

# Incidence of barotrauma in the formation of cadets aviators in the Brazilian air force

## Abstract

Middle ear barotrauma is a pathology that can occur due to ineffective equalization between the external and internal pressures of the middle ear and can be caused by everyday conditions, which we sometimes do not notice before a flight. It is important to instruct the aviators to identify conditions that expose them to this pathology in order to make their instructions at the Air Force Academy (AFA). This study aims to measure the level of consciousness of the cadets on the subject, the recurrence of conditions that lead to the emergence of barotraumata, and the preventive measures used. A questionnaire with seven questions about barotrauma knowledge was applied to a sample of 40 Cadet Aviators of the second Squadron in 2023. All these cadets were conducting the Air training course when they answered the questionnaire. All were questioned as to their knowledge of barotrauma, symptoms, procedures for relief and treatment. The results showed that although cadets have broad knowledge on the subject, and more than half of those questioned admit to performing instructional flights in non-ideal health conditions. This behavior, besides greatly increasing the risk of occurrence of a barotrauma, shows that a preventive culture is not being cultivated in the cadets. It is necessary to reaffirm the dangers of a barotrauma during the training of cadets who are going to begin flight instruction. Cadet awareness of pathologies involving air activity is important to everyone, as it is, a matter of flight safety.

**Keywords:** barotrauma, Bysbarism, Valsalva, Boyle, aerospace medicine

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## Introduction

Barotrauma is one of the pathologies that can occur to any aircraft operator during their work routine. It is caused by the maintenance of negative pressure in the middle ear during the ascent and landing of the airplane, causing inflammation. Failure of the Eustachian tube is responsible for the pressure imbalance between the middle ear and atmospheric pressure, which can have serious consequences for hearing, such as perforation of the ear membrane and even rupture of the round window membrane.<sup>1</sup>

However, the specific type of functional deficit is important, since ears with a completely obstructed Eustachian tube may be less susceptible to barotrauma than those with a Eustachian tube that opens passively but does not dilate in response to muscle activity.<sup>2</sup>

When an aircraft climbs to a high altitude, its crew is subjected to a lower pressure than at ground level. As a result, the gaseous masses and body fluids inside the body must have their pressures equalized to that of the external environment as the aircraft climbs.<sup>3,4</sup>

If for some reason this doesn't happen, barotrauma can occur.<sup>4</sup> The pressure differential between the environment and the middle ear is fundamental to the development of barotrauma. Pathologies resulting from dysbarism are a reality in aviation worldwide.<sup>1,4</sup> In addition, there are predictors of barotrauma, such as upper respiratory infections and allergic rhinitis, which increase the risk of pathology

in the changing pressure environment.<sup>5</sup> For this reason, it is important to instruct airmen to identify the conditions that expose them to this pathology.<sup>6</sup>

At the Air Force Academy (AFA), aviation cadets are exposed to latent risk conditions that could result in barotrauma. The peculiarity of flight instruction at the AFA, with rapid manoeuvres and great variation in altitude, creates a potentially exposed group, since the equalization of internal and external body pressures must be very effective in order to avoid trauma to the middle ear. Measures must therefore be taken to prevent the occurrence of barotrauma and create it in the airman's training.<sup>7</sup> Barotrauma is a problem that worries international aviation bodies. One of the warnings is not to fly with the flu or sinusitis, precisely because of the possibility of barotrauma on an ordinary domestic flight, used daily by thousands of people.<sup>1</sup>

Barotrauma of the middle ear is an acute or chronic traumatic inflammation caused by changes in atmospheric pressure. The most common cause is the change in atmospheric pressure during descent on commercial flights associated with the passenger's inability to balance the pressure in the middle ear (ME) with atmospheric pressure.<sup>8</sup> During descent, the difference in pressure between the OM and the ambient pressure must be equalized to prevent barotrauma. For some, this balance can be easily achieved by swallowing, jaw movements and yawning. For others, it is necessary to perform the Valsalva maneuver several times during the descent, and even then, many passengers do not achieve results.<sup>1,3,4</sup>

In pressurized aircraft, the difference in pressure between the atmospheric environments is greatly attenuated, which makes it easier to equalize the pressure between the two. At the Air Force Academy, the cadet conducts his instruction flights in two aircraft, the Neiva T-25 Universal and the Embraer 312 T-27 (Figures 1&2). Both aircraft are not pressurized, even though they reach a considerable altitude during instruction.<sup>9</sup>



**Figure 1** Airplane T-25 Universal.

**Source:** Brazilian Air Force.



**Figure 2** Airplane EMB 312 T-27.

**Source:** Brazilian Air Force.

The most common cause of middle ear barotitis is the change in atmospheric pressure during the descent of commercial flights associated with the individual's inability to balance the pressure in the middle ear with atmospheric pressure. Due to the risk of barotrauma, crew members are advised not to fly with respiratory symptoms, which are easily caused by their working conditions such as: dry air, atmospheric pressure fluctuations, air currents through open aircraft doors at airports, passenger infections and weather changes.<sup>10</sup> The human hearing system can be divided into three parts: the inner ear, the outer ear and the middle ear. It is in this system that the human body receives sound waves, transforms them into nerve impulses and then analyzes them in the brain.

For airplanes, the Valsalva maneuver is indicated at the moment of descent, when there is an increase in atmospheric pressure. As the atmospheric pressure becomes higher than the pressure inside the middle ear, the eardrum bulges and consequently the risk of barotrauma increases.<sup>2,11,12</sup> The aeronautics cadet corps (CCAER), inserted in this context, becomes a group to be studied in order to analyze the incidence of this pathology in flight instruction in non-pressurized aircraft and possible prophylactic measures applicable to instruction at AFA. By educating cadets in training, the Brazilian Air Force will have the next generation of officers imbued with the prevention of flight-related pathologies. The aim of this study was to analyze the degree of knowledge of cadet aviators about what barotrauma is, the risks it poses and preventive measures.

## Methods

### Ethics committee

Ethical considerations were based on scientific purposes, with confidentiality of the identity of the pilots and cadets, free from

coercion or conflict of interest on the part of the institution or people involved in the project. Collections complied with technical safety protocols. The volunteers were informed in advance and the ICH measurement was analyzed with their express consent on a specific form (Free and Informed Consent Form - FICF), in accordance with resolution 196/96 of the CEP. Opinion number: 1.015.756.

### Inclusion/exclusion criteria

Cadets who passed the aeronautics health inspection conditioning assessment test and technical instructions,

The following were considered FIT for this study:

- Aviators who passed the Physical Conditioning Assessment Test (TACF) regulated by the Systemic Standard of the Air Force Command (NSCA). (NSCA) 54-1 (2004), carried out every semester at AFA;
- Aviators who have undergone an annual examination at the Aerospace Medicine Centre (CEMAL), an Aeronautical Health Organization (OSA), designated by ANAC, through an agreement with the Aeronautical Command (COMAER), and have obtained the Certificate of Physical Capacity (CCF) in the inspections;
- Cadets who have passed the periodic medical assessment of aircrew established by the - Technical Instructions for Aeronautical Health Inspections. ICA 160.1 of the Aeronautics Command, carried out every semester in the FAB.

Cadets who were considered UNABLE to participate in this study were:

- Failed any of the reports relating to the Conditioning, Evaluation Test and medical evaluation, in accordance with the Technical Instructions for Air Force Health Inspections;
- Have completed all the flights scheduled for the 2nd year at AFA.

### Questionnaire

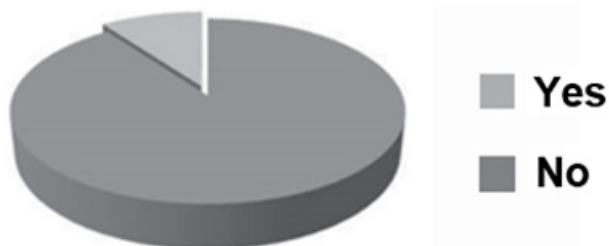
A questionnaire on knowledge of barotrauma was administered to a sample of 40 (forty) Cadet Aviators from the Second Squadron in 2023. All of these cadets were undergoing air training when they answered the questionnaire, which increases the reliability of the data collected since the questions focus on day-to-day training occurrences. The following 7 questions were asked:

- Do you know what barotrauma is? ( ) Yes ( ) No
- Have you ever experienced any of these symptoms during a flight? (You can tick more than one option). ( ) Sensation of a 'plugged' ear. ( ) Ear popping ( ) Tinnitus.
- How often did you experience these symptoms during your instruction at the 2nd EIA? ( ) Never ( ) Sometimes ( ) Often ( ) Always
- Do you use any techniques when you feel this discomfort in your ear (Valsalva, chewing gum) to try to relieve it? ( ) Yes ( ) No
- If yes to the previous question, which technique did you use? ( ) Valsalva ( ) Yawning ( ) Chewing gum ( ) Other: \_\_\_\_\_
- Have you ever flown with the flu, a cold or sinusitis? ( ) Yes ( ) No How many times? \_\_\_\_\_
- Have you ever been warned about the dangers of flying with the flu, a cold or sinusitis? ( ) Yes ( ) No

## Results and discussions

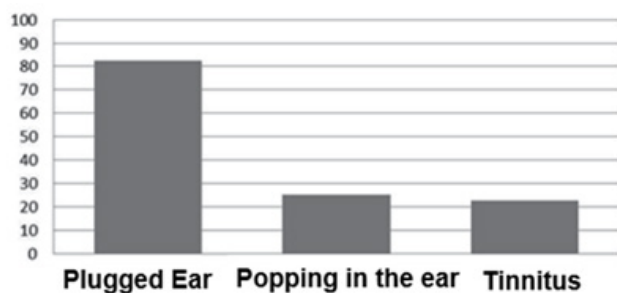
The first question asked whether the cadet knew what barotrauma was. This question aimed to quantify how many cadets knew at least what barotrauma is. Of the 40 cadets asked, 36 (90% of the total) said that they knew what barotrauma was, showing that this is a subject that has been covered at some point, either through the experiences of other cadets or some medical instruction.

However, 4 cadets (10% of the total) said they did not know what barotrauma is, which is proportionally worrying since all the cadets have been or will be exposed to risky conditions, as measured in other questions in the questionnaire (Graph 1).



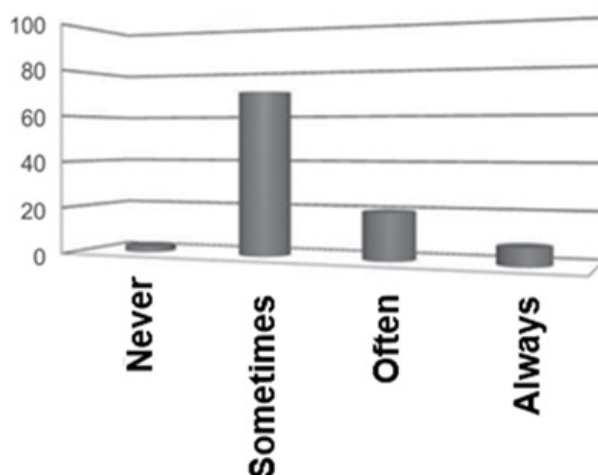
**Graph 1** Cadets' knowledge of barotrauma in %.

The second question presented some of the most common symptoms of a person who might suffer barotrauma during a flight. These sensations are common during a flight and will not necessarily lead to any pathology, but they do show that everyone has been exposed to conditions favorable to the appearance of trauma. Those asked could select more than one option, mainly because they are symptoms that can appear simultaneously. Of the cadets asked, 33 (82.5%) said that they had ever felt their ear 'plugged up', which makes it difficult to hear and generates discomfort. 10 (25%) cadets in the sample reported ear popping, a phenomenon that occurs naturally and can be caused by the natural equalization of the internal pressure of the ear with the external pressure. 9 (22.5%) cadets even experienced tinnitus, which to some extent hinders hearing and generates discomfort (Graph 2).



**Graph 2** Barotrauma symptoms in %.

The third question asked how often the respondents had experienced the symptoms presented in the previous question. This question shows how common the symptoms that indicate a difference in pressure between the middle ear and the external environment are in cadets' daily lives, and in some specific cases they can lead to barotrauma. Almost all of the cadets had experienced some of these symptoms (70%), with 20% reporting that they were frequent, 7.5% always and only 2.5% reporting that they had never felt anything, mainly due to the fact that these are normal, expected situations during the ascent and descent of the aircraft (Graph 3).



**Graph 3** Barotrauma symptoms in %.

So both the second question about the appearance of barotrauma symptoms and the third question about the number of times, i.e. how often, these symptoms appear are fundamental to understanding what happens to the airman.

These symptoms can be explained by the fact that when traveling by plane, people reach altitudes where the total air pressure is much lower than at sea level. In most military aircraft, the cabin pressure at cruising altitude, 10,000 to 20,000 feet, is generally maintained at a pressure comparable to an altitude approximately 2440m above sea level. It is a physiologically different environment compared to the environment found on land, with the cabin at this altitude being hypoxic relative to the terrestrial to the earth's atmosphere due to the drop in oxygen pressure.<sup>8</sup>

According to Boyle's law, volume is inversely proportional to pressure, so at this lower pressure, gas volumes increase and the air inside the middle ear expands with the rise in altitude.<sup>7</sup> The difference in pressure in the middle ear and Eustachian tube at altitude is great, even in a pressurized cabin. For this reason, it is necessary to reduce the pressure in the middle ear so that it is in balance with the outside pressure.<sup>3</sup> In this situation, as the plane ascends, the pressure is regulated by air escaping from the middle ear through the Eustachian tube into the nasopharynx. At altitude, the space inside the middle ear is thus in balance with the reduced atmospheric pressure.<sup>12</sup>

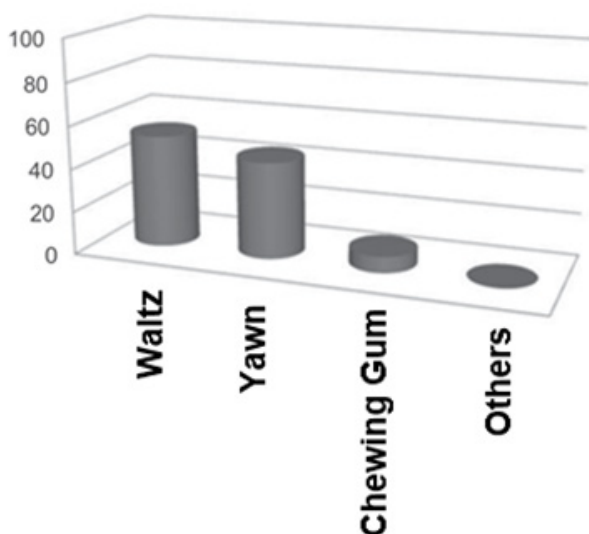
As the plane descends and atmospheric pressure increases, the middle ear equalizes the pressure by periodically allowing air to enter through the Eustachian tube.<sup>4</sup> When this equalization is not achieved, as negative pressure builds up in the middle ear, a vacuum effect is created, which can be painful. Upon landing, the air bubble in the middle ear continues to decrease in size as the atmospheric pressure increases the tissues of the middle ear.<sup>3</sup> Since the tympanic membrane is the most malleable of these tissues, it is pulled inwards, causing pain. Therefore, the aim of this questionnaire, and the questions presented above, was to understand what the main symptoms are and how they relate to the frequency of flights in this group of Cadet Aviators.

The fourth question asked whether the cadets who answered the questionnaire used any techniques to ease the discomfort generated by the symptoms they reported in question 2. It was found that 80% of the cadets use some technique, which shows two important points. Firstly, the discomfort generated is great and to some extent hinders

the progress of instruction. Secondly, it shows that techniques for equalizing internal and external ear pressure are popular among cadets.<sup>13</sup>

When asked if they used any technique (Valsalva, chewing gum) to try to relieve this discomfort in the ear, 80% said yes, while 20% denied it.<sup>14</sup> The fifth question asked which technique is most commonly used by the sample of cadets to ease the discomfort generated during the flight by the symptoms mentioned in the previous question.

The Valsalva procedure is very popular among cadets, with 52.5% of them doing it. Simulating yawning is the second most used technique 45. Chewing gum is reported by only 7.5% of cadets. Respondents were given the option of ticking more than one option and also the possibility of spelling out any other technique used, but none of the respondents did so (Graph 4).



**Graph 4** Barotrauma relief procedures in %.

Question number 5 asked whether the cadets had ever flown on an instruction flight with a cold, flu or sinus symptoms up to the date of the questionnaire. This question raises both the occurrence of conditions conducive to middle ear trauma during air instruction at 2° EIA, and also shows to some extent the cadets' level of awareness of their health and the risk they took when flying in these conditions. Of the 40 cadets asked in the survey, 54% said they had already flown with the flu, a cold or sinusitis. This figure is very worrying, as it shows that more than half of those questioned did not give due consideration to the risk they had run.

Question 6 asked whether cadets had ever been warned about the risk of flying with the flu, a cold or sinusitis. The result showed that only 3% of cadets said they had not been warned about the risk of flying with these symptoms, which is very positive. Few studies related to barotrauma are found in the literature, however, a study was carried out on middle barotitis in civil aviation crew members, who were seen at the ENT outpatient clinic of the Ruben Berta Foundation/RJ (FRB/RJ), where 17 individuals were analyzed, showing that all had otalgia during the descent of the plane, 14 individuals complained of aural fullness, and 2 complained of tinnitus.

At the time of the flight, 11 of the patients had symptoms suggestive of an associated upper airway infection. After analysis, Teed grade 1 barotrauma was observed in 17.6% of cases, grade 2 in 58.8% of cases

and 23.6% grade 3.<sup>15</sup> When we compare the results of this research with the data obtained in the questionnaire applied to cadets at the Air Force Academy, we find an alarming result, because when asked about the most common symptoms of a person who might suffer barotrauma during a flight, 82.5% of the cadets asked said they had already experienced one or more symptoms, and of the cadets who reported feeling these symptoms, 20% said they were frequent, 7.5% always felt them and only 2.5% said they had never felt anything. In addition, of the 40 cadets asked, 54% said they had already flown with the flu, a cold or sinusitis, which can create conditions conducive to causing barotrauma, as shown in the study cited above.

Despite this high number of cadets taking part in flight instruction without good health conditions, the results of the questionnaire showed that 90% of those asked know what barotrauma is, but 10% of the total said they were unaware of the condition. And only 3% of cadets said they had not been warned about the risk of flying with these symptoms.

Based on the analysis of this study, we can say that the factors that trigger the occurrence of this disease are everyday in the life of any person, these results indicate that it is important to investigate techniques to minimize the risk of any injury during flights, in addition to carrying out work to raise awareness and prevent cadets from this pathology, because, like most diseases related to aviation, prevention is a factor that substantially reduces the possibility of physiological damage resulting from dysbarism.<sup>16</sup>

One of the ways of preventing barotrauma is through physical breathing exercises. However, the literature is somewhat scarce in terms of data resulting in positive results.

## Conclusions

The results showed that the sample of cadets has a basic knowledge of what barotrauma is, representing almost all of the group surveyed, reflecting the knowledge acquired through lectures on aerospace medicine and guidance provided by the squadron doctor. It also showed that middle ear pressure equalization techniques are popular and widely used during flight instruction at AFA. The vast majority of cadets reported that they had already been warned about the risk of flying with colds and flu, which generally shows that they are aware of the subject.

However, it was also pointed out that even with all the instruction given to them, highlighting the factors that cause and the consequences of barotrauma, more than half of the cadets continue to fly in less than ideal health conditions. Flying with the flu, a cold or sinusitis is still normal for more than half of those questioned which is worrying as it is a health risk during instruction. We can also infer that the preventive culture that will accompany these future officers throughout their careers needs to be improved.

Cadets need to be made more aware of the risk of flying in less than ideal health conditions before they begin their flying lessons. Exposing statistics and testimonies would show the seriousness of the problem, which can sometimes seem far from the reality of instruction at 2°EIA due to the low level of flying.

During the flying period, especially before phases in which there is rapid variation in altitude such as formation flying and instruction in manoeuvres and acrobatics, lectures should be given to emphasize the risk of barotraumas. In general, cadets need to be monitored more closely by flight instructors and medical officers in order to prevent avoidable risks from occurring.



Barotrauma is one of the pathologies that can occur to any airman during his work routine. The factors that trigger the occurrence of this condition are commonplace in anyone's life, but it can have serious consequences for hearing.

As with most aviation-related illnesses, prevention is a factor that substantially reduces the possibility of physiological damage resulting from dysbarism.

Flying with the flu, a cold or sinusitis is still normal for more than half of those questioned which is worrying as it is a health risk during instruction.

## Acknowledgments

None.

## Conflicts of interest

The authors declare that there is no conflict of interest.

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