Abstract

Evolutionarily, man is a terrestrial mammal, adapted to land. Aviation and now space/microgravity environment, hence, pose new challenges to our physiology. Exposure to these changes affects the human body in acute and chronic settings. Since skin reflects our mental and physical well-being, any change/side effects of this environment shall be detected on the skin. Aerospace industry offers a unique environment with a blend of all possible occupational disorders, encompassing all systems of the body, particularly the skin. Aerospace dermatologists in the near future shall be called upon for their expertise as we continue to push human physiological boundaries with faster and more powerful military aircraft and look to colonize space stations and other planets. Microgravity living shall push dermatology into its next big leap-space, the final frontier. This article discusses the physiological effects of this environment on skin, effect of common dermatoses in aerospace environment, effect of microgravity on skin, and occupational hazards of this industry.

Key Words: Aerospace, aircrew, air force, astronaut, occupational dermatoses

Introduction

Human physiology in its nature of evolution is adapted for land. Any change in such environment exposes skin to unaccustomed parameters which may manifest adversely early or over a period. Air travel is just another mode of travel with no longer a “luxury tag” attached to it. However, extremes of unaccustomed physiological changes encountered by aircrew and passengers in military aircraft flying at very high altitude, long-haul flights as well as those in zero gravity and interplanetary expeditions do increase the possibility of skin disorders hitherto rarely seen.

Aerospace industry exposes its workers to a unique set of occupational hazards, which may manifest with typical dermatoses. These must be recognized and managed early to prevent chronicity, permanent sequelae, and loss of person-hours. Any preexisting dermatosis shall only worsen outcome if exposed to hazards of unaccustomed environment or offending occupational agents.

Aerospace Physiology and its Effect on Skin

Earth’s atmosphere is interpreted for our easier understanding as concentric shells. Each successive shell or sphere as we move outward from the land has a lower temperature, lower partial pressure of oxygen, lower humidity, and increased levels of ozone, ultraviolet, and cosmic radiation. Human exposure to aerospace environment may occur as an aircrew or a passenger in a passenger or cargo aircraft, helicopter, as a military aircraft pilot, or as an astronaut and rarely space diving. Each of these has peculiarities which may affect the skin adversely.

Protected flight environment in transport and passenger aircraft keeps the flyers and crew safe from most of this harsh environment, and their effects are negligible in short-haul flights.

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Temperature control in the present day aircraft provides controlled environment in civilian aircraft. In military fighter and light helicopters, despite cooling, the greenhouse effect results in higher temperatures resulting in excessive sweating especially so if they are on standby on the tarmac. Good absorbent clothing and improved aircraft materials prevent this skin insult.

While flying, the cabin altitude is maintained at 8000 feet or lower to provide maximum possible comfort to the passengers and crew, while in space shuttles and the International Space Station (ISS), it is maintained at sea level, “shirt-sleeve” at all times. This protection is limited in smaller helicopters and high altitude ejections. High altitude and space flight entail increased exposure of cosmic radiation. Although studies have not found increased incidence in skin cancers in commercial flights, an astronaut may be exposed to 50–2000 mSv of ionizing radiation with a fluency rate of 1–1.8 mSv/day, during space travel, in the ISS, or on the moon with a higher exposure of 0–100 mGy/h in case of a solar particle event. Studies have utilized theoretical models for determining the malignancy risk in long space travel; their exact impact on skin is still uncertain and opinion remains divided.

With higher flying altitudes and longer duration flights, this exposure is increased. Prolonged duration in days, months, and years in times to come shall increase the risk of ionizing radiation more than the atmospheric changes.

Exposure to high $+G_z$ acceleration creates high-pressure differences across walls of capillaries, resulting in fluid transudation and petechiae from capillary rupture. These may be seen in fighter aircraft pilots who routinely “pull high Gs” commonly referred to as “G measles” over their extremities. Rupture of veins or venues may give rise to painful self-resolving ecchymosis. Exposure to $-G_z$ for a few seconds leads to eyelid puffiness and petechiae over the head and neck region. Anti-G maneuvers and anti-G suits prevent extreme positive G effects to a large extent.

Subatmospheric decompression due to exposure to sudden low atmospheric pressure and release of entrapped nitrogen in tissue may result in “creeps” characterized by itching, tingling, and numbness, accompanied in some cases by motting of skin and urticaria with persistent severe itch lasting a few days. The cabin altitude ceiling for aircraft is 8000 feet beyond which symptoms may appear. Although this holds good for civilian aircraft, in routine sorties by lighter military helicopters in high altitude areas such as Siachen and other military aircraft carrying on very long sorties with availability of mid-air refueling, this would not be possible. Hence, military aircraft resort to a maximum cabin altitude limit of 22,000–25,000 feet above mean sea level depending upon operational requirement, but with high-pressure oxygen systems on board to prevent complications. Preoxygenation or denitrogenation for 3 h before such flights and avoiding exposure to higher than one atmospheric pressure for the preceding 24 h period may help reduce the incidence.

### Occupational Dermatoses in Aerospace Industry

Aircraft industry employs a number of personnel engaged in different sectors of aircraft care. Tarmac and near tarmac duties such as air traffic controllers and maintenance staff as well as nontarmac workers are also affected. Jet fuel components, aircraft batteries, aircraft components, and several chemicals, all serve as irritants or allergens to the skin. Since Lounsberry in an early review of occupational dermatoses in airline industry highlighted the dermatoses arising from contact with duralumin covered with fish oil and chromic acid, many such agents have been described. These include N-phenyl-l-naphthylamine, dielectric fluids, sealants, kerosene, deicing agents, cutting oils, hydraulic fluid, and jet fuel. In a study by Jindal et al. in personnel of an air force station, 33% of occupational diseases were occupational dermatitis. A majority of these were in those engaged on tarmac duties and aircraft maintenance.

Aircrew has been reported to develop allergic contact dermatitis to flight gloves, hearing muffs/headphones. Ultraviolet light has been shown to cause photodermatoses in aircrew as well as ground crew. Improved materials in aircraft have reduced the incidence in aircrew; however, ground crew exposed to prolonged duration on the tarmac must be protected with adequate amounts of sunscreen. Limiting duration of exposure shall also help in reducing this hazard.

The author has encountered allergic contact dermatitis in those exposed to cutting oils, jet fuel, and irritant contact dermatitis in those working in battery rooms. Polymorphous light eruption has been the next common dermatoses encountered mainly in those employed on tarmac duties and helicopter pilots. Preventive measures with protective gear and regular use of sunscreens have reduced their incidence.

### Aeromedical Concerns of Coexistent Dermatoses

Dermatoses not necessarily precipitated by the act of flying or exposure to flying environment may coexist in this population. These may be precipitated or occur independent of the environment. Once present, they have a definite bearing on the affected population. Flying or exposure to airline industry environment may worsen it, resulting in a constant distraction with...
impaired performance, increased morbidity, and loss of crucial person-hours. Severe skin conditions may debar a person for joining this field or may result in grounding of pilots/aircrew or disqualification from service of any of these including ground personnel. The implications of commonly encountered dermatoses in flying are further elaborated.

**Acne vulgaris**

Active severe nodulocystic acne at entry level is a cause of rejection from active military service as they may interfere with flying or exacerbate in the hostile environment this personnel is exposed to. Acne lesions on the face interfere with wearing of masks, respirator seals, and helmet straps. Lesions on the shoulders and back cause discomfort when sitting for a long time. Use of oral medication in military flying is discouraged, especially so for antibiotics such as minocycline (increased incidence of vertigo), isotretinoin (decreased night vision, association with corneal opacities, inflammatory bowel disease, hyperlipidemic states, musculoskeletal symptoms, pruritus, epistaxis, and xerosis), and spironolactone in cases of polycystic ovarian syndrome.

**Atopic dermatitis and other eczematous dermatitis**

Cockpit environment although controlled for temperature and pressure may nevertheless expose the pilots to low humidity, higher or lower temperatures, depending on the aircraft and flying environment, especially so in military aviation. Atopic dermatitis usually manifests early in life and may persist with a chronic relapsing and remitting course with a high degree of morbidity. Persistent itching, dry skin, acute exacerbations, and association with other atopic disorders make these individuals unfit as aircrew if it persists beyond late childhood. Contact dermatitis in aircrew had reduced from when it was initially noticed, owing to the improved materials used in aircraft industry. The author does however face occasional with allergic contact dermatitis to helmets and gloves. Contact dermatitis as mentioned earlier is commoner in personnel engaged in aircraft maintenance. Seborrheic dermatitis may persist as a constant irritant and interfere with wearing of helmet.

Management with oral medications such as systemic corticosteroids, other immunosuppressives, and antihistamines are not conducive to military aviation. Oral nonsedative antihistaminic such as fexofenadine and loratadine may be allowed under certain conditions. Topical therapy is allowed with generous hydration of skin in atopers.

**Urticaria**

Urticaria and angioedema threaten to distract and incapacitate aircrew in situations which may need critical decisions and hence threaten the very nature of any mission. Aircrew is grounded during the acute episodes till the event subsides.

Unpredictability of idiopathic urticaria makes their fitness for flying questionable. Cold urticaria, angioedema, and a history of anaphylaxis are considered as causes of permanent unfitness. Use of antihistamines is elaborated above.

**Psoriasis**

Among dermatological disorders under consideration, psoriasis by its high incidence, usually a later onset in life, relapsing and remitting course, involvement of palms, soles, and scalp, and persistence for a long duration, probably has the most severe impact on military flying. The causes of concern are the usual with any dermatological disorder such as wearing of aviation clothing and equipment, discomfort, more so if a larger body surface area is involved, and Köebner’s phenomenon. Excessive operational flying which military pilots are exposed to in war, war-like scenarios, and natural calamities worsens psoriasis by repeated trauma to skin as well as joints.

Management considerations from aeromedical point of view place topical therapies which are nonirritant as safe. Topical calcineurin inhibitors are not approved in military aviators due to subclinical neurotoxicity; oral photochemotherapy is contraindicated along with immunosuppressives such as methotrexate, sulfasalazine, and tumor necrosis factor alpha (TNF-α) inhibitors. Narrowband ultraviolet B phototherapy is well tolerated, topical therapy with emollients, tar if nonirritant, calcipotriene, and limited use of topical steroids.

Limited psoriasis by itself is not unfit for flying, but such aviators must be carefully screened annually for symptoms of joint involvement by their squadron medical officers.
Others

All other skin disorders must be evaluated by a dermatologist/aviation medicine specialist to ascertain its impact on the aircrew/ground personnel, their restriction on duties and treatment.

The author manages aircrew with topical therapy for the above dermatoses. While on systemic therapy, aircrew is grounded temporarily and placed back in flying duties after treatment. Recalcitrant disorders such as severe atopic dermatitis, recurrent contact dermatitis, palmoplantar hyperhidrosis (Figure 2), and actinic dermatitis have led to permanent excuse from flying in aircrew and change of trade duties in ground maintenance staff.

Space Dermatology

Importance of skin care in space was initially recognized and a Space Dermatology Foundation was set up and was active from 1986 to 1993.²⁵ Effect of space environment on the skin and other systems is a topic of research as it is now more than ever that humans look to colonize other planets and stay longer in space stations.

Skin changes in space

Space age has resulted in exposure of astronauts and space tourists to conditions of very low gravity ranging from $1 \times 10^{-4}$ to $1 \times 10^{-5}$ G known as microgravity.²⁶ Mars visitors and inhabitants shall be exposed to 0.38 G. Hypergravity situations are experienced during conditions of lift off and landing by astronauts (less than a half hour up to 3.2 G during takeoff and 1.4 G on re-entry) and briefly by air force jet pilots. Although skin changes are observed in persistent hypergravity in experimental conditions, these are currently of limited importance in clinical dermatology since hypergravity exposure is for limited time only. Other skin changes as elaborated above in jet pilots on exposure to +G forces may be seen in astronauts too.

Microgravity results in physiological changes in the skin. Space induced skin thinning and loss of elasticity was initially described by Tonnier et al. in 2006.²⁷ This was later confirmed by König using multiphoton tomography who demonstrated epidermal thinning in astronauts after long-term space flights,²⁸ which may reduce to 30 μm at the end of 6 months and even further after a year on Mars. Epidermal thinning exposes lower layers to low-wavelength ultraviolet and cosmic radiation which otherwise do not penetrate deeply. This increases chances of cutaneous malignancy. In contrast, dermal collagen increases by up to 143%. These changes were reported to be reversible after return to earth (1 G environment).²⁹

Fluid shifts and edema have been reported in long-haul aircraft flights.³⁰ Such changes can be expected to occur in long space flights. Lowrey et al. reported hypersensitivity of skin receptors found in astronauts postlanding.³¹ These have been postulated to be compensatory to the reduced vestibular inputs in microgravity situations.

Cellular and immunological changes in space

Spacelife even for short duration is known to alter immune reactivity and induce cellular changes. Cellular activation may be reduced in microgravity,³² alterations in cell signaling, apoptosis, stress response, adhesion molecule regulation have been demonstrated.³²,³³ Complement levels display changes with elevation of C3 and immunoglobulin A, M, and G are elevated, interferon alpha are raised, and interferon gamma are reduced; CD4/CD8 ratio is lowered, with reduced interleukin levels and reduced TNF-α.³⁴,³⁵ All these changes on account of microgravity and low-dose ionizing radiation exposure lead to an altered response to inflammation and infections.

Infections

Personal hygiene needs special attention in view of limited supply of water.³⁶ Skin infections hence are a possibility and may occur as a consequence of activation of latent infections.³⁷ Contributory factors include enhanced virulence of microbial flora,³⁸-⁴⁰ increased biofilm formation,³¹ immune system dysregulation with an altered immune response and cellular changes. Confining living conditions in space travel, space stations, and future “away from earth-human colonies” increase the chance of transmission of infection between individuals as direct transmission, aerosols, or contact with free-floating condensates.³³-⁴⁶

Space dermatoses

With the evolution of space dermatology, the number of dermatology disorders reported shall only increase. So far, their numbers continue to be limited with reports of contact dermatitis, recurrent palmoplantar peeling, fissuring of fingertips, and dermatophytosis.³⁷,³⁸ The challenges of clinical diagnosis can be overcome to an extent with teledermatology, but on board
staining of biopsy, specimens and surgeries will pose a challenge.[49,50] Management with gels and powders are restricted due to their inflammability and inhalation potential. Drugs’ pharmacokinetics continue to be under investigation.[51,52] Recognizing possible increase in space travels, a space passenger task force laid the guidelines in 2002 wherein any skin disease which interferes with life support equipment and communicable diseases were considered not safe for space travel.[5,53]

Conclusion
Skin reflects our physical and mental health. Skin diseases had been considered in the past to be not of important aeromedical significance. However, their potential to interfere with safe aircraft and space environment assumes significance as even split second distraction to a jet pilot or spacecraft crew may assume serious proportions if unchecked. Noncommunicable cutaneous disorders in aircraft passengers do not generally affect travel. This shall not hold true with space travel as dermatology care may not be available at hand. Aerospace dermatology hence now assumes importance more than ever and dermatologists must be aware of these.

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Conflicts of interest
There are no conflicts of interest.

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