings led investigators to discover the Comet's deficient hull strength, unable to withstand the pressure differential between the cabin and atmospheric pressure at high altitude.[17] The Comet disasters marked the beginning of aerospace pathology, and soon thereafter, Departments of Aerospace Pathology were set up in both the U.S. (at the Armed Forces Institute of Pathology [AFIP]) and in the United Kingdom (at the Institute of Pathology and Tropical Medicine). The U.S., Canada, and Great Britain formed the Joint Committee on Aviation Pathology in 1955.[18] An emerging literature issued from this advance, and many are listed as either footnotes or references at the end of this section. Still, autopsies in conjunction with aircraft accident investigations were sporadic and sometimes very abbreviated.

The evolution of jumbo jets, airliners capable of

carrying well over 300 passengers, amplified mishap casualty rates. Mass disaster took on a new meaning with the collision of two Boeing 747 airliners at Tenerife, Canary Islands, on 27 March 1977. The pragmatic and logistical dilemma of managing greater than 580 fatalities altered tenets of the accident investigation process. Medical investigators faced an additional challenge of identifying large numbers of remains obscured by charring, fragmentation, and commingling.

The first completely successful identification of mass disaster remains took place after the U.S. Army's 101st Airborne Division (Air Assault) lost 248 soldiers and eight crew on a contract DC-8-63 airliner in Gander, Newfoundland, on 12 December 1985. This accident marks the first successful use of the exclusion matrix method of victim identification in aircraft mass disasters.[19] Various other disciplines became enrolled in the investigation such as anthropologists, computer programmers, dentists, and radiologists.[20] Aerospace pathologists adopted techniques for accident investigation used in other modes of public transportation and modified them to fit the aviation mishap. At Dover Air Force Base, DE, where the team performed the identification and autopsies of the Gander victims, investigators used a system of 10 consecutive workstations to process remains.[21] Also, for the first time, researchers studied the health status, in particular, the post-investigation psychological well being of the investigators and their assistants.[22] The use of such "mainstream" techniques was very evident in the TWA 800 crash investigation in New York in 1997. Investigators reconstructed over 90% of the aircraft from the wreckage, and a long identification phase of passenger remains ensued.

After the explosion of the Space Shuttle Challenger mission 51-L shortly after launch on 28 January 1986, staff from the AFIP underscored the "space" component of Aerospace Pathology and participated in that controversial investigation. The official presidential commission report is silent on medical input to the findings.[23] Speculation remains on the exact time and cause of death and how long they were conscious post explosion.[24]

Challenges for the future include: the increased chance of midair collisions in the crowded skies and an aging commercial fleet with aging pilots. The role, if any, of cardiovascular disease, crew coordination, terrorism, human immunodeficiency virus positive pilots, exotic diseases, and other factors are still unknown.

Why investigate aircraft accidents and incidents? The military has lead the way in privileged investigations trying to get to the "ground truth" to improve flight safety. Governments want to regulate the aviation industry to ensure public health, safety, and welfare, as well as guard against international or homegrown terrorists and weapons of mass destruction. Survivors of those who died in aircraft crashes want evidence for litigation in the courts with claims for damages. Finally, the general public has a morbid curiosity about death and catastrophe, and this boosts newscast ratings.[25]

The supplemental role of aerospace pathology, the function of medical investigation, and the contribution of human factors in aircraft accident investigation is now well established. It still, however, lacks unity and a uniform process. Publications such as this can only help.

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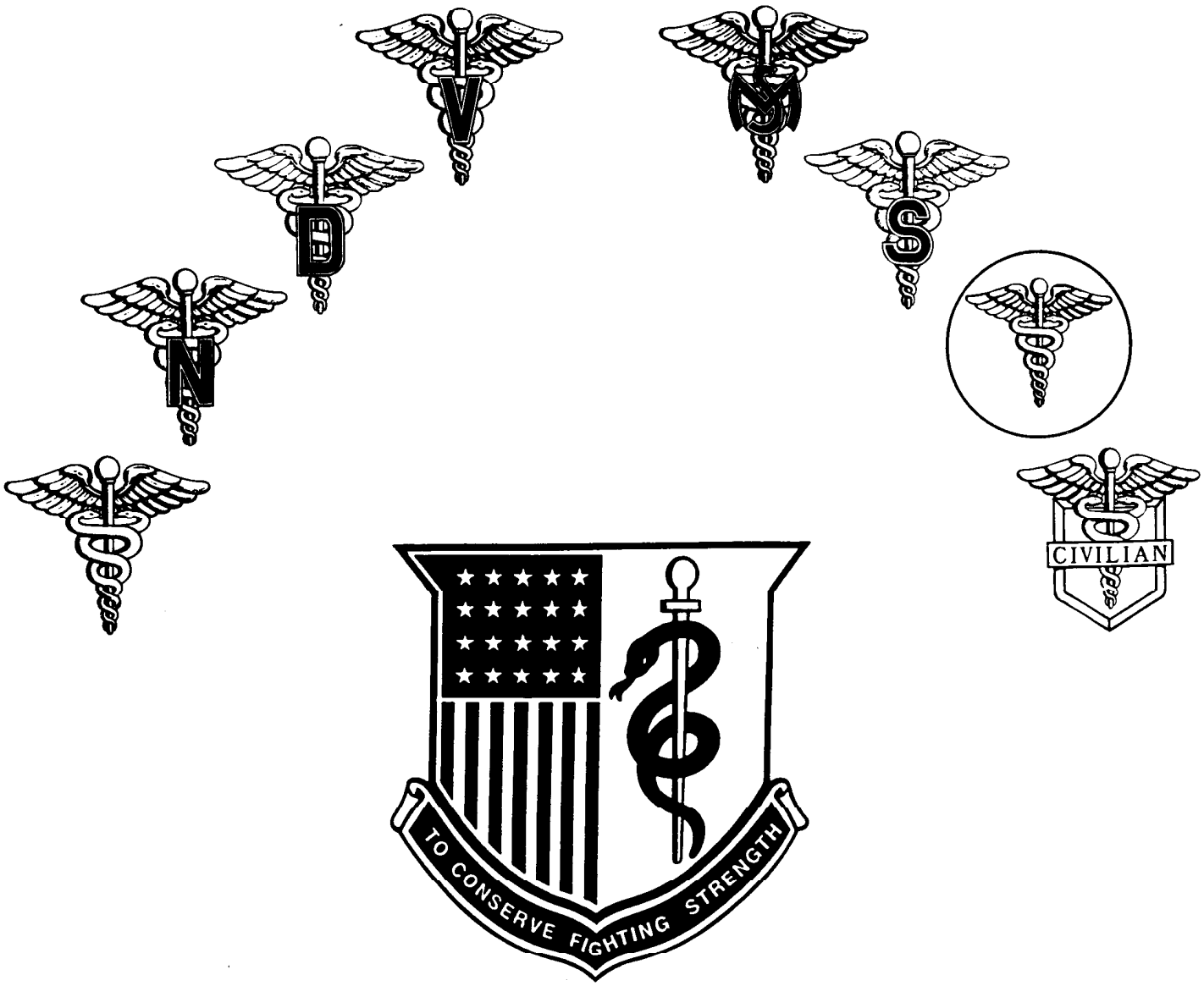
TO CONSERVE FIGHTING STRENGTH

Combat Medic Prayer

Oh Lord, I ask for the divine strength to meet the demands of my profession. Help me to be the finest medic, both technically and tactically. If I am called to the battlefield, give me the courage to conserve our fighting forces by providing medical care to all who are in need. If I am called to a mission of peace, give me the strength to lead by caring for those who need my assistance. Finally, Lord, help me to take care of my own spiritual, physical, and emotional needs. Teach me to trust in your presence and never-failing love.

Amen



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