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Point Prevalence of Barotitis and Its Prevention and Treatment with Nasal Balloon Inflation: A Prospective, Controlled Study

*Sven-Eric Stangerup, †Mads Klokker, †Søren Vesterhauge, ‡Samuel Jayaraj, ‡Peter Rea, and ‡Jonathan Harcourt

**ENT Department, Gentofte University Hospital, Copenhagen, Denmark, †Departments of ENT and Civilian Aviation, Rigshospitalet, University Hospital, Copenhagen, Denmark, and the ‡ENT Department, Charing Cross Hospital, London, U.K.*

Introduction: The most common cause of barotitis is pressure changes induced during descent in aviation. The incidence after air flight has been reported to vary from 8% to 17%.
Objectives: We conducted this study to estimate the incidence of barotitis after flight, to evaluate whether the incidence of barotitis can be reduced by nasal balloon inflation during descent, and, finally, to estimate the effect of nasal balloon inflation in case of negative middle ear pressure after landing.
Study Design: Aircraft passengers were examined by otoscopy and tympanometry before and after flying and filled in a questionnaire inquiring about ear problems. On half of the flights, the passengers were asked to inflate a nasal balloon during descent, whereas the other half were control flights.
Results: A total of 188 passengers filled in the questionnaire. Of these, 134 were examined before and after the flight. Otoscopic signs of barotitis were found in 15% of the ears in the control group compared with 6% in the balloon inflation group. In ears with a negative pressure after flying, the pressure could be equalized by Valsalva's maneuver in 46%. Passengers who were unable to equalize the pressure in this way inflated a nasal balloon, and in 69%, this maneuver cleared the middle ear pressure.

Conclusion: The incidence of barotitis in this study of aircraft passengers was 14%. This figure could be reduced to 6% in passengers who performed nasal balloon inflation during descent. We recommend nasal balloon autoinflation in aircraft passengers who have difficulty clearing their ears during and after flying. **Key Words:** Barotrauma—Autoinflation—Valsalva—Otovent—Teed's classification—Negative middle ear pressure.

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Barotitis is defined as an acute traumatic inflammation caused by environmental pressure changes (1) and is characterized by pain and impaired hearing in the affected ear, and occasionally by vertigo (2). In rare cases, sudden deafness caused by rupture of the round window can occur (3,4). The most common cause of barotitis is pressure changes induced during descent in aviation in passengers unable to equilibrate the negative middle ear pressure. In a modern aircraft, the cabin pressure at cruise level is adjusted to approximately three-fourths of the atmospheric pressure. During descent, the pressure difference between the middle ear and the ambient pressure must be equalized to prevent barotrauma. Many passengers easily achieve equilibration by swallowing, yawning, or chewing, whereas other passengers have to perform Valsalva's maneuver to achieve this.

The present study is a follow up of a previous one (5) in which we examined passengers by otoscopy and tympanometry immediately after landing. Barotitis occurred in 20% of the children and 10% of the adult passengers. Unfortunately, the passengers were not examined before the flight and the preflight status of their ears was therefore not known. There could thus have been a selection bias among the passengers volunteering to take part in the examination after the flight.

Like in the previous study, the aims of the current study were to estimate the point prevalence of middle ear problems before, during, and after air flight and to evaluate the efficacy of nasal balloon inflation for preventing barotitis during descent. In addition, the efficacy of Valsalva's maneuver and nasal balloon inflation was assessed for their ability to restore normal middle ear pressure. The passengers in this study were examined before departure as well as after arrival. To assess a possible

Address correspondence and reprint requests to Dr. Sven-Eric Stangerup, ENT Department, Gentofte University Hospital, Niels Andersens vej 65, DK-2900 Hellerup, Denmark; E-mail: stangerup@pc.dk

This study has been approved by the Danish Medical Ethical Committee.

selection bias among the passengers who volunteered to attend the examination before and after a flight compared with those who did not have the examination, a reference group of passengers was included who were asked to fill in a similar questionnaire as the attendees.

SUBJECTS AND METHODS

Aircraft passengers traveling with Scandinavian Airline System (SAS) on eight flights from Copenhagen to London or from London to Copenhagen on November 24, 2001, were offered an ear examination, including otoscopy and tympanometry, at the gate before departure. Three of the authors formed the team at Copenhagen Airport and the other three the team at Heathrow Airport, London. Half of the flights were randomized to be "autoinflation flights" and the other half to be "control flights." In both groups, the passengers were given written information about the study and instructions on how to perform the Valsalva maneuver. On the "autoinflation flights," the passengers were given an Otovent nasal balloon (Abigo Medical AB, Askim, Sweden) and asked to inflate the balloon 2 to 3 times during descent if the Valsalva maneuver failed to relief the pressure symptoms (Fig. 1).

In addition, the passengers were given a questionnaire to fill in before landing. The questionnaire inquired about any history of nasal allergy, the presence of current nasal congestion, previous ear problems during flight, otalgia, and use of any decongestants during the present flight. The passengers in the autoinflation group were asked about their use of the nasal balloon and if this had relieved the pressure symptoms. At the destination, the passengers underwent an examination identical to that before departure. The investigators were blinded to the findings of the group at the departure airport.

The passengers with negative middle ear pressure after flying were instructed to perform Valsalva's maneuver. If the pressure remained negative, the passengers were instructed to inflate the nasal balloon.

The inclusion criteria were age 18 years or older and no indications of acute ear or sinonasal infection. All passengers included in this study had given their informed consent.

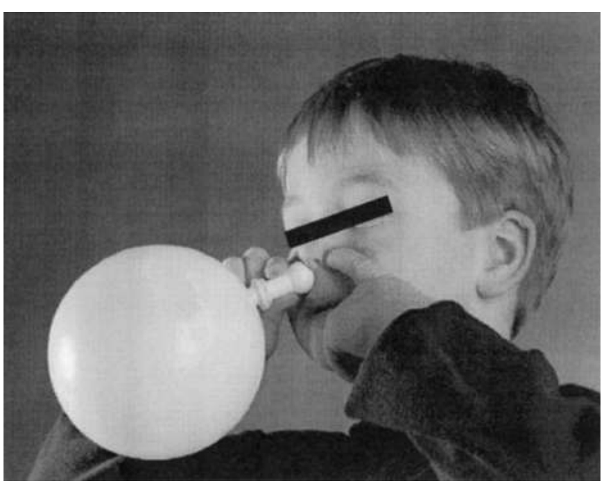

FIG. 1. Otovent nasal balloon autoinflation. The nosepiece is held airtight into one nostril, the opposite nostril is compressed with a finger, and with the mouth closed, the balloon is inflated through the nose.

Otovent

The Otovent set consists of a nose tube mounted with a special membrane. The nose tube is held airtight to one nostril, the opposite nostril is compressed with a finger, and with the mouth closed, the balloon is inflated through the nose. During the inflation phase, a positive pressure of 600 dPa is created in the nose and nasopharynx, which can equalize the middle ear pressure through the eustachian tube, the normal opening pressure of which is approximately 400 dPa. The Otovent nasal balloon was originally developed as a method to improve middle ear ventilation in children with eustachian tube dysfunction and secretory otitis media (6). Our previous study (5) showed that in passengers with negative middle ear pressure after flying that could not be cleared by Valsalva's maneuver, 40% of the children and 68% of the adult passengers achieved this by means of the nasal balloon.

Questionnaires

Approximately 750 passengers traveled with SAS from Copenhagen to London Heathrow or from London Heathrow to Copenhagen on Saturday, November 24, 2001. Because of the hectic activity of boarding the airplane and performing the examinations, the questionnaires were given to only 227 of the 750 passengers (30%). Of these, 188 (83%) filled in and returned the questionnaires (Table 1).

Autoinflation Group

A total of 77 passengers on "autoinflation flights" underwent the examination before take off. The median age was 39 years (range, 18–62 years). Of these, 58 filled in the questionnaire and 54 (70%) attended the ear examination at the destination (Table 1). Forty of the passengers in this group inflated the nasal balloon during descent as instructed and is hereafter referred to as the "autoinflation complier group."

Control Group

A total of 108 passengers on "control flights" underwent the examination before the flight. The median age was 41 years (range, 18–85 years). Of these, 88 filled in the questionnaire and 80 (74%) attended the ear examination at the destination (Table 1).

Reference Group

A nonselected group of passengers served as a reference group. Shortness of time meant that these passengers did not undergo the ear examination but they were asked to fill in the same questionnaire as the control group. A total of 42 passengers entered this group. The median age was 49 years (range, 24–80 years) (Table 1).

Otoscopy

The otoscopic findings were scored according to Teed's classification of barotitis (7): grade 0—normal drum, grade 1—retraction with redness in pars flaccida (Shrapnel's membrane) and along the manubrium, grade 2—retraction with redness of the entire tympanic membrane, grade 3—same as grade 2 plus evidence of fluid in the tympanum or hemotympanum, and grade 4—traumatic perforation of the drum.

Tympanometry

The middle ear pressure was measured using a Madsen 901 tympanometer (Otometrics, Denmark) calibrated on site before the study. The tympanometric result obtained in each ear was displayed digitally and recorded manually. Negative pressures equal to or exceeding −200 dPa were considered pathologic.

TABLE 1. *Material*

	Reference group	Control group (N = 108)		Autoinflation group (N = 77)		Total
		Examined at departure and arrival	Examined at departure only	Examined at departure and arrival	Examined at departure only	
Filled in the questionnaire	42	78	10	53*	5†	188
Did not fill in the questionnaire		2	18	1	18	39
Total	42	80	28	54	23	227

*Of these, 40 inflated the Otovent.
†Of these, 4 inflated the Otovent.

Statistics

The statistical evaluation of the otoscopic and tympanometric findings was based on the ear with the most pronounced pathology. The χ^2 test and the Mann-Whitney rank sum test were used for evaluation of the outcome, and the level of significance was chosen at $p < 0.05$.

RESULTS

Questionnaires

The results of the questionnaires in the three groups of passengers appear in Table 2. There were no statistically significant differences between the three groups with regard to the question reports. Almost all of the passengers asked (98%) had traveled by airplane before. Forty-nine passengers (26%) reported having had previous ear problems, nonflight-related, and half of the passengers had experienced ear pain during previous flights. Nasal allergy was reported by 13% and actual nasal congestion by 16% of the passengers. More passengers in the control group and the autoinflation group (44% and 48%) reported to have felt unpleasant pressure changes during descent compared with 36% in the reference group. This difference is not statistically significant. Ear pain during flying was reported by 41% of all responders. Five percent of the passengers had used nasal decongestants during the flight. All passengers on the autoinflation flights were given an Otovent set together with instructions on how to use it, and they were asked to inflate the nasal balloon during the descent before landing. Forty-four of 58 (76%) inflated the Otovent as instructed, and 35 of these 44 passengers (80%) reported relief of the pressure symptoms after the inflation.

There was a significant relation ($p < 0.001$, χ^2) between a history of ear problems and ear pain during the actual flight. Among passengers with previous ear problems, 73% complained of pain compared with 31% of passengers with no previous ear problems (Table 3). Of the 16 passengers who reported previous ear problems and actual ear pain during the flight and who inflated the nasal balloon, 14 (88%) felt that the symptoms improved.

There was also a significant relation ($p < 0.001$, χ^2) between a history of ear pain during previous flights and the reporting of ear pain during the actual flight. Fifty-nine percent of passengers with previous ear problems reported actual ear pain during the flight compared with 25% of the passengers with no previous ear problems (Table 3).

We found no significant relation between reports of nasal allergy and actual ear pain, or between nasal congestion and actual ear pain during descent.

Otoscopic Findings

Table 4 demonstrates the frequency and grade of barotitis at otoscopy before and after landing. There was no significant difference in the otoscopic findings at departure between those who attended and those who did not attend the examination after arrival.

TABLE 2. *Questionnaire results in the different groups*

	Reference group (n = 42) Yes		Control group (n = 88) Yes		Autoinflation group (n = 58) Yes		All asked (n = 188) Yes	
Questionnaire	No.	Percent	No.	Percent	No.	Percent	No.	Percent
Previous ear problems (nonflight-related)	11	26	20	23	18	31	49	26
Air flight before	41	98	87	99	56	97	184	98
Ear pain during previous flights	21	50	42	48	31	53	94	50
Nasal allergy	5	12	12	14	8	14	25	13
Actual nasal congestion	7	17	16	18	8	14	31	16
Pressure change now unpleasant	15	36	39	44	28	48	82	44
Ear pain during actual flight	16	38	33	38	29	50	78	41
Used nasal decongestants	3	7	5	6	2	3	10	5
Used ear plugs during this flight	—	—	2	2	1	2		
Otovent inflation during this flight	—	—	—	—	44	76		
If yes, did it relieve the symptoms (35 of 44)	—	—	—	—	35	80		

Statistical significance: There were no significant difference between the 3 groups with regard to the question reports.

TABLE 3. *Relation between previous ear problems and ear pain during previous flight and ear pain during the recent flight*

		Actual ear pain during the present flight		
		Yes (n = 77)		No (n = 107)
Previous ear problems	Yes (n = 48)	35		13
			*	
	No (n = 136)	42		94
Ear pain during previous flight	Yes (n = 91)	54		37
			*	
	No (n = 93)	23		70

*Chi-square p <0.001.

We found no significant difference in the otoscopic findings between the control group and the autoinflation group before departure. There was a significant difference ($p < 0.001$, Mann-Whitney) in the otoscopic findings before and after flying in the control group. Also in the autoinflation group, there was a higher Teed score after flight, but the difference was not significant. After arrival, there were significantly ($p < 0.05$, Mann-Whitney) more pathologic ears, according to Teed's classification, in the control group compared with the autoinflation group. In the control group, only 54% had grade 0 on arrival, and 10 of 69 passengers (15%) had grade 2 or 3, indicating some degree of barotitis. In the autoinflation group using Otovent, 28 of 36 (78%) passengers had grade 0, and 2 of 36 (6%) passengers had grade 2 or 3 changes. Eight of the 12 passengers having Teed grade 1 or 2 before departure were in transit and had just arrived from an earlier flight.

In the group of passengers with Teed grade 0 at departure (Table 5), 8 of 59 (14%) had Teed grade 2 or 3 after landing on a control flight compared with 2 of 34 (6%) on the autoinflation flights using the nasal balloon during descent ($p < 0.05$, Mann-Whitney). Among passengers in the control flights, indicating ear pain during descent, barotrauma could be identified by otoscopy in 9 of 28 passengers (32%) compared with 1 of 39 (3%) in the group who did not experience ear pain during the flight.

Tympanometric Findings

There were no statistically significant differences in the tympanometric findings at departure between those who attended and those who did not attend the examination on arrival. The tympanometric findings before the flight showed no significant differences between passengers in the control group and in the autoinflation groups who underwent the ear examination both before and after flying (Table 6). After arrival, there were significantly more ears with a high negative middle ear pressure (≤−200 dPa) in the control group compared with the autoinflation group ($p < 0.05$, Mann-Whitney). At arrival, 12 of 80 passengers (15%) in the control group had a pathologic negative middle ear pressure compared with 1 of 38 (3%) in the autoinflation complier group.

In the group of passengers with normal middle ear pressure at departure (>-200 dPa, Table 7), significant more ($p < 0.05$, Mann-Whitney), 10 of 77 (13%), had pathologic negative middle ear pressure after landing on a control flight compared with none in the autoinflation complier group.

Tympanometry After Valsalva and After Nasal Balloon Inflation

At the examination performed on arrival, all passengers with negative middle ear pressure (<0 dPa) were asked to perform Valsalva's maneuver and tympanometry was repeated. If negative middle ear pressure remained, the passengers were instructed to perform nasal balloon inflation after which tympanometry was repeated.

After the flight, negative middle ear pressure (<0 dPa) was found in 114 passengers (Fig. 2). Tympanometry was repeated in 105 of these after Valsalva's maneuver, and in 48 of 105 subjects (46%), the pressure could be equalized to zero or positive. In the remaining 57 passengers with persisting negative pressure after Valsalva's maneuver, tympanometry was repeated in 52 subjects after nasal balloon inflation, at which time only 16 still had negative pressure (31%), whereas the pressure was

TABLE 4. *Otoscopic findings before departure and after arrival in the control group and the autoinflation complier group*

Otoscopic findings	Control group (N = 80)				Autoinflation group (N = 40)			
	Departure		Arrival		Departure		Arrival	
	No.	Percent	No.	Percent	No.	Percent	No.	Percent
Teed 0	65	87	37	54	36	95	28	78
Teed 1	8	11	22	32	1	3	6	17
Teed 2	2	3	4	6	1	3	1	3
Teed 3	—	—	6	9	—	—	1	3
Teed 4	—	—	—	—	—	—	—	—
All evaluated	75	94	69	86	38	95	36	90
Missing data	5	7	11	14	2	5	4	10

Mann-Whitney test: I—p < 0.001—I I—p < 0.05—I. I—NS—II—NS—I.
NS, not significant.

TABLE 5. *Otoscopic findings after arrival in the ears with Teed grade 0 at departure in the control group and the autoinflation complier group*

Otoscopic findings after arrival	After arrival: Control group (N = 65) No.	Percent	Autoinflation group (N = 36) No.	Percent
Teed 0	32	54	27	79
Teed 1	19	32	5	15
Teed 2	4	7	1	3
Teed 3	4	7	1	3
All evaluated	59	91	34	94
Missing data	6	9	2	6

Mann-Whitney test: I—$p < 0.05$—I.

zero or positive in 36 of 52 (69%) of the passengers. Thus, a total of 84 of the 100 passengers with negative pressure after flying could increase their middle ear pressure after Valsalva's maneuver or nasal balloon inflation. It is noteworthy that of the six ears with flat tympanometry curves that did not improve by Valsalva's maneuver, four had a middle ear pressure of zero or above after balloon inflation.

DISCUSSION

In most commercial airplanes, the cabin pressure at a cruising altitude of 30,000 to 40,000 feet is usually kept at a pressure comparable to an altitude of 8000 feet (6000 dPa). During ascent, the relative, positive pressure in the middle ear is readily equalized, because air can easily escape through the eustachian tube. During descent, with a cabin pressure descent rate comparable to 400 feet/minute, the situation is different because the eustachian tube acts as a flutter valve until the pressure differential reaches a critical level of 1000 to 1200 dPa. This level is reached if equalization does not occur at least every 7 to 9 minutes during descent, and in this event, otic barotrauma is likely to occur. In simulated flights in pressure chambers, the relative frequency of barotitis among 101,716 U.S. Air Force trainees was reported to be 17% (8). In a study of Australian Defense Force (ADF) personnel (9), subjective postchamber barotrauma was reported by 23 of 80 (29%) and could be identified by otoscopy in 52% of those experiencing symptoms.

The first objective of this study was to estimate the point prevalence of barotitis after flying. We found otoscopic signs of barotitis after the flight in 14% of the passengers with normal findings at otoscopy before the flight, which is the same percentage as in our previous study (5). Tympanometric sign of barotitis was found in 13% of passengers with normal tympanometry (>−200 dPa) before the flight.

The high incidence of barotitis found in the group undergoing the ear examination might be attributable to a possible, unintentional selection of subjects who had experienced ear problems during the actual flight. This seems not to be the case because there was no significant difference in the reporting of previous or actual ear pain between the reference group and the attendees. There was also no difference in the otoscopic or tympanometric findings between the group attending the examination before and after flying and the group undergoing only the examination before the flight.

The second objective of the study was to evaluate the effect of nasal balloon inflation in preventing barotitis from developing. Otoscopic signs of barotitis occurred significantly less frequently (6%) in the group of passengers who inflated the nasal balloon during descent compared with the control group in which this was found in 15% (Table 4). Also, the middle ear pressure after flying was significantly higher in those who inflated the balloon compared with the control group (Table 6). Pathologic negative middle ear pressure occurred in 3% after flying among passengers having inflated the Otovent compared with 15% in the control group.

The third objective of the study was to evaluate the ability of the subjects to equalize a negative middle ear pressure developing during flying. Based on our clinical experience that nasal balloon inflation is more effective in clearing the middle ear than Valsalva maneuver, we decided that passengers with negative middle ear pres-

TABLE 6. *Tympanometric findings before departure and after arrival in the control group and the autoinflation complier group*

Tympanometric findings	Control group (n = 80) Departure No.	Percent	Arrival No.	Percent	Autoinflation group (n = 40) Departure No.	Percent	Arrival No.	Percent
Positive/zero	14	18	8	10	8	21	8	21
−5 to −99	57	71	52	65	27	69	28	74
−100 to −199	6	8	8	10	1	3	1	3
−200 to −400	1	1	6	8	2	5	1	3
Flat curve	2	3	6	8	1	3	—	—
All measured	80	100	80	100	39	98	38	95
Missing data	—	—	—	—	1	3	2	5

Mann-Whitney test: I—$p < 0.05$—I I—$p < 0.05$—I. I—NS—II—NS—I.
NS, not significant.

TABLE 7. *Tympanometric findings after arrival in ears with normal tympanometry (>−200 dPa) at departure in the control group and the autoinflation complier group*

	After arrival			
	Control group (N = 77)		Autoinflation group (N = 36)	
Tympanometric findings after arrival	No.	Percent	No.	Percent
Positive/zero	8	10	7	20
−5 to −99	52	68	28	80
−100 to −199	7	9	—	—
−200 to −400	5	6	—	—
Flat curve	5	6	—	—
All measured	77	100	35	97
Missing data	—	—	1	3

Mann-Whitney test; I—$p < 0.05$—I.

sure after flight should first perform a Valsalva maneuver and then if unsuccessful, inflate the nasal balloon. Of passengers with negative middle ear pressure after flying, 46% could normalize the pressure by performing Valsalva's maneuver. Among those who could not normalize the pressure in this way, 69% achieved this by nasal balloon inflation.

CONCLUSION

Otoscopic or tympanometric signs of barotitis were found in 18% of aircraft passengers in this study. Inflation of a nasal balloon during descent reduced the prevalence of barotitis to 3%. Forty-six percent of the passengers were able to normalize the negative pressure obtained during flight by performing Valsalva's maneuver, and among those who could not equalize the negative middle ear pressure in this way, 69% achieved pressure equalization by nasal balloon inflation. We recommend the use of nasal balloon inflation during descent for passengers with a history of ear problems and ear pain during previous flights.

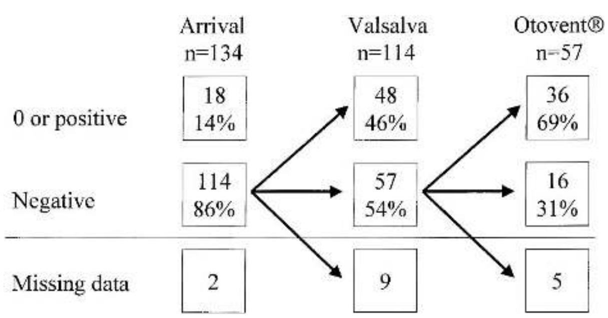

FIG. 2. Tympanometric findings in the worse ear at arrival after Valsalva's maneuver and after balloon inflation.

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