IAPO Interamerican Association of Pediatric Otorhinolaryngology

XI IAPO Manual of Pediatric Otorhinolaryngology

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Barotrauma and Air Travel

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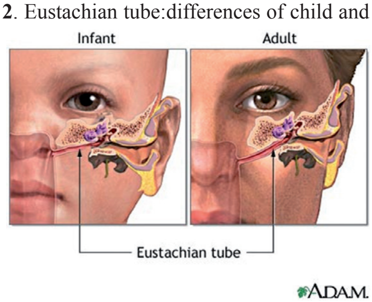
Who among us has not sat in an aircraft near a child and thought: “I hope that kid doesn’t cry.” (**Figure 1**) We will comment briefly on what we have found in the literature on barotrauma.

Figure 1. Child with earache

What is “barotrauma”? Barotrauma is discomfort in the ear caused by pressure differences between the middle ear (behind the eardrum) and the ear canal (atmospheric pressure). Normally, alterations in pressure do not affect us, since the human body consists of cells that are not contain fluid and are therefore not compressible. The parts of our bodies that hold gas, however, are more vulnerable, because they are subject to alterations in pressure. These parts include the middle ear (ME), paranasal sinuses, and the lungs.

The Eustachian tube (ET) is directly involved in barotrauma pathophysiology, as its main function is to maintain ventilation of air spaces, particularly those in the mastoid and other parts of the temporal bone (it is responsible for the pneumatization of the temporal bone). Another important role of the ET is equalizing pressure in the ME space with the surrounding environment. There are differences, however, in the ET in adults and children, which make children more susceptible to barotrauma. In general, the child’s ET tube is short, floppy, and horizontal compared to adults, (**Figure 2**), which impedes air exchange and favors the entry of secretions from the rhinopharynx towards the ME.

Figure 2. Eustachian tube:differences of child and adult



Normally, the ET is closed, when in repose. When we yawn or swallow, the tensor veli palatini muscles (which play a very important role), together with the levator veli palati muscle separate the lateral and median walls of the ET, opening it.

What happens? We swallow without realizing this at least once a minute when we are awake, and at least once every five minutes when we are asleep. The same pattern occurs among children, making it more difficult to equalize pressure when sleeping. Consequently, a sleeping child is more likely to develop barotrauma when placed in a situation (e.g., descent of an airplane) that creates a pressure gradient between the ME and the external environment. During sleep, the air is renewed more slowly, if the ME is free of pathology.

When the tube is closed, what happens? The mucous tissue of the ME around the promontory (which has intense vascularity) will absorb the air and form a slight negative pressure in the middle ear. If the ET remains constantly closed, if it is not patent, what happens? This inner pressure in the ME cavity will increase and, if not equalized, will result in the steady retraction of the eardrum or tympanic membrane (TM), with inflammatory alterations that we find in the middle ear with chronic pathologies.

Children face additional challenges with ET function. Many children spend their childhood with chronic or frequent nasal obstruction, caused by enlarged adenoids, recurrent upper respiratory infections, or both. They consequently have a baseline negative pressure in their middle-ear space caused by swallowing with a nasal obstruction (Toynbee maneuver). When the palate rises with swallowing a positive pressure is created in the child's nasopharynx, which rapidly becomes negative when the palate drops (to experience this yourself, pinch your nose shut and swallow twice without letting go). Since children tend to have floppy, patulous ETs, this pressure is readily transmitted to the ME, where it sets the stage for acute otitis media and makes a child more prone to barotraumas.

What alterations occur when we enter an aircraft? Everyone has felt these alterations at least once. When we board an aircraft that is about to take off, at the start, while we are still at sea level, we feel nothing. As the aircraft starts to gain altitude (40 to 60 meters) a change of 3 to 5 mm de mercury (Hg) occurs, when we get a feeling of "stuffed or blocked ears". At this point the TM would appear slightly curved on otoscopy. The aircraft continues to rise, and when reaching an altitude of about 160 meters, we feel a "pop" in the ear; at this moment, the TM returns to its previous position and the stuffed ear feeling vanishes. This happens if the ME and ET function normally. Subsequently, during the flight, the ET is forced to open and remain in its normal position and another shift in atmospheric pressure occurs.

What happens? During take-off, barotrauma is not often noted. It is noted far more frequently on landing, as the negative pressure in the ME cavity is far more severe when the airplane descends, which can "lock" the ET because of excessive negative pressure and prevent it from opening. The ET will open only if we take physiological steps that result in the contraction of the tensor veli palatini muscle (which occurs when swallowing), for example, moving the jaw, chewing gum, or through non-physiological maneuvers such as the Valsalva or Politzerization. (**Figure** 3) Normally, we are quite unaware of this; however, children do not know how to do this alone, unaware that they must swallow and they do not even know how to do so consciously.

Why does this happen on some flights, and not on others? This is not a mathematical rule, although it might even be a predictive mathematical model, according to studies by Kanick and Doyle [1]. For example, it depends on the

Figure 3. Chewing gum and Valsalva maneuver

difference in altitude between the place of take-off and the place of landing. This is just one of the factors. If the person has a cold or a stuffy nose, with nasal secretion, this may also lead to barotraumas, because of the Toynbee effect (noted above) and because of edema and inflammation of the ET and peritubal tissue.

Another factor is the type of aircraft, as there are many differences in the rate at which altitude is lost. When descending very rapidly (the 737 model, for example, drops very quickly at 150 meters or feet an hour) the barotrauma index is higher. Other aircraft lose altitude more gradually. The ideal time for the aircraft to lose altitude before landing is between 15 and 20 minutes. When the flight attendant announces: "We are starting the landing procedures", some 15 to 20 minutes is enough time for a passenger to equalize the pressure in the ME, avoiding barotrauma. Consequently, these alterations may occur.

Stangerup and colleagues [2] conducted a study with asymptomatic patients, measuring the ME pressure before and after a flight: 20% of the adults presented negative pressure in the middle ear and 10% had alterations to the TM observed through otoscopy, after landing. Meanwhile, 40% of the children presented negative ME pressure and 22% showed alterations to the TM during otoscopy. These findings help further explain why children are more susceptible to barotraumas with air travel compared to adults.

Consequently, the prevalence of barotrauma depends on altitude (difference in altitude between the departure and arrival points), the type of aircraft, and personal characteristics.

There are also many adults who develop barotrauma. It is important to know that barotrauma may cause the transudation of liquid inside the ME, resulting in alterations to the TM, and may even result in hemorrhage into the middle ear (hemotympanum) with conductive hearing loss of 30 to 40dB.

Next, some factors will be considered that do not encourage barotrauma, together with others that may make it more likely.

The question that arises is: Do children with otitis media with effusion (OME), or chronic otitis media have more barotrauma? This is an important question.

Sade and co-workers[3] conducted a study of patients with OME, and TM alterations such as atelectasis or previous cholesteatoma surgery. The authors compared seventeen patients with barotrauma (normal patients with no ME pathologies, meaning with no chronic pathology), and 171 patients with ME alterations characterized as "chronic ear" infections. A mastoid pneumatization of the mastoid was assessed radiologically. It was noted that patients with barotrauma had larger mastoids (16.85 cm^2). This difference in mastoid size was significant in relation to the control group (12.9 cm^2) with no barotrauma. The pneumatization of the mastoid in the ears with chronic pathology was 3.6 cm^2.

Consequently, if the ET (which is responsible for the pneumatization of the mastoid) does not function properly as the child grows, it will be less pneumatized and, as a result, the child will have a smaller mastoid in "chronic ears".

During commercial flights, this shift in equalization must occur, this alteration in air volume at around 20%, meaning that the ME equalizes 20% of the gas volume. The smaller the mastoid, the smaller the volume of air that must run through the ET in order to keep the ME pressure equalized during the flight. Consequently, patients with OME, with atelectasis of the TM and cholesteatoma rarely present barotrauma [3]. This is finding has direct clinical relevance, because parents of children who have OME can be reassured that their child is at low risk for barotrauma and is unlikely to have ear pain during airplane descent. This is especially true if the tympanogram is completely flat (type B tracing), meaning there is no mobility of the TM and likely very little air in the ME space.

Another factor that results patients with atelectasis rarely presenting barotrauma is the flaccidity of the eardrum or tympanic membrane, which adapts better to pressure changes. Also in OME, there is liquid in the ME cavity, rather than air. The liquid is not compressed and is not subject to alteration, with no pain as there is no negative pressure. This also explains why patients with OME rarely present barotrauma [4].

The following factors [5] may well lead to barotrauma: nasal congestion, upper respiratory infection (URI) or nasal sinus allergy, recurrent otitis media (not a patient who already presents chronic otitis or OME, but a patient who frequently has repeat oititis), a person with rhinosinusitis, adenoid hypertrophy, ET obstruction due to a tumoral mass, with a cleft palate and anyone who has deep-dived 24 hours before the flight. In addition to children, the elderly are more likely to develop barotrauma. It is important to stress that barotrauma results from a ventilation failure in the ME cavity, caused mainly by edema of the rhinopharynx (URI or rhinitis). The peak incidence is proportional to the incidence of the URI [6].

What makes a person without ear disease or ET problems develop barotrauma, when this has hardly every happened previously? One example is nasal congestion. Traveling with a blocked nose. Here again is an example of how the Toynbee effect (described above) can impact ET function and set the stage for barotrauma under the right conditions (e.g., airplane descent). There is significant pain, and the person reaches their destination with a feeling of deafness or "stuffed or blocked ears". The symptoms vary from mild otalgia and a "blocked ear" feeling, to severe otalgia, buzzing and dizziness, with a possible rupture of the TM and severe hearing loss.[5]

The otoscopy is proportional to the symptoms, varying from retraction of the TM to hemotympanum. The appearance may vary, with congestion of the TM, peripheral hyperemia of the TM and on the malleus handle, areas of the TM with hemorrhage, presence of liquid in the ME or even bullae, transudates (**Figure 4A**), hemotympanum (**Figure 4B**) and even perforation of the TM (**Figure 4C**), in the more severe cases.

Figure 4A. TM with bullae **Figure 4B.** Hemotympanum **Figure 4C.** Perforated TM

The treatment is specific, depending on the clinical findings. If transudation is absent, with the patient seeing the doctor only with a feeling of "blocked ears": advise on the Valsalva maneuver (for aerating the ear) and the use of a topical nasal decongestant.[7] The use of a topical nasal decongestant must precede the Valsalva maneuver, in order to ensure that it is fully efficacious. This may be continued for several days until the tube function is re-established.

When transudation occurs, it is important not to engage in ear aeration maneuvers. Start treatment with a systemic and topical nasal decongestant (a phenylephrine, with or without antihistamine) together. When the ET starts opening and the blisters may already be seen in the ME, the Politzer device may be used. When the patient starts to respond to the Valsalva maneuver, Politzerization is no longer necessary. A small, comfortable device is already available on the US market for puffing air through the ET, known as Otovent® (**Figure 5**). The Otovent® has been specifically studied and shown to help improve middle-ear pressure when used on airplanes. It is available internationally and is inexpensive (around $15 USD) . **It is important to recall that no ET insufflation maneuver through the nose may be performed before nasal cleaning, and expelling all and any remaining secretions. Otherwise, nasal secretions may be forced into the ME during insufflation, resulting in even more severe ear problems.**

Figure 5. Otovent®

The treatment for hemotympanum may vary from a corticosteroid to an antibiotic, taken for around ten days. For patients (both children and adults) with severe discomfort, it is important to recall that it will take two weeks for all the blood to be reabsorbed. When a person develops an OME due to barotrauma, the effusion takes about two weeks to resolve.

Myringotomy can be performed to relieve ear congestion and pain, but does not immediately restore ET function. For anyone not used to it, however, the feeling of "blocked, stuffed ears" may be unbearable.

With regard to more severe alterations caused by barotrauma, it is important to be aware of the possibility of developing a perilymph fistula. In this case, an exploratory tympanotomy will be indicated, together with a conservative treatment that includes repose, a laxative diet, raised position, and sometimes a vasodilator in order to increase perfusion in the ciliated cells area.

What advice can be offered to parents traveling with their children? In order to prevent barotrauma in small children: offer the child something to drink during take-off and landing; carry a bottle of juice or milk or even a pacifier (**Figure 6**).

Figure 6. Preventing barotrauma: child swallowing

- **Make sure the child is awake when the plane is landing**, which allows the ET to function better. **Letting the child sleep when landing,** to try and avoid crying from ME pressure changes, rarely works and **is likely to only worsen the problem later on.**
- For a child who is already symptomatic (with URI, for example) it is important to make sure that **the nose is clear and clean before the flight starts**.
- For children who are severely congested, provide guidance on the use of a **topical nasal vasoconstrictor**.
- When an **older child** presents moderate symptoms of URI, it is important to recommend the **use of chewing gum during take-off and, above all when landing, in addition to a topical nasal vasoconstrictor**. When should the use of a topical nasal vasoconstrictor be recommended? In the boarding lounge, 30 minutes before the flight, placing a few drops in each nostril. When the nose is severely blocked, repeat the application, in order to be certain that the nose is quite clear, ensuring proper tube function.
- For a **child with recurrent symptoms (who cries constantly whenever flying)**, a more effective approach is needed, **using a systemic decongestant with a topic nasal medication**. This should be repeated on flights lasting more than twelve hours. Some practitioners also recommend **a spray squirt of nasal corticoids for smaller children**. **It is important to travel with a clean, secretion-free nose, meaning that cleaning the nose before the flight is vital**.

For adults, such as business executives who travel more frequently, barotraumas is very common. Among those with a previous history of feeling “stuffed or blocked ears” the use of a topical nasal decongestant is always recommended before the flight, as well as chewing gum during take-off and landing. This process should be repeated for flights lasting more than twelve hours.

Finally, prevention and treatment of predisposing factors are important for symptomatic patients (whose histories include rhinitis, rhinosinusitis, URI or earache) with the possibility of developing barotrauma, whenever they travel by air.

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