Original Article

Study of middle ear pressure in relation to Eustachian tube patency

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ABSTRACT

The current practice of declaring an asymptomatic aircrew, having middle ear pressure (MEP) beyond the range of ± 25 mm of HO pressure (as ascertained by tympanometry) as unfit needs re-evaluation, vis-avis, the present international standard of normal middle ear pressure, which is ± 100 mm 11,0 pressure. The present study was undertaken to objectively assess the Eustachian tube patency of asymptomatic individuals, with middle ear pressure beyond ± 25 mm of HO, in the hypobaric chamber. Asymptomatic cases of retracted TM (tympanic membrane), and of asymptomatic scar TM with middle ear pressure beyond ±25 mm of I1,0 were included in the study. These asymptomatic subjects were subjected to 'Ear Clearance Run' in the hypobaric chamber (Decompression Chamber) in the Institute of Aerospace Medicine (IAM), with standard rate of ascent and descent, for objective assessment of Eustachian tube patency. The study found a range of middle ear pressure, which can be accepted fit for flying, as confirmed by successful Ear Clearance Run, in the Hypobaric chamber of IAM.

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The aviation environment exposes the aircrew to rapidly changing ambient pressures, Such pressure changes, which occur, more so in military flying affect the air containing cavities of the body, which include the semi-closed middle ear cavity. The aircrew must be able to equilibrate the pressure on both sides of the tympanic membrance and this is possible only with a normal tubal function. Failure to equalize pressure across the tympanic membrance may result in otitic barotraumas [1-7]. Difficulty with clearing the ears during flight is a common cause of temporary or even permanent grounding of aircrew.

Ascent to altitude usually offers no trouble because the gas in the middle ear cavity expands and escapes along the Eustachian tube into the nasopharynx, so that the pressure remains equal on both sides of the tympanic membrane. [1, 8, 9]. During descent, equilibration is brought about by the passage of air into the middle ear through the Eustachian tube. During descent, gas from the nasopharynx must enter the middle ear in order to maintain equilibrium between the atmospheric pressure outside and the gas pressure in the middle ear. The one-way valve mechanism of

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the Eustachian tube prevents the back flow of gas back into the middle ear cavity. The resultant relative increase of pressure on the outside of the tympanic membrance pushes the membrane into the middle ear cavity. As descent continues the membrane is pushed further into the middle ear cavity unless gas enters it though the Eustachian tube to equalize the pressure across the tympanic membrane preventing the development of otitic barotraumas.

It is usually necessary to perform some active manoeuvre to open the Eustachian tubes. Although there are several simple manoeuvres such as swallowing, yawning and jaw movements (methods of free choice), which may open the tube, these are often not very effective [1]. These individuals have to raise the pressure in the nasopharynx in order to force gas into the middle ear cavities. The rise in pressure is usually achieved by performing either a Valsalva or Frenzel's manoeuvre. Valsalva's manoeuvre is generally not recommended because of problems of performing it in the critical phase of flight or when wearing oxygen mask. It may also cause alternobaric vertigo or can cause convulsive syncope in pilots with low 'G' tolerance [1, 8, 9, 10]. The Frenzel's manoeuvre has the advantage of opening the Eustachian tube at lower nasopharyngeal pressures and of being performed during any phase of respiration but is also not recommended because of problems of performing in the critical phase of flight. Normal Eustachian tube function is, thus, an essential prerequisite for acceptance for aircrew duties.

Tympanometry is a noninvasive and objective method, which facilitates a complete evaluation of patency of the Eustachian tube, measurement of MEP and compliance of ear drum [2, 11-23]. When the tympanic membrane is intact, tubal function can be assessed during tympanometry by noting the MEP at maximum compliance. If MEP lies within the normal range, then the normal Eustachian tube function can be assumed.

The middle ear pressure is expressed in mm of H_20 pressure or deka Pascal (daPa) units (1 mm of H_20 pressure = 1.02 deka Pascal unit). If there is no air space in the middle ear cavity (e.g. when the tympanic membrane has undergone adhesive changes or the middle ear cavity is filled up totally with fluid) there is no peak (or maximum compliant point) and the tympanogram is flat. Similarly, if the Eustachian tube is blocked there will be a negative pressure because of continuous absorption of gases from the middle ear space [24]. High negative middle ear resting pressure is indicative of obstruction of the Eustachian tube. The finding of normal resting middle ear pressure does not necessarily indicate normal Eustachian tube function, but the finding of the negative middle ear pressure is presumptive evidence of Eustachian tube dysfunction [25].

The normal range for the middle ear pressure is somewhat controversial, as different researchers have suggested slightly different ranges. Jerger [26] postulates that negative MEP in excess of 100 mm of H_20 pressure only should be accepted as pathological. Negative middle ear pressure is attributed to faulty Eustachian tube function [15]. Presently internationally accepted range of normal middle ear pressure is + 100 mm of H_20 pressure [6, 11, 13, 15, 20, 25, 26].

A prerequisite for studying the pressure equilibrating function of the Eustachian tube is a pressure gradient between the middle ear and the ambient pressure, In experiments it is possible to induce such pressure gradients directly by changing ambient pressure by means of a hypobaric or decompression chamber. By these means it is possible to induce both positive and negative middle ear pressure in subjects with intact eardrums, independent of their active equilibrating capacity [1, 2, 27].

The present study was undertaken because the current IAF practice of assessment of the Eustachian tube function by checking the middle ear pressure by tympanometry was in variance with the International standard. The study aimed to review the present Indian standard and to define or identify the range of middle ear pressure that could be accepted fit for flying. Objective reevaluation of the range of middle ear pressure as safe for military flying in IAF, would help in reducing the grounding time of asymptomatic

aircrew, having middle ear pressure outside the present accepted range of + 25 mm of H_20.

Materials and Method

The subjects for the study were chosen from the civil and military pilots who reported to the IAM for ENT evaluation. They were all healthy aviators, presently asymptomatic with previously healed ear pathology. They all had intact tympanic membrane and MEP beyond +25 mm of H_20 pressure.

The subjects served as their own controls. Also, asymptomatic volunteers amongst aviators and nonaviators, with middle ear pressure within + 25 mm of H_20, who would report to Department of ENT of IAM, were chosen as controls.

After selecting and segregating the presently asymptomatic aircrew with previously healed ear pathology, they were all subjected to tympanometry. Asymptomatic aircrew having middle ear pressure beyond the range of + 25 mm of H_20 pressure were exposed to a maximum pressure change, to test the Eustachian tube patency in the hypobaric chamber, at the Dept of High Altitude Physiology, IAM, after thorough ear examination, during which cerumen (if any) was removed. The same was repeated with controls (MEP within + 25 mm H_2O). The subjects were instructed to swallow or to open their mouth and move their jaws side to side, and to clear his mouth. Of These procedures were called methods of "Free Choice". In case of persistence of symptoms the subjects were instructed to do Valsalva's manoeuvre as an emergency remedial measure,. Such a test was considered unsuccessful.

All the subjects were taken up for ear clearance run to test the Eustachian tube patency. They were taken up from ground level to 8000 ft, then leveled off and then again brought back tc ground level. Graded rate of ascent and descent were maintained with first at 500 ft/min and then subsequently with 1000, 2000 and 3000 ft/min i.e. till the ear clearance run was completed with the rate of ascent & descent of 3000 ft/min. Communication with the chamber technician was maintained with a two-way intercom.

If there were no signs and symptoms of otitic barotraumas or deterioration of already healed middle ear pathology and otoscopic examination at various altitudes ruled out any signs of otitic barotraumas or Eustachian tube insufficiency, the individual was considered to have successfully completed the ear clearance run in the hypobaric chamber, signifying patent Eustachian tube.

Results

A total of 153 subjects, with healed tympanic membrane, who reported to IAM for evaluation were screened for the study (Table-1). Out of these, 141 subjects were found to have middle ear pressure within + 25 mm H_20 and 12 had a MEP beyond + 25 mm H_20. These 12 subjects were evaluated for the Eustachian tube patency in the decompression chamber. The results are given in Table-2. All the subjects were male and out of these 10 were civil pilots and two from military background one being from Air Force and one from Indian Navy respectively. All the subjects were asymptomatic. Their age ranged from 24 to 56 years. The middle ear pressure in the subjects ranged from -28 to -100 mm H.O and all the tympanograms were of the 'C type except in 1 subject where it was an 'A' type. Thus all subjects were with middle ear pressures ranging within the internationally accepted range of + 100 mm of H_20. All subjects successfully passed the ear clearance run by using the method of Free Choice' as the means of clearing Eustachian tube indicating the patency of Eustachian tube.

Discussion

The range of + 25 mm of H,0 of middle ear pressure can be accepted, fit for flying in India also. However military flying may involve much larger, more rapid and frequent changes in the ambient pressure changes in the ambient pressure than the ones used in this study. In Royal Air Force, UK three distinct

Table 1 : Total number of aircrew evaluated

Asymptomatic aircrew with healed middle ear pathologies	Asymptomatic aircrew with MEP within + 25 mm H_20	Total asymptomatic Aircrew (civil + military) with MEP beyond ± 25 mm H_20 (subjects)	Asymptomatic aircrew with MEP beyond + 25 mm H_20 (civil) (subjects)	Asymptomatic aircrew with MEP beyond + 25 mm H_20 (military) (subjects)
[A]	**[B]**	**[C]**	**[D]**	**[E]**
153	**141**	**12**	**10**	**02**

Table 2 : Results of Ear Clearance Run (n=12)

SI. No.	Date	Rank	Sex	Age in Yrs	MEP in mm/H_20	Tympanogram Results (Type)	Ear clearance Run Results (Free Choice)
1	8.6.99	Capt (Civ)	M	25	-30	'C (Rt)	Successful
2	22.6.99	FltLt	M	26	-35	•C(Lt)	Successful
3	29.6.99	Capt (Civ)	M	56	-40	•C(Lt)	Successful
.4	14.6.99	Capt (Civ)	M	25	-76	•C(Lt)	Successful
5	29.7.99	Capt (Civ)	M	**35**	-100	C'(Lt)	Successful
6	20.8.99	Capt (Civ)	M	**26**	-34	•C(Lt)	Successful
7	6.10.99	Capt (Civ)	M	29	-92	'C (Rt)	Successful
8	6.10.99	Capt (Civ)	M	24	-33	C'(Lt)	Successful
9	5.7.2000	Capt (Civ)	M	32	-28	'A' (Bil)	Successful
10	15.4.99	LtCdr	M	30	-45	•C(Lt)	Successful
11	22.3.2000	Capt (Civ)	M	33	-100	'C(Rt)	Successful
12	1.3.99	Capt (Civ)	M	33	-54	'C(Rt)	Successful
MEAN				**31.16667**	**- 55.6667**		
SD				**± 8.663752**	**± 28.836**		

decompression test profiles are employed for fast jet, multi-engined and propeller aircraft, and helicopter pilots, using a hypobaric chamber. Each test profile is graduated to simulate increasingly rapid descents [1]. In these profiles the subjects are exposed to variations in the ambient pressure from 10,000 feet to ground level at 6000 ft/min rate of descent. This is different from the protocol followed at IAM, IAF where the protocial stipulates 3000 ft/min as the maximum rate of descent allowed from 8000 feet to ground level.

In order to define acceptable middle ear pressure range for military flying, the Eustachian tube can be more realistically assessed, if the Royal Air Force, decompression test profile is employed for the Eustachian tube evaluation.

Conclusion

There is a need for further studies on larger number of subjects, for conclusively recommending a safe range of middle ear pressure beyond the present

accepted range of + 25 mm of H_20. An ideal range of middle ear pressure for safe flying in India could then be evolved and also incorporated in the IAF standards. After such studies are conducted, more asymptomatic aircrews with healed middle ear pathologies, having 'Middle Ear Pressure' within the functional range, could then be declared fit for flying thus significantly reducing wastage of trained man-hours.

Till such time as these researches are conducted on larger number of subjects and the revised range of normal middle ear pressure is conclusively established, the present accepted range of normal middle ear pressure in India for evaluation of Eustachian tube patency, holds good.

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