Measures to prevent Barotitis when flying

Symptoms and effects of Barotrauma

Summary

Half of all air passengers know the uncomfortable pressure feeling or pain in the ear that occurs mainly while landing. Mostly, the discomfort can be resolved relatively quickly by equalising the pressure, for e.g., by yawning or swallowing.

The symptoms are often more severe in case of children and the pressure cannot be equalised so easily. Barotrauma sets in when the pressure cannot be equalised, which can begin with the symptoms described above. The following article explains why children are affected by Barotrauma of the ear and shows some ways of preventing the serious effects of Barotrauma.

Introduction

The cabin pressure changes by about 0.2 bar during take-off and landing of the aircraft. Whereas the the pressure decreases during take-off and is usually equalised between the nasopharynx and middle ear through a passive opening of the Eustachian tube, the increase in ambient pressure must be equalised actively by the passenger during landing. This is done by swallowing, yawning, or other active pressure balancing methods under physiological conditions. Barotrauma can set in if the pressure is not equalised for some reason. It is the most common disorder associated with flying and occurs in about 5% of adult passengers and 25% of children.

The Eustachian tube

The Eustachian tube was first described in the 16th century by Bartolomeo Eustachi. The tube is about 35 mm long and runs from the middle ear to the middle of the head and down towards the nasopharynx. A distinction is made between the Pars ossea (bony part) at the upper and a Pars cartilaginea (cartilaginous part) at the lower section of the Eustachian tube [2].

The three functions of the Eustachian tube are to protect against germs and sound (protection), removal of secretions (drainage) and ventilation (ventilation) of the middle ear. Various muscles are involved in the active opening of the Eustachian tube. It is a complex teamwork of the throat muscles. The most important opener is the Musculus tensor veli palatini.

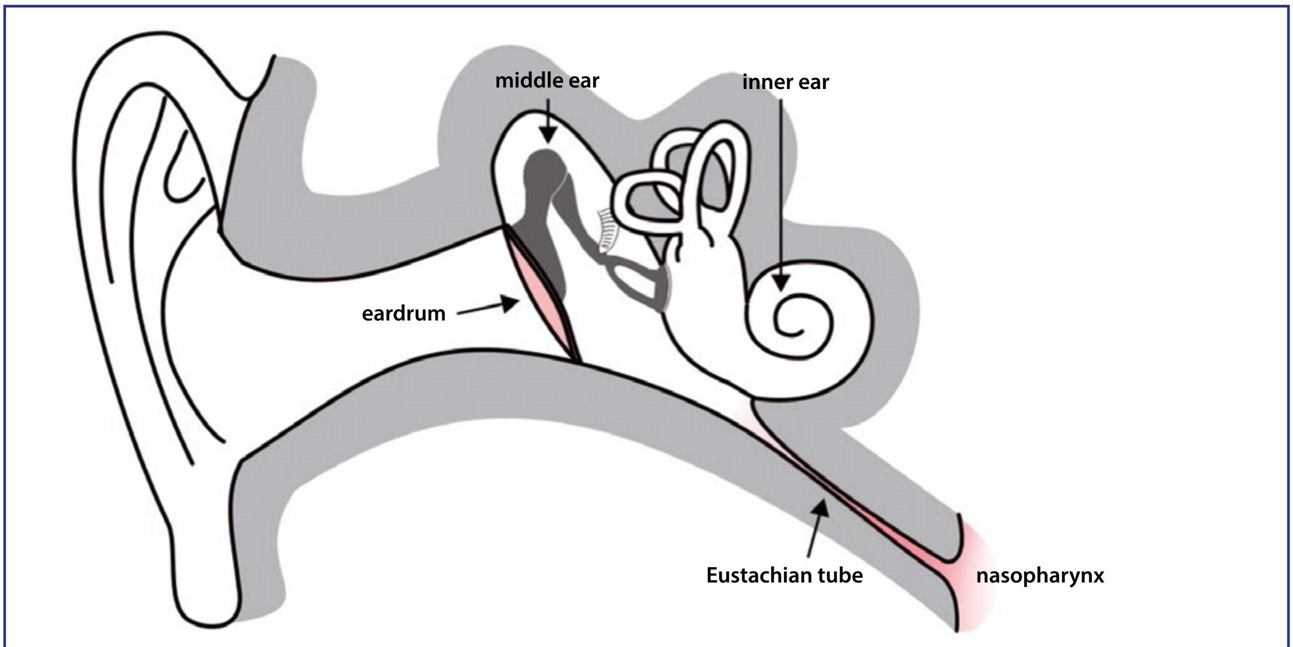

Fig. 1: Construction of the ear (Copyright M. Bischoff, Charité Berlin)

Barotrauma

The word comes from Greek trauma (wound / injury) and baros (heaviness / weight). The term describes an organ or tissue-specific injury to air-filled, rigid-walled and flexible body cavities, caused by a lack or insufficient ventilation when the ambient pressure changes resulting in a difference between the internal and external pressure. As per the Boyle-Mariott law, the volume of air-filled cavities (for example, that of the middle ear) is inversely proportional to the pressure. This means that the volume increases when pressure reduces (E.g. when the aircraft takes-off) and decreases when the pressure increases (E.g. when the aircraft lands). The volume change is very limited in case of the middle ear.

Grade 0	Normal
Grade 1	Retraction and partial redness of the eardrum
Grade 2	Retraction and complete redness of the eardrum
Grade 3	Grade 2, and fluid or blood behind the eardrum
Grade 4	Rupture of the eardrum

Tab. 1: Teed's classification of Barotrauma of the middle ear (modified)

What happens in Barotrauma of the ear?

Rapid changes in ambient pressure can cause Barotrauma in humans. The terms describe health disorders caused by low or high pressure in air-filled body cavities due to rapid changes in pressure when diving or flying.

The middle ear is often affected during pressure changes due to the anatomical feature of the narrow Eustachian tube.

The eardrum closes the middle ear towards the ear canal, and the pressure cannot be equalised here. This can be done only by opening the Eustachian tube. Normally, the difference in pressure between the middle ear and the surroundings can be actively equalised as described above. The pressure between the nasopharynx and the middle ear can be equalised by opening the Eustachian tube. Barotrauma of the ear can set in if the pressure cannot be equalised actively. The symptoms are pain, loss of hearing, and nausea. It causes the eardrum to retract and even bleeding in the middle ear. In rare cases, the eardrum may even rupture and lead to deafness.

Barotrauma is much more common in children and very painful and often leads to rupture of the eardrum. This can be partly explained by the fact that the structure of the Eustachian tube is different compared to adults. The cartilage is more elastic in children, which means that when the opener muscles of the tube contract, it may not necessarily open the entire Eustachian tube. In addition, the anatomy is significantly different from that of adults which makes the opening and thus ventilation more difficult [3]. The Eustachian tube is shorter in children, which often leads to an increase of (potentially infective) secretion in the middle ear. In addition, children suffer more frequently from infections of the upper respiratory tract resulting in swollen mucous membranes in the nose-tracheal area, which in turn makes pressure equalisation more difficult or impossible.

The frequency of spontaneous tube openings is specified as once in 5 minutes for babies and once per minute in adults [4]. It should be noted that these values apply only when one is awake. The frequency of openings is significantly lesser when one is asleep.

Effects of pressure difference

If the pressure is not equalised during landing, then there is a pressure difference between the cabin pressure and the pressure in the middle ear. This relative negative pressure in the middle ear can have the following effects:

6 hPa	Feeling of fullness in the middle ear and unpleasant feeling of pressure
< 8 hPa	Closure of the Eustachian tube, pressure can be equalised only with effort, sensation of pain
> 8 hPa	Pressure cannot be equalised any more,
10-15 hPa	potential rupture of the eardrum with stoppage of pain, but loss of hearing, frequent dizziness and vomiting [6].

	Pascal (Pa)*	Bar (bar)	mm quicksilver (mmHg)
1 Pa	1	0,00001	0,0075
1 bar	100000	1	10,075
1 mmHg	133	0,0013	1

Tab. 2: Conversion of pressure units (Pascal, bar, mercury)

*The mean atmospheric pressure of air at sea level or standard pressure is 101 325 Pascal = 1013.25 hPa = 101.325 kPa.

Pressure differences when flying

Take-off:
On the ground, the pressure in the aircraft is the atmospheric pressure at sea level (1013 hPa). The cabin pressure in a modern passenger aircraft reduces by about ¼ by the time the aircraft reaches the cruising altitude. The rate at which the cabin pressure changes is about 18.3 hPa per minute when the aircraft is climbing [9].

Cruising altitude:
The cruising altitude of airliner is approximately 10,000 m. The cabin pressure is artificially maintained by the air conditioning system at ¾ of atmosphere pressure, which is about 750 hPa. The feeling in the cabin is that of being at 2500 m.

Landing:
When the aircraft starts descending from the cruising altitude, the cabin pressure is increased once again to the atmospheric pressure at an average rate of 11 hPa per minute [9]. In some aircrafts like the Boeing 737, a pressure difference builds up relatively quickly when the aircraft start descending. Thus, the risk of suffering Barotrauma is higher compared to other types of aircraft like Boeing 747, DC-10 and Airbus 310 [5].

Ways of prevention

Since the pressure can actively equalised by various activities like yawning, chewing or swallowing, it is possible to support this, for example, by chewing a (tooth-friendly) chewing gum and by drinking a lot of fluids especially during landing. Children should be woken up and fed if possible because the number of spontaneous tube openings (see above) decreases in sleep. If this is not enough, the so-called Valsalva movement can be carried out repeatedly.

This involves covering the mouth and nose and building up a pressure in the nasopharynx by „breathing out" against this resistance. Unfortunately, it is often impossible for small children to understand and carry out this procedure.

For those suffering from colds or allergies that cause the mucous membrane in the nose and nasopharynx to swell, it is advisable to drink a lot of fluids before and during the flight to improve the blood circulation in the mucous membranes. The use of decongestant nasal drops (E.g. Oxymetazoline, Xylometazoline) is often advised in such cases. However, the study does not show any clear effect on preventing Barotrauma [6,7,8].

It is important to carry out or start the measures described above before the discomfort starts, to prevent a large pressure difference from building up. An ear plug that has been specially developed for air travel with a built-in pressure reducer (SANOHRA fly®) promises a non-medical aid. This slows down the rate of the change in pressure between the surroundings and the area in front of the eardrum and thus creates a lower pressure gradient. Thus, there is sufficient time for the Eustachian tube to adapt to the pressure differences, especially when landing. Special earplugs are also available for children.

The pressure reducer slows down the increase in pressure during landing. In a measurement carried out in a passenger aircraft, the pressure change lasted for 25 minutes during the descent and the cabin pressure increased by about 250 hPa in this time. The time for attaining the full ground pressure was increased to a period of 40 minutes by the ear plugs. Thus, the ear had more time to equalise the pressure.

Scientists at the Berlin University Clinic Charité studied volunteers with known flying problems. The doctors at the ENT clinic at the Charité Center campus tested the pressure-reducing ear plug SANOHRA fly® in a systematic prospective study. To do this, a landing was simulated in a pressure chamber (pressure difference 0.1 bar, rate of pressure change 0.05 bar per minute).

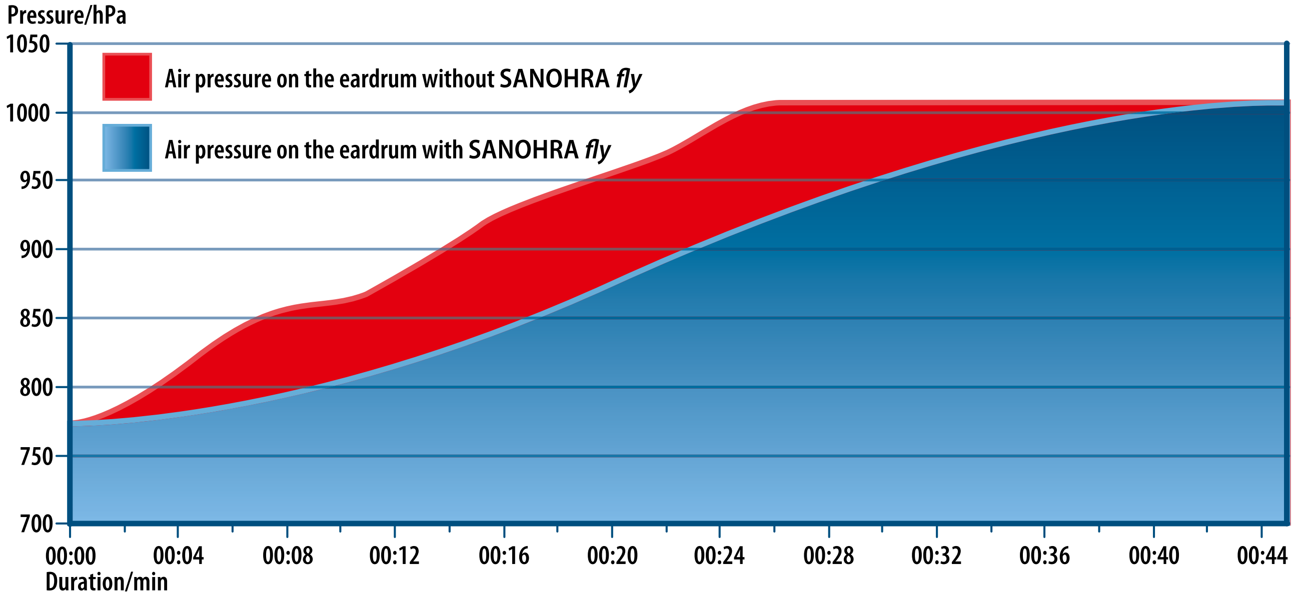

Abb. 2: Increase in pressure during landing. The ground pressure is attained within 25 minutes in the aircraft's cabin, whereas the ear plugs delay this pressure change to 40 minutes.

The study shows that there is a change in subjective condition of the volunteers with and without ear plugs and that the number of successful pressure equalising actions increases when the ear plug is used.

The results show a delay in pressure increase in all the cases. The pressure was increased in the test chamber to the normal pressure within 2 minutes in the test. The filter delayed this pressure change to 9.28 ± 0.87 minutes. Here, the small deviation with which the filter affects the pressure must be noted. According to the manufacturer, this shows the high manufacturing quality of the pressure reducer. The subjective condition of the volunteers, specified on the VAS scale (Visual analogue scale), was much more comfortable when the ear plug was used. This analysis of the results of Charité confirms that the pressure in front of the eardrum increases slowly when SANOHRA fly® is used and this contributes to the well-being in case of pressure changes.

In the study, the number of pressure equalisation actions with and without using the earplugs did not differ significantly. The scientists consider this as a confirmation of the theory that pressure sensors give an adequate stimulus for deflecting the eardrum in the area of the nasopharynx.

Conclusion

Due to the anatomical features of the Eustachian tube and frequent infections of the upper respiratory tract, children are particularly sensitive to pressure differences during flying. But many adults also struggle with this problem. In addition to active equalisation actions like chewing and swallowing, drinking fluids frequently and decongestant nasal drops help in case of infections.

Ear plugs have proved effective, which regulate the changes in pressure better and thus give more time to the Eustachian tube to equalise the pressure.

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