EUSTACHIAN OBSTRUCTION AND OTITIC BAROTRAUMA IN AIR-CREWS OF HEAVY BOMBERS

BY

R. M. S. MATTHEWS, M.B., B.Chir., M.R.C.S.

Flight Lieut., R.A.F.V.R.

The following report is presented from the academically elementary but administratively important viewpoint of the unit medical officer because of the subject's interest and as a possible guidance to civilian practitioners in the medical administration of aerial transport in the post-war era. The paper is based on the personal observation of 66 cases during a recent 30-weeks period with a heavy bomber squadron of the Royal Air Force.

These two conditions present one of the greatest problems that beset the medical officer on a flying station. The former condition, Eustachian obstruction, is so mildly incapacitating on the ground, unless the obstruction be sufficiently severe to form a complete block, that it is difficult to imagine how much administrative trouble may result therefrom. The limitation of the flying duties of one man may mean the cancellation of a sortie by a complete air-crew. But the decision to let a man fly with established Eustachian obstruction may equally well result in otitic barotrauma—which is therefore a lesion directly attributable to Service conditions—quite apart from the man's discomfort and the inefficient performance of his duties. The following figures are eloquent. During the 30-weeks period under review 56 men suffering from Eustachian obstruction were passed as unfit for full flying duty for periods of 24 hours or more, with a total loss of 145 "man nights"—an average, therefore, of approximately 2.5 nights lost per man. But for otitic barotrauma the corresponding figures are 10 men removed for a total of 204 nights, which gives an average of 20.4 "man nights" lost.

The term "Eustachian obstruction" has been used to cover all those cases presenting a reduction in the patency of the Eustachian tubes, whether partial or absolute. Strictly, the term "Eustachian obstruction" should be confined to cases of absolute "block," but terminology here is not easy. "Eustachian catarrh" is convenient but not always pathologically accurate. The term "Eustachian tube insufficiency" has been suggested, but is cumbersome; and "insufficiency" belongs more happily to the endocrine system than to an anatomical structure. "Otitic barotrauma" is a more exact and accurate descriptive term, and refers to those cases presenting persistent abnormal drum appearances and hearing changes.

Anatomy and Physiology

Some basic facts are worthy of recall. The Eustachian tube runs downwards, forwards, and medially from the middle ear to the nasopharynx. There is a bony part derived from the skull and a cartilaginous portion which lies under the mucous membrane to produce an elevation, and the tube is narrowest at the junction of these two parts. It is lined with ciliated columnar epithelium continuous with the pharynx; in the lower end of the tube are some mucous glands, and around the orifice some adenoidal tissue is present. Medial to the tube is the levator palati muscle, and the tensor palati lies lateral thereto. The salpingopharyngeus muscle arises from the inferior side of the cartilaginous portion and, in company with the former two muscles, is inserted into the soft palate. Consequently when these three muscles contract in swallowing the lower part of the tube receives a pull outwards in three directions and so should normally open.

The tympanic membrane consists of two layers—an outer layer derived from the skin and an inner derived from the mucous membrane of the pharynx—with an intervening sandwich layer of fibrous tissue. The drum derives a nerve supply, among others, from the auriculo-temporal nerve, which also supplies the lining of the external auditory meatus, and this has an interesting practical application, as will be seen later. The drum normally appears slightly concave externally and the tubes are generally closed.

Pressure Changes

On ascent, as the atmospheric pressure falls, there is a progressive increase of pressure in the middle ear, which is eased spontaneously by the opening of the Eustachian tubes and the expulsion of a volume of air sufficient to equalize the pressure. This occurs without any discomfort, and all the subject notices is a succession of "clicks" in the ears. In none of these cases has there been any complaint of pain on the way up. On reaching and remaining at a constant altitude equilibrium between the internal and external pressure on the drum is maintained by the above mechanism. On descent the external pressure on the drum builds up, and to restore normality air must enter the middle ear. But the tubes open more readily to an increase of pressure from the aural end than to a similar increase at the pharyngeal opening, and this is where the difficulty starts.

Swallowing is the normal physiological way of opening the tubes, and is therefore the first manoeuvre tried. Certain people achieve greater success by manipulating the mandible in an antero-posterior plane or by wide chewing movements. In difficulty, however, the most universally effective method is auto-inflation, by Valsalva's method, in which there are several important points. First, the cheeks should not be puffed out, as the extra pressure is taken up in the buccal cavity, whereas it is in the post-nasal passage that the increase is desired. Secondly, the pressure should be slowly built up, as the tubes open more comfortably to a slowly increasing pressure than to a sudden short burst. Lastly, it is helpful to incline the head forward with the chin on the chest.

A greater change of pressure takes place between 10,000 feet and ground level than between 20,000 feet and 10,000 feet, and so auto-inflation is more necessary during the later stages of a descent than during the earlier; in practice it is usual to auto-inflate about six times from 20,000 feet to 10,000 feet and every 1,000 feet thereafter. Meteorological conditions do not affect the pressure very much, and the greatest change that could be produced by barometric disturbances on a horizontal flight would equal a descent of 1,000 feet from London to Edinburgh.

Clinical Findings

(i) *Eustachian Obstruction*.—In the series of cases examined the Eustachian obstruction encountered has been due to nasopharyngitis, either catarrhal or mucopurulent. The leading symptoms are monotonous in their consistency. The patient reports complaining of a cold and that his ears are "blocked," and if he has flown before reporting he states that his ears have caused him "trouble." The presence of a nasal discharge is variable. The throat is not described as sore, but there may be a tickle due to the irritation of the post-nasal discharge. On examination the throat may show injection and there may be, but not necessarily, a post-nasal discharge. The drum is always examined, and in pure Eustachian obstruction is only slightly invaginated in appearance, but if the man has discovered his condition only through flying there may be barotraumatic appearances as well. On attempting auto-inflation no movement is observed and no subsequent click is heard. An important point is that, even in normal people, after prolonged attempts at auto-inflation the leash of vessels overlying the head of the malleus becomes engorged from venous back-pressure, giving a spurious appearance of "injected drum-head." But of course this is only a transitory phenomenon, a true injection of the drum from barotrauma persisting much longer. The problem arises whether the tubes are patent when there is no movement of the drum on auto-inflation. It is doubtful if this is the case in experienced fliers, whose drums usually move with an audible click. No movement, however, may be found in less experienced air-crew and, further, a previously damaged and scarred drum will often fail to move. These last conditions render the diagnosis of Eustachian obstruction dependent in a few cases on the individual's own statements. This of course raises the awkward problem of possible psychological reactions to flying, which is beyond the scope of this report. (The following figures have since been supplied: in a series of 2,000 ears examined the tympanic membrane was visibly mobile in 91.7%; the tubes were audibly patent in 49.8% and negative in 7.4%.) It is emphasized that

it is quite possible to have a "cold" and to experience no discomfort from the ears during flight owing to the Eustachian tubes remaining patent. Chronic rhinitis, mild forms of acute pharyngitis, and tracheitis do not necessarily curtail flying duties.

The pathology of the condition is conjecturally simple, although of course there has been no opportunity for verification in this series. The changes must either be a generalized catarrhal or occasionally inflammatory congestion in the epithelium—these cases give the sluggish response to auto-inflation—or there must be oedema of the adenoidal tissues at the pharyngeal orifice of the tube, giving a more substantial block. Among civilians, where the patients will not fall in the same healthy age group, the condition will be less simple. Adenoidal children will presumably present a special difficulty.

(ii) *Otitic Barotrauma*.—The symptoms are first a sensation of fullness in the ears, then increasing deafness, and lastly pain, which increases with the rate of descent and eventually becomes very severe. If no relief is obtained from opening the Eustachian tube the drum may eventually rupture. As the initial pain of a fracture may ease off in spite of persistent anatomical displacement, so may the initial pain of otitic barotrauma pass off to some degree in an hour or so after landing, giving rise to the false supposition that the Eustachian tube has opened. In mild cases many patients consider that there is wax in the external auditory meatus, and it is suggested that this is due to sensations from the auriculo-temporal nerve supply of the drum being referred to the lining of the meatus. Before proceeding further it must be admitted that, with the few cases seen, no hard-and-fast conclusions can be drawn. However, from these 10 cases certain tentative deductions can be made. Five only out of the 10 had colds before experiencing barotrauma, and so presumably there was no degree of Eustachian obstruction in the other five before flying. From the findings on examination of these 10 cases a rough classification under three headings has been made.

(a) *Slight*.—In heavy bombers this is the most common. There is slight impairment of hearing and the drum appears invaginated, injected, and indrawn. A number of the cases with Eustachian obstruction show mild degrees of barotrauma after discovering the disabling nature of their cold on short flying trips in the daytime, when there has been plenty of time for descent and repeated attempts at auto-inflation have been made. This stage is also seen in air-crew who have not had colds, but have lost the last 1,000 feet of descent rapidly. The majority of air-crew must have suffered from some trifling otitic barotrauma during their careers.

(b) *Moderate*.—The symptoms are the same, but height has been lost more rapidly and the trouble may have begun at a higher altitude and so there has been a longer strain on the drum. Hearing is more impaired than in the slight cases. An additional feature, however, is the appearance of haemorrhagic areas in the drum, usually in the postero-inferior quadrant, analogous to an ecchymosis of any other traumatized region. These haemorrhages are between the layers of the drum and may distort the drum features, or a solitary one may simulate a perforation. Recovery in these cases, as judged by the absence of symptoms on an air test, will take longer than in group a.

(c) *Severe*.—The findings are the same as above, but two complications can occur: first, a long-continued barotrauma may produce an effusion into the middle ear; and, secondly, the pressure may be so severe as to rupture the drum. The latter is very rare, and not one case has been seen in this 30-weeks period, nor, indeed, during twelve months with Bomber Command.

Treatment

Preventive.—Prevention is of the greatest importance from the Service point of view, and time spent by the medical officer in instruction in these conditions is well paid by the saving of time lost to the air-crews. It is the practice to see every air-crew on arrival at the station and to give a standard lecture on aviation medicine, including this condition. It may be argued that to dwell too much on the possible sources of a disability may be to sow the seed of a neurosis, but in this 30-weeks period this was found to be not true. With the aid of a diagram the elementary anatomy is shown and the Eustachian tube is likened to "an inch and a quarter of flabby drinking-straw" through which with a funnel it is possible to blow but not suck. This gets over the problem of why the air can get down but not up the tubes, whether it be the strict truth or not. The essential points in auto-inflation as described above are stressed along with a very practical point—namely,

that the captain must tell his crew when height is about to be lost so that they can auto-inflate before the onset of symptoms. Only three of a crew can tell the altitude from instruments, and very often, if auto-inflation has not been carried out, the ears give the first intimation to the others that the aircraft is descending. It is obvious that methods of preventing nasopharyngitis are of paramount importance on flying stations, and at the lecture mentioned the equation "Infection + impaired individual resistance = cold" is stated as a binding truth. The infective factor is considered endemic, but the virtues of unimpaired resistance or positive health are stressed and attention is directed towards the three basic physiological requirements to achieve it—viz., food, sleep, and exercise. Facilities are also available for supplementing a very adequate diet by vitamin A and D capsules, which have an undoubted psychological effect on air-crew. Lastly, ultra-violet light is available, and a full course is recommended during winter months: colds do not exist among the really conscientious attenders.

Curative: (a) Eustachian Obstruction.—In the type of case most commonly seen pyrexia and systemic features are not necessarily present and in-patient treatment is not required unless there are urgent administrative reasons for intensive treatment. Eustachian obstruction arising from nasopharyngitis will disappear as soon as the congestion at the mouth of and in the lumen of the tubes has resolved. To facilitate this use is made of a standard treatment given in the out-patient department, and the patient reports three times a day. A sympathicomimetic drug causing constriction of arterioles is used, and this can be supplied either with a nasal spray or in oily drop form. Opinion in this unit seems equally divided, but the oily drop method has the better theoretical chance of reaching the orifice of the Eustachian tube if given correctly. A prescription containing 0.75% ephedrine in liquid paraffin is used. It avails nothing if the patient sits in a chair and merely throws his head back; after blowing his nose he must lie horizontal over a couch with his head unsupported, and the head must be dorsiflexed on the neck until either the tip of the chin and the ear or the tip of the nose and the eye are in the same vertical plane. In this position three drops are placed in each nostril and have no option but to slide down into the nasopharynx when the head is raised with slight rotatory movements to ensure equal distribution. When the patient reaches an upright position proof of thorough administration is furnished by the desire to expectorate some of the solution that has slid over the soft palate. The patient waits three minutes for the ephedrine to act and then tries to auto-inflate. It may be argued that persistence in auto-inflation with nasopharyngitis may lead to the spread of infection to the middle ear. There has been no such unfortunate incident in this series. The patient now receives an inhalation. The standard inhaling earthenware pot is not necessary, for a saucer under a towel provides a wide evaporating surface, but of course does not give off vapour for so long. From observations in this series it is considered that the standard tinct. benzo'n. co. is too weak for this purpose though of great use in other conditions. Better results are gained from vap. menthol et eucalypt. (N.W.F.), using a teaspoonful to a pint of hot water. When stocks are short a crystal of menthol in hot water is useful, as are a few drops, similarly used, of lin. methyl. salicyl., lin. terebinth., and even liq. picis carbon. Stocks of materials from which inhalations can be made are of paramount necessity at all flying stations. After receiving this treatment all sufferers feel their heads to be clearer, and it is necessary to detain them for a period before they proceed out of doors to meet a cold rush of air causing immediate hyperaemia of the nasal mucous membrane.

The man is examined after his first treatment and an opinion formed as to his fitness for flying duty. Even if the tubes are now patent a temporary limitation is given—not for barometric reasons, as will be understood from earlier remarks, but because it will ensure that he will only be able to fly on non-operational duties, where there will be plenty of time for descent and for auto-inflation should the obstruction recur. From the operational point of view, however, he is a "man night" lost. If there is still no patency of the tubes after treatment the patient is confined to ground duties. The average

time for recovery to fitness for full flying duty has been found, as stated, to be 2.5 days. Dominion personnel are notoriously prone to catch colds, and recurrence of Eustachian obstruction is therefore common. In this series there have been approximately 17% of Dominion patients. After recurrence, evidence of possible sinus infection is looked for by transillumination and x-ray examination. The proprietary "benzedrine" or "karsodrine" inhaler is most convenient for air-crew, and those who have difficulty in auto-inflation often derive considerable benefit by using these before and after descent. Politizerization has its place in the treatment of Eustachian obstruction, and will be discussed later.

(b) *Otitic Barotrauma*.—The symptoms can be most satisfactorily relieved by immediate ascent to a height above that at which the barotrauma originally began and by subsequent slow descent with frequent auto-inflation. Indeed, many cases in which this has been done never find their way to the medical officer. But for military or meteorological reasons the danger to all the crew from delay caused by this manoeuvre may outweigh the advantage to the individual, and so reascent may not have been carried out. On landing the individual must report for examination and treatment at the earliest opportunity, as the first essential is to get the Eustachian tubes patent. The regime outlined above is tried, and many cases respond within 24 hours. Valsalva's method is persisted with forcibly. If these simple measures fail and there is no purulent nasopharyngitis then recourse to politizerization is necessary. The nasal olive is too small for many nostrils, and a fellow medical officer has suggested the very useful practice of slipping over the olive a pierced rubber cap of a 10-c.cm. T.A.B.C. vaccine bottle as manufactured by the Lister Institute. This has proved most successful in securing a good airtight fit. The last stage in the therapeutic crescendo is Eustachian catheterization. In this series, however, this has only three times been necessary, and in the type of flying that will be experienced in peacetime passenger transports it should similarly be as seldom needed. After the tubes have become patent it is necessary to wait until the effects of the trauma to the drum have resolved before flying is recommenced, otherwise there will be pain on change of pressure. This is the time-consuming part of the treatment, which is purely "masterly inactivity," and accounts for the 20.4 days average stated above. Discoloration of the drum at the site of the haemorrhagic areas mentioned earlier may persist after freedom from symptoms, and the point can therefore only be satisfactorily decided after an air test, which is generally carried out around the 14th day.

Case Histories

Case 1.—Warrant Officer D. Diagnosis: nasopharyngitis and slight otitic barotrauma. Had a cold before flying. While listening to morse on descent from 20,000 ft. noticed that the signals were getting weaker. Then felt pain in both ears, increasing till 2,000 ft. Rate of descent 1,500 ft. a minute. Auto-inflation at 2,000 ft. with only partial success. On examination after removal of cerumen both drums injected, indrawn, and immobile on Valsalva test. Received drops and inhalations t.i.d. Next day right Valsalva was positive; left Valsalva still negative and nose catarrhal. Continued on same treatment for two days and then politizerized. Two days later left ear was very easily inflatable. Resumed full flying duty after total absence of five days.

Case 2.—Flying Officer W. Diagnosis: slight otitic barotrauma. No cold prior to flying. No record of altitude changes, and landed away from this unit with symptoms of barotrauma (left). Politizerization before return, and on arrival here complained of persistent aural pain. On examination drum injected and wrinkled in appearance. Two days later ear still painful; auto-inflation increased pain and caused further pain in left mastoid region. Three days later this mastoid pain was more severe, and relief was obtained only from resting on a hot-water bottle and from analgesics. Eventually fit for full flying duty after 12 days' absence.

Case 3.—Pilot Officer W. Diagnosis: slight otitic barotrauma. No cold before flying. Descended from 21,000 ft. and experienced pain in right ear to 15,000 ft. Pilot thereafter descended more slowly, but only partial success with auto-inflation. Three hours after landing flew again to 15,000 ft. with some relief. Reported four days later: Right drum injected, indrawn, and immobile. Politizerized next day by E.N.T. surgeon, with good air entry and some immediate improvement. Continued to receive inhalations, and resumed full flying duties after 25 days' absence. When examined 20 weeks later there were no signs of impairment of hearing.

Case 4.—Sergeant C. Diagnosis: severe otitic barotrauma. No cold prior to flying. No record available of altitude changes, but complained of immediate pain in right ear on descent. On examination the normal features of the tympanic membrane were obscured by "bubbles" due to a serous effusion in the middle ear. Received routine drops and inhalations, and two days later the Valsalva test became suddenly positive spontaneously, and on examination the bubbles were seen to have disappeared, to leave haemorrhage in the drum, which was mobile on auto-inflation. He then proceeded on nine days' leave, and on return the haemorrhages had resolved. He proceeded on non-operational flying duties, and after a satisfactory air test resumed full flying duties after a total absence of 20 days.

Case 5.—Sergeant M. Diagnosis: severe otitic barotrauma. No cold before flying. Aircraft involved in fast dive from 13,000 ft., and pain developed in left ear, becoming very severe. Captain reascended to above 10,000 ft. and pain eased off, but recurred again and was acute after landing. On examination the drum was intact and mobile on auto-inflation. Received drops and inhalations, and pain passed off completely. Six days later flew again and experienced pain from 4,000 ft. at three-quarters of previous strength. Next day, when examined by the E.N.T. surgeon, the drum was inflamed, was mobile on auto-inflation, and there were the remains of a serous effusion in the middle ear. Watch-tick heard only on contact, and Weber test referred to the right ear. Six days later the inflammation of the drum had subsided, and in a further seven days the hearing had returned to normal. Thirteen days later he resumed full flying duties after a total absence of 27 days.

Case 6.—Flight Sergeant T. Diagnosis: nasopharyngitis and severe otitic barotrauma. Coryza before flying. Pain in right ear on descent from 23,000 ft., increasing to a maximum at 20,000 ft. and then easing off. Reported next day. On examination nose inflamed, drum inflamed and indrawn with haemorrhagic posterior patch, and could just hear watch-tick against the ear. Politizerized by the E.N.T. surgeon next day. Seven days later cold persisted and the Eustachian tubes were catheterized by the E.N.T. surgeon. Thereafter auto-inflation daily and politizerization at unit on "negative" days. Eleven days later still—i.e., 20 days after barotrauma—patch still present on drum. Four days afterwards his cold had cleared, his drum appeared normal, and his hearing had returned. Resumed flying below 5,000 ft. After a satisfactory air test resumed full flying duties after 45 days' absence.

Conclusion

Once again it is stated that this paper does not attempt to give a comprehensive picture of otitic barotrauma, but merely depicts those features that have been observed with air-crews of heavy bombers by a unit medical officer. There is much more that could be discussed in the way of treatment—for instance, by those who have the opportunity of seeing more of these cases. Inhalation of helium-oxygen mixtures, drum punctures, and the implantation of radon tubes into the nasopharynx around the tubal orifices of patients with recurrent nasopharyngitis are all interesting remedial measures.

On R.A.F. stations there is no difficulty in the diagnosis or disposal of cases of severe otitic barotrauma, but the handling of air-crew with nasopharyngitis presents a problem that will be found in any form of aviation. It is hoped, therefore, that the remarks on prevention may be of interest and may indicate one way in which the medical branch, by applying the science of aviation medicine, can join with the other sections at R.A.F. stations in helping the air-crews to carry out their task in greater comfort.

Summary

During a 30-weeks period with a heavy bomber squadron of the Royal Air Force 56 cases of Eustachian obstruction and 10 cases of otitic barotrauma have been encountered.

From this series the importance of these two conditions, their anatomy, physiology, pressure changes, clinical appearances, preventive and curative treatment, and some case histories, are described and discussed with reference to civilian aerial transport.

Cases of severe otitic barotrauma have been found to be rare, and the incidence of all cases can be lessened by instruction in auto-inflation, by the prevention of nasopharyngitis, and by curtailing the flying duties of patients with Eustachian obstruction.

Grateful acknowledgments are due to Air Cdre. E. D. D. Dickson, R.A.F. Consultant in Oto-rhino-laryngology, for his helpful comments, and to both Squad. Ldr. W. L. James, for interest and encouragement in the preparation of this paper, and Squad. Ldr. J. W. Cope, E.N.T. surgeon, for reading the proofs; also to the staff of Station Sick Quarters for undertaking the clerical work in their spare time.