Chapter 6

THE OTOLARYNGOLOGIC ASPECTS OF AEROSPACE MEDICINE

INTRODUCTION

Atmospheric pressure changes occur under a variety of conditions and circumstances. Military aircraft may ascend vertically faster than a mile a minute, maintain altitudes over 50,000 feet, and dive at speeds in excess of 10 miles a minute. If a parachute jumper delays opening his chute, he may attain a rate of descent approximating 10,000 feet per minute. Elevators in large office buildings ascend and descend at rates approaching 1,000 feet per minute. Day-to-day weather variations may produce pressure changes approximating a few hundred feet of ascent or descent.

When a cavity (such as a sinus) with a small opening to the exterior is moved through environments of different barometric pressures, equilibrium between the gas inside and outside the cavity will be established with a speed that will depend upon the size of the opening and the extent of change in pressure. This principle follows the laws of gaseous expansion and compression (Boyle's Law). The degree of expansion depends on the difference in density or pressure of the gas inside and outside a given chamber, and on the elasticity of the walls of the chamber.

Within limits, a closed expansible chamber, such as a rubber balloon, will vary in size as it ascends or descends until equilibrium of pressures is established. One volume of a dry gas at sea level becomes two volumes at 18,000 feet, three volumes at 28,000 feet, four volumes at 33,000 feet, and five volumes at 38,000 feet. On descent, the volume changes are reversed. When exposed to the flight environment, a rigid-walled cavity communicating with the outside is not expected to vary in size because pressure equilibrium will be established through its opening at all altitudes.

BAROTITIS MEDIA

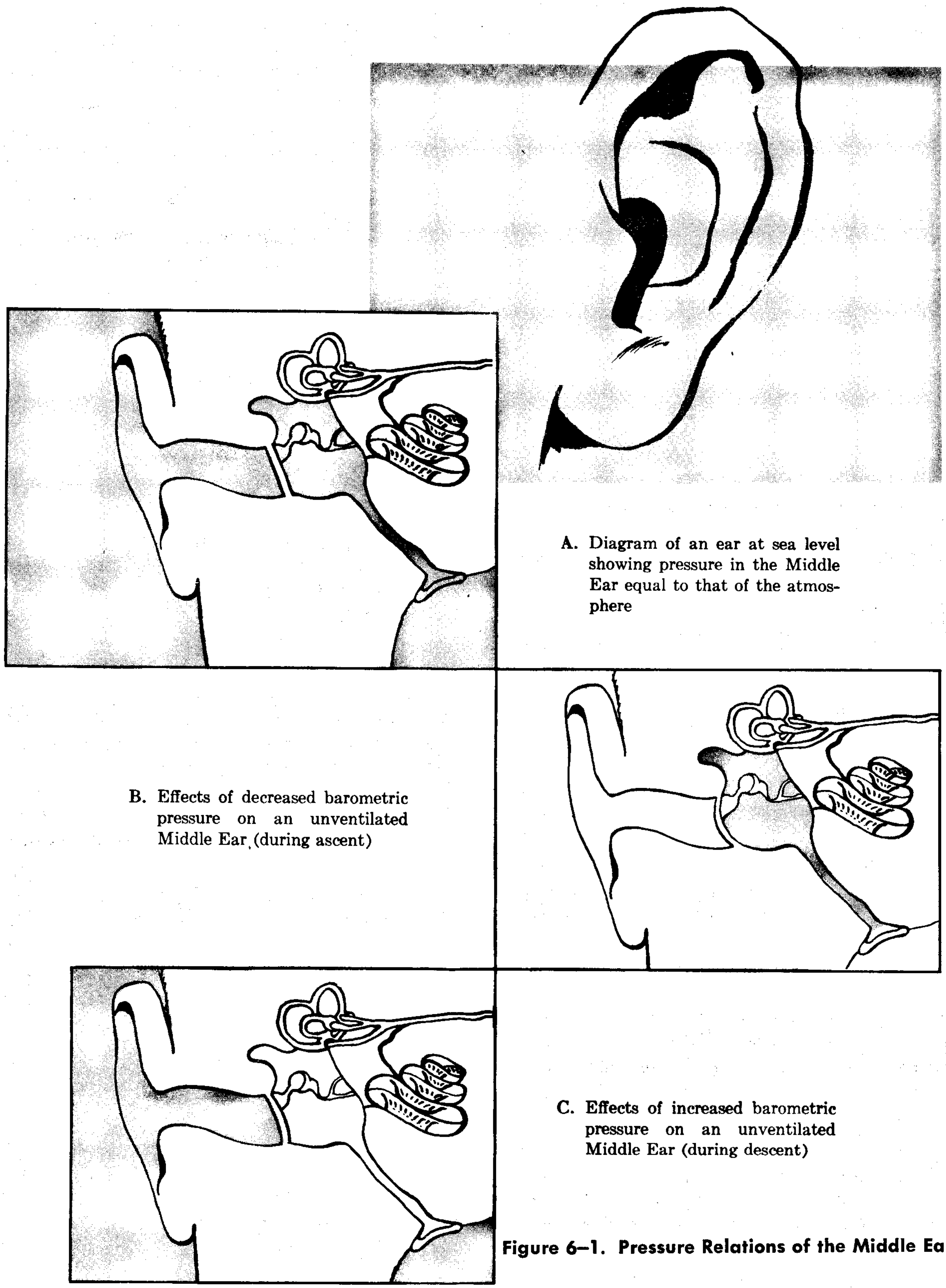
Barotitis media is an acute or chronic traumatic inflammation caused by pressure difference between the air in the middle ear and that of the surrounding atmosphere.

Structural Considerations—Anatomical

The middle ear is a membranous-lined, bony cavity, ventilated through the eustachian tube, with a thin, semielastic partition externally (tympanic membrane). The eustachian tube is a bony channel extending from the middle ear which unites with a membrano-cartilaginous channel extending from the nasopharynx. Normally, the tube is closed because of mucosal irregularities and cohesive mucosal surface. It reacts similar to a flutter valve and only opens via swallowing, yawning or yelling when the tensor and levator veli palatini muscles contract. The levator veli palatini arises partially from the medial lamina of cartilage of the auditory tube, and the tensor veli palatini arises partially from the lateral wall cartilage of the auditory tube. Consequently, when these muscles contract, they open the eustachian tube. Limited displacement of the tympanic membrane allows for some equalization of pressure, but this averages only 100 to 300 feet atmospheric pressure change.

Physiology

Ascent. From sea level to 110 to 180 feet altitude, 3 to 5 mm Hg pressure change occurs and produces slight fullness in the ear. The tympanic membrane bulges slightly and the pressure increases until 500 feet (15 mm



A. Diagram of an ear at sea level showing pressure in the Middle Ear equal to that of the atmosphere

B. Effects of decreased barometric pressure on an unventilated Middle Ear (during ascent)

C. Effects of increased barometric pressure on an unventilated Middle Ear (during descent)

Figure 6-1. Pressure Relations of the Middle Ear.

Hg pressure change) when a sudden "click" is heard and felt in the middle ear. At that time, the tympanic membrane snaps back to near normal as increased pressure in the middle ear forces air out. From that point on, the cycle is repeated with the exception that "clicks" occur at approximately 11.4 mm Hg (435 feet altitude). Eustachian tube opening requires approximately 15 mm Hg excess pressure at sea level. The tube remains open until pressure is reduced to 3.6 mm Hg when it again closes to retain 3.6 mm Hg (130 feet altitude) excess pressure in the middle ear. From then on, there is 11.4 mm Hg differential, but this decreases to 3.5 mm Hg at 40,000 feet. This can probably be explained on the basis of rarified or less dense air passing more readily through the eustachian tube. This is variable between individuals, but average figures for a given individual remain constant in multiple tests.

Descent. On descent, a totally different problem exists. The eustachian tube acts as a flutter valve and remains closed under all degrees of pressure (one subject tested to —470 mm Hg) unless actively opened by muscle effort or high positive pressures. Voluntary opening of the eustachian tube equalizes all pressure completely. However, after negative pressure of 80 to 90 mm Hg or more develops, it is unlikely that the eustachian tube muscles will overcome it and ascent is usually necessary to allow a patient to open the tube.

Etiology

Barotitis is usually the result of failure of ventilation of the middle ear on changing from low atmospheric pressure to high atmospheric pressure. A cold or upper respiratory infection is the most common cause. Swallowing normally occurs several times a minute during waking hours and once every 5 to 7 minutes during sleep, thus relieving or equalizing pressure. Failure to relieve pressure during a letdown from altitude may be due to ignorance or carelessness.

Pathology

Negative pressure in the middle ear (similar to application of a suction cup on soft tissue) results in a partial vacuum, vascular engorgement, and serosanguineous transudation and exudation into the tympanic cavity. This partially neutralizes pressure and leads to relief of tension on the collapsed eustachian tube. Pinpoint ecchymotic areas appear on the periphery of the tympanic membrane when hemorrhage by diapedesis occurs along the course of arteries of the malleus.

ACUTE BAROTITIS MEDIA

Acute barotitis media is an acute traumatic inflammation of the middle ear caused by pressure differences (either positive or negative) between the air in the middle ear and that of the surrounding atmosphere, and characterized by pain, deafness, tinnitus and, occasionally, vertigo.

Symptomatology

Ascent. A 3 to 5 mm Hg differential pressure is perceptible as a mild fullness in the ear; 10 to 15 mm Hg is perceptible as fullness, mild decrease in hearing and annoying discomfort; 15 to 30 mm Hg results in increased discomfort, possibly tinnitus, pain and mild vertigo; and over 30 mm Hg causes increased tinnitus, vertigo, and unbearable pain. Normally, 15 mm Hg pressure will force air out through the eustachian tube, thus relieving symptoms.

Descent. Pressure in the ear becomes relatively negative and is seldom relieved through its own force because of the flutter-valve-like action of the eustachian tube. At almost 60 mm Hg negative pressure, pain is severe and resembles that of acute otitis media. Tinnitus is marked and there is usually vertigo with the beginning of nausea. A 60 to 80 mm Hg negative pressure causes severe pain which radiates from the ear to the temporal region, the parotid gland and, occasionally, to the mastoid process. Deafness is marked, and vertigo and tinnitus usually increase. At a differential pressure of 100 to 500 mm Hg, the tympanic membrane ruptures, a loud sound is heard, and there is a sharp piercing pain, vertigo, nausea, and possibly collapse or generalized shock. After rupture, the pain decreases quickly and the nausea and vertigo subside. An 80 to 90 mm Hg differential pressure is usually impossible to overcome by muscular action, such as swallowing or performance of the Valsalva maneuver, and it is necessary to return to higher altitude to clear the ears. If trauma has occurred, opening the eustachian tube does not necessarily relieve all symptoms. Moderate trauma is followed by a sense of soreness in the ears and deafness lasting for several hours. Severe trauma is followed by pain, deafness, vertigo, and tinnitus for several days and perhaps up to 2 weeks.

Common signs in order of increasing severity are: a. Initially depressed tympanic membrane; b. inflamed tympanic membrane, pink-tinged or angry red; c. petechial hemorrhage; d. serous otitis media to hemotympanum; and e. perforation of the tympanic membrane.

Treatment

Swallowing, chewing gum, use of nasal vasoconstrictors, such as neo-synephrine, or performance of the Valsalva maneuver often proves effective, however, a return to higher altitude with gradual descent while performing the Valsalva maneuver should be accomplished if possible.

For a depressed tympanic membrane, myringotomy or politzerization should be done. Either the politzer bag or a source of compressed air may be used. For the bag method, the olive tip is placed in one nostril, the nose is compressed between the physician's fingers, and the patient is then instructed to swallow or say "kick, kick, kick, kick" while the bag is squeezed, increasing the pressure in the nasopharyngeal cavity. If compressed air is used, the pressure is turned down very low (beginning with 1 and never exceeding 6 pounds per square inch of pressure) and an olive tip, connected by a short hose to a bottle which, in turn, is connected through a thumb-operated valve to the compressor, is used. The nose and olive tip are compressed between the fingers, similar to the bag method, and the valve is closed by the thumb of the opposite hand. It may be necessary to increase the pressure gradually and carefully several times until air enters the middle ear via the eustachian tube.

For serous otitis media, politzerization usually helps very little. Myringotomy should be done only if the patient complains bitterly about deafness and stuffiness, since the serous otitis media will most likely recur after the drum heals.

For hemotympanum, treat conservatively.

For perforation of the tympanic membrane, treat conservatively; keep the ears dry and avoid local treatment.

RECURRENT BAROTITIS MEDIA

Recurrent barotitis media is a recurrent barotitis due to chronic eustachian tube obstruction, secondary to pathology in either the nose or nasopharynx.

Etiology

The most common causes of recurrent barotitis media are: Hypertrophied adenoids, allergic rhinitis, chronic granular pharyngitis, stenotic eustachian tube, Gerlach's tonsils, sinusitis, and deflected nasal septum.

Treatment

Treatment should be directed toward resolving the primary problem.

DELAYED BAROTITIS MEDIA

Delayed barotitis media occurs following the breathing of 100% oxygen for a time and refers to that condition in which an aircrewmember has no difficulty in ventilating his ears during flight, but develops signs and symptoms suggestive of acute barotitis several hours later. Personnel who fly in certain jet aircraft equipped with a system that delivers 100% oxygen, from the beginning to the end of the flight, are most prone to develop delayed barotitis. The condition occurs less frequently and symptoms are rarely severe in jet aircraft equipped with a diluter-demand oxygen system.

The victim of this condition usually terminates a flight in the late evening hours or during the night and is asymptomatic at that time. A short while later, he retires and is awakened in the early morning hours with a sensation of one or both ears being "stopped up" and frequently painful. Upon examination, the tympanic membrane appears the same as in acute barotitis media—retraction, hyperemia, and possibly fluid in the middle ear.

Physiology

The physiological mechanism involved in delayed barotitis media is assumed to be that of oxygen absorption from the middle ear. While the pilot is awake, he swallows several times a minute, and when asleep, he swallows once every 5 to 7 minutes. Thus, the eustachian tube opens more frequently during the waking hours and serves to equalize any negative pressure that may develop in the middle ear. With the infrequent swallowing associated with sleep, the negative pressure may become of such magnitude that the eustachian tube does not open during the swallowing maneuver.

The total pressure of gases in venous blood is 706 mm Hg. The partial pressure of oxygen in venous blood is 40 mm Hg. The partial pressure of 100% oxygen in the middle ear at sea level is approximately 760 mm Hg. Thus, there is partial pressure of oxygen in the middle ear about 54 mm Hg greater than in the venous blood. Only a few seconds are required for oxygen absorption to take place. As the oxygen is absorbed, the ambient atmospheric pressure of 760 mm Hg forces the tympanic membrane inward and thus, causes pain. Remember that not only the middle ear, but also the entire mastoid cellular structure is filled with 100% oxygen after breathing it for several hours.

CONCLUSION

Careful examination during the selection process will eliminate from flying many men who experience difficulty in ventilating the middle ear. Aircrewmembers should be taught the simple facts about cause, effect, and prevention of barotitis media. Exposure to marked barometric pressure changes should be avoided when the function of the eustachian tube is embarrassed to any degree. The Flight Surgeon's warning, "Do not fly when you have a cold or a sore throat!," is hard to get across when experience has taught us that many people can and do fly without sustaining discomfort in the ears. The loss of the services of an aircrewman for a few days, as the result of a severe cold, is far less detrimental to operational activities than the loss of his services for weeks or even months because of barotitis media.

The following principles of treatment are recommended:

a. Do not put anything in the external ear canal to relieve pain. It is not effective and makes examination of the tympanic membrane difficult.

b. Be conservative and keep in mind that the objective of your therapy is the restoration of the normal pressure gradient between the middle ear and ambient atmosphere.

c. Direct your therapy toward the nasopharynx and the eustachian tube.

d. Be gentle! The mucous membrane is delicate. Do not add to the existing trauma by rough handling.

e. Restore the middle ear physiology to normal as quickly as possible.

From these principles, it is obvious that treatment is essentially conservative. Acute symptoms may be relieved immediately with the voluntary opening of the eustachian tube in the act of swallowing or performance of the Valsalva maneuver. In cases where pressure has already produced trauma, introduction of air into the middle ear cavity will not necessarily relieve the symptoms of trauma; they may persist until recovery has taken place. Pressures that may be only uncomfortable at first may finally become painful. A safe and simple method for the rapid inflation of the middle ear is politzerization.

Aircrewmen should be placed on duty not involving flying while they have active barotitis media. Treatment of any conditions which predispose to development of barotitis is essential.

BAROSINUSITIS

Barosinusitis (sinusitis due to barotrauma) is an acute or chronic inflammation of one or more of the nasal accessory sinuses, caused by pressure differences (usually negative) between the air in the sinus cavity and that of the surrounding atmosphere. The condition is characterized by severe pain in the affected region.

Etiology

When the sinus is normal and the ostium is patent, free flow of air between the cavity and the exterior, resulting from a difference in pressure between the air in the sinus cavity and the surrounding atmosphere, brings about equilibrium during ascent and descent without sensation of change of structure (see figure 6–2). However, during the flow of air, several untoward events may occur. Fluid, mucus, pus or similar substances may enter the ostium, along with the air, as outside pressure is increased (see figure 6–3). Obstruction of the ostium by redundant tissue or anatomical deformities may prevent equalization of pressure (see figure 6–4). If blockage of the ostium by swollen tissues or anatomical deformities does occur, the relative pressure of the cavity is positive on ascent and negative on descent. Barosinusitis is usually frontal, but it can involve any of the sinuses.

Symptoms and Signs

The occurrence of pain with barosinusitis on ascent is far less frequent than on descent. The pain is severe and, in agreement with the accepted view of referred sinus pain, is usually localized in the frontal region. Local tenderness over the sinus is often present and persistent. A sucking noise high up in the nose is described by some patients and is often thought to be indicative of submucosal hemorrhage. Occasionally, a patient will exhibit lacrimation. Purulent and mucopurulent discharge will be seen in a great number of patients. Roentgenography gives the most reliable evidence of a sinus lesion (thickened lining, polyps, opacity) but does not clearly differentiate the contributory

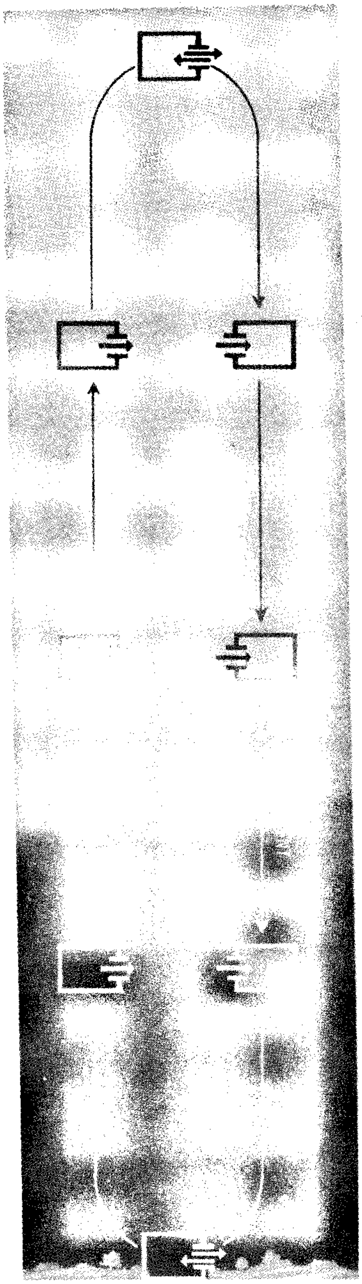


Figure 6–2. Barometric Adjustment Within the Sinus on Change of Altitude.

On ascent, adjustment of sinus pressure is made by escape of air from the sinus. On descent, adjustment of sinus pressure is made by entry of air into the sinus.

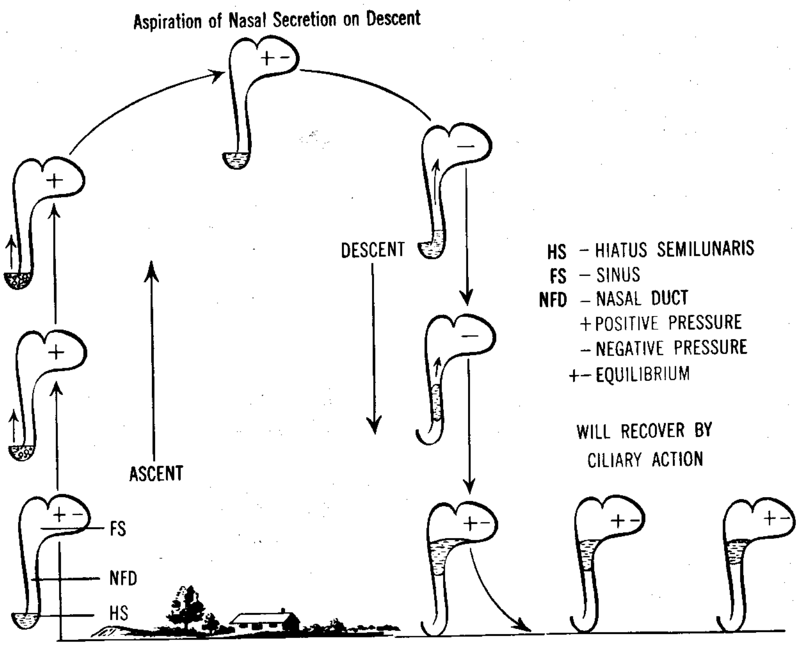


Figure 6-3. Frontal Sinus During Flight.

factors of preexisting disease or anatomical abnormality from the result of barotrauma.

Treatment

The immediate treatment of barosinusitis is reascent until the air pressure within the sinus is the same as that of the outside atmosphere. Subsequent descent should be as gradual as possible, thus affording every opportunity for pressure equilibrium to take place. In the treatment of barosinusitis, the following should be kept in mind: Time will cure a great percentage of the cases, but it is cruel to allow time to be the only therapy in your armamentarium. Barosinusitis is produced by mechanical blockage, and mechanical measures must be taken to overcome the condition. Thorough intranasal shrinkage is a must, with particular attention devoted to the areas beneath the middle turbinates. Analgesics should be employed if pain is severe. Systemic vasoconstrictors are necessary in addition to intranasal shrinkage. When shrinkage of the nasal mucosa by means of sprays and packs to the middle meatus is ineffective, the middle meatus should be anesthetized with a local anesthetic and the middle turbinate infracted. Normally, infraction is beyond the expected capabilities of the average Flight Surgeon and should be done by a qualified specialist except in the most unusual circumstances. The procedure for infraction consists of inserting a narrow instrument, such as a submucous elevator, into the anterior portion of the middle meatus and, with firm pressure toward the midline, fracturing the turbinate bone. It is necessary to fracture at least the anterior half of the middle turbinate and move it toward the midline since the ostia to the sinuses are located in this area. The goal of treatment is restoration of sinus physiology and equalization of pressure as quickly as possible. If conservative methods are ineffective, the maxillary sinus should be entered with a cannula through the natural ostium, or with a needle through the inferior meatus. If the attack is precipitated by the edema attending an infectious process in the upper respiratory tract, appropriate antibiotics should be employed in addition to the preceding measures. If the condition is not alleviated within 24 hours and the physician has reached the limit of his experience, the patient should be placed in the hands of the nearest otolaryngologist.

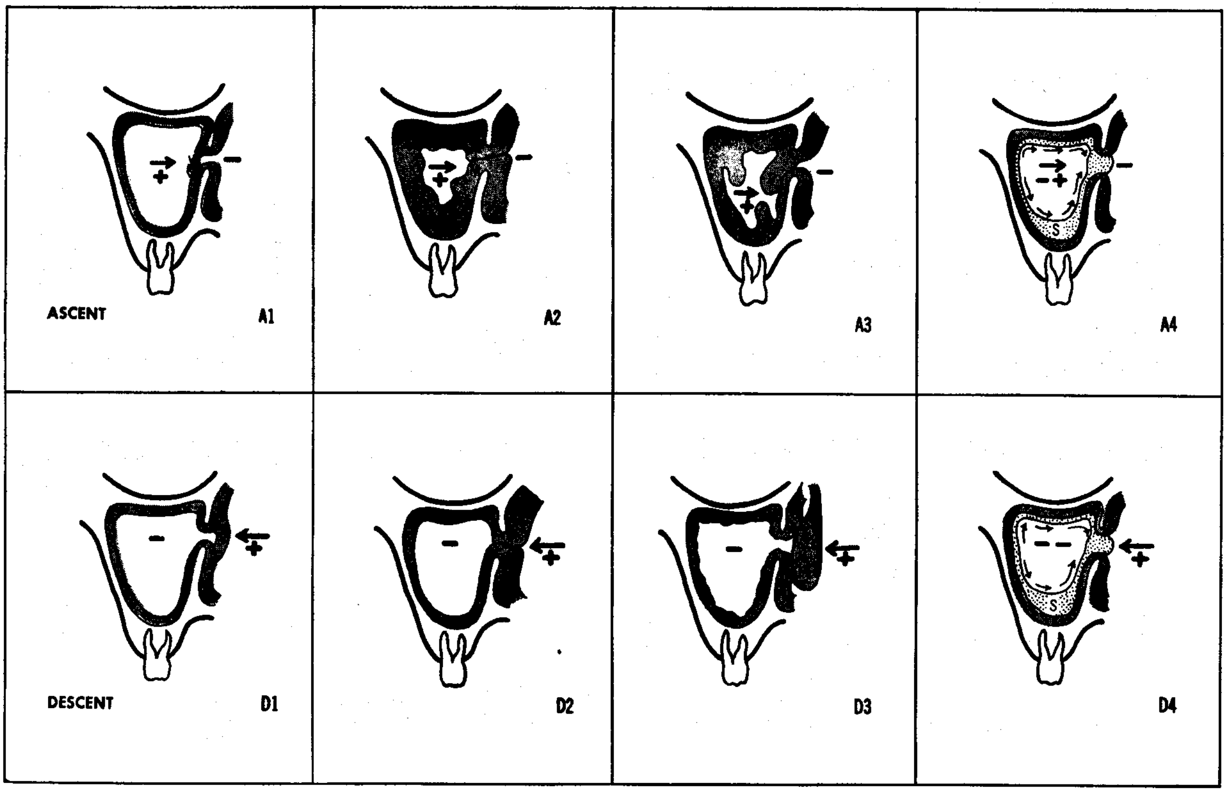


Figure 6–4. Occlusal Factors in Maxillary Antrum in Flight.

A. During ascent any valvular formation within the sinus cavity will prevent the exit of air from the sinus as the atmospheric pressure decreases. D. During descent and increase of atmospheric pressure similar formations on the nasal side of the ostium will prevent the entrance of air into the sinus. A. Ascent A 1. V—Developmental flap-valve formation of sinus mucous membrane. A 2. M—Swelling of the mucosa of sinus with flutter-valve effect. A 3. P—Mucosal polypus in sinus constituting a ball-valve. A 4. S—Effusion in sinus cavity acting as an exhaust-piston. D. Descent D 1. V—Developmental flap-valve formation of nasal mucous membrane with flutter-valve effect. D 3. P—Polypus presenting in nasal fossa and acting as a ball-valve. D 4. S—Effusion in sinus cavity with exhaust-piston effect. (Reproduced by the permission of Dickson, E. D. D., et al., Contributions to Aviation Otolaryngology, London, Headley Brothers, 1947.)

Prophylaxis

Primary conditions which affect the nose (septal deviation, allergy, polyps, infections) must be corrected before a candidate is qualified for flying. Temporary factors contributing to the blockage of the sinus ostia, such as an acute upper respiratory infection, are cause for grounding flying personnel until the condition has subsided. Should emergency conditions require flying when aircrewmen have an upper respiratory infection, nasal vasoconstrictors should be employed before ascent or descent.

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