Otosclerosis and Fitness to Fly

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BACKGROUND: When an aircrew member is referred for otosclerosis, his flight fitness may be questionable. The objective of this retrospective study was to describe a case series of otosclerosis in an aircrew population and to discuss the decisions about their flight waivers.

METHODS: There were 27 aircrew members who were referred to the ENT-Head and Neck Surgery Department of the National Pilot Expertise Center. Their medical files were retrospectively examined.

RESULTS: Out of 16 patients who had surgery, 2 did not obtain a flight fitness waiver afterwards. Among the 14 who received waivers, 12 had no restrictions on their flight fitness. Among the nonoperated patients, 1 of 11 did not obtain a waiver. Seven patients were declared medically fit to fly without a waiver and three obtained a waiver.

DISCUSSION: Fitness was based on auditory and balance statuses and the follow-up of these findings. A postoperative CT-scan and the operative report were used to determine the quality of stapes surgery. Professional speech audiometry in noise might be as interesting. The results made it possible to determine a patient's fitness to fly with a waiver, which is more or less associated with restrictions. In our series, only 3 aircrew members out of 27 did not obtain a flight fitness waiver. The few published studies on the resumption of flight for patients who underwent surgery and our experience in France with similar waivers in commercial and military aviation suggest that under certain conditions and after relevant vestibulocochlear assessment, stapes surgery may allow for a safe recovery of aviation activity.

KEYWORDS: otosclerosis, flight fitness, expertise.

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Otosclerosis is a primary disease of the otic capsule and bones that manifests as progressive conductive or mixed hearing loss. The auditory symptoms may also be associated with vestibular symptoms. Surgical treatment creates a vestibular cavity opening and a prosthesis is implanted to restore the columella effect. However, exposure to barometric changes and G forces during aviation may induce barotrauma of the inner ear and a perilymph fistula, with consequent sudden incapacitation in flight and risk of air accidents. When an aircrew member is referred for otosclerosis, their flight fitness often becomes questionable. The objective of this retrospective study is to describe a case series of otosclerosis in an aircrew population and to discuss the decisions about their flight fitness.

METHODS

Subjects

In French aviation (civilian and military), nearly 16,000 experiments are conducted on aircrew members (4000 pilots) in the ENT – Head and Neck Surgery Department of the National Pilot Expertise Center (Clamart, France) each year. The mission of this center is to select and monitor aircrews with specialized expertise in aeronautics, naval, and aerospace. It is the main center for military personnel and it supports many individual (private) pilots and those employed by commercial airlines. When conductive hearing loss suggestive of otosclerosis is identified during a routine visit, the staff records this information into a register, which allowed us to locate these patients' ENT records for analysis. The inclusion criterion for this study was a finding of progressive conductive hearing loss with a normal eardrum. The exclusion criteria were incidental findings upon admission that contraindicated selecting this candidate.

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The examination aimed to determine the possibility of granting the patient a flight waiver. The hospital ethics committee exempted this study from the need for consent because it only involved retrieving data from medical records (Scientific Committee for Clinical Trials of the Percy Hospital, September 2012).

Methods

Our study focused on patients with expertise records from the last 7 yr. It involved all aircrew members who presented with otosclerosis during the course of systematic monitoring at the ENT – Head and Neck Surgery Department of the National Pilot Expertise Center. The medical files were retrospectively examined, and the following data were analyzed:

- Age, gender, job, date of diagnosis;
- Pure tone and speech audiometry, audiometric air-bone gap;
- Mean hearing loss in each ear [(500 Hz + 1000 Hz + 2000 Hz + 4000 Hz)/4] and the evolution of the hearing loss during the survey;
- Time of follow-up;
- Year of surgery; and
- Fitness to fly results.

Statistical Analysis

The statistical analysis was performed with SPSS/PC software version 10.0 (SPSS Inc., Chicago, IL). The analysis was descriptive and aimed to illustrate and explain the purpose of the discussion, i.e., the fitness-to-fly decision.

RESULTS

The files of 27 aircrew members (19 men and 8 women) were collected and analyzed (**Table I**). Seven patients presented with bilateral involvement. Therefore, 34 ears were included in the study protocol. The patients were on average 47.5 ± 8.5 yr old at the time of examination. The audiometric follow-up lasted an average of 22.8 yr (range: 3–39 yr). The time to follow-up from the diagnosis of otosclerosis was 11.1 yr on average (range: 1–29 yr). The patients were 35.6 ± 7.2 yr old at the time of diagnosis. The aircrew members were divided into the following categories: fighter pilot (7 ears), line pilot (15 ears), cabin crew (9 ears), and others (private pilot, navigator: 3 ears) (**Table II**).

There were 11 patients (16 ears) who did not undergo surgery and were followed with observation only. The flight fitness determination depended on audiometry results. Flight fitness was assessed in 7 out of 11 patients (11 out of 16 ears) with a mean hearing loss (MHL) of up to 40 dB.

Three nonoperated patients (four ears) were declared unfit to fly during a routine visit, but obtained a waiver based upon their speech discrimination in noise results. These patients had a mean MHL of 47 dB. One patient (one ear), a navigator, was declared unfit to fly as result of nonsymptomatic ipsilateral vestibular areflexia. This vestibular loss was well compensated for in activities of daily life. In this case, the patient was deemed unfit to fly because of the theoretical risk during the flight, which includes conditions that differ from activities of daily life.

Frequency-by-frequency hearing loss before or without surgery progressed an average of 2.2 dB per year. This evolution was very different according to the patient's sex; hearing loss progressed much more rapidly in the women than in the men, especially at low frequencies (**Table III**).

Concerning bone conduction impairment, bone curves were not obtained systematically at each visit, making it impossible to establish a reliable growth curve. However, comparing the average bone conduction loss (in dB per year) between the first manifestation of the disease and the last visit or the last preoperative audiogram, we observed that over an average disease course of 9 yr, there was a loss of bone conduction mainly at medium frequencies in comparison to healthy ears. This difference was not significant at 4000 Hz.

There were 16 patients (18 ears) who underwent surgery. The mean age at the time of stapes surgery was 40.1 yr. The average duration between diagnosis and surgery was 8.6 yr, but this group encompassed two distinct populations:

- Five ears underwent stapes surgery after an average period of 11.6 yr (range 8–16 yr). In these cases, surgery was conducted in an attempt to restore fitness that was otherwise not possible.
- There were 13 ears, however, that required surgery within an average of 4.9 yr (3-6 yr) because of rapid worsening of the disease (average 3.42 dB loss per year versus 2.1 dB for the other patients) or the presence of bone conduction impairment, particularly at high frequencies.

The stapes surgery was a stapedectomy in one-third of the cases and a calibrated stapedotomy in two-thirds of the cases. The prosthesis used was a Teflon piston. The follow-up time after the stapes surgery was on average 4.8 yr (range: 2–10 yr). The audiometric results did not show significant differences between the two techniques. The average gain in terms of the audiometric pre- and postoperative air-bone gap was important at low frequencies, but more limited at medium and high frequencies (Table III).

The mean hearing loss among those who received a waiver was 21.8 dB. Flight fitness after a 6-mo postoperative period was judged to be good enough with a waiver in 14 out of 16 patients (16 out of 18 ears). There were 12 patients (14 ears) who were declared fit to fly without restriction. The restrictions affected only the fighter pilots. Two out of the five fighter pilots were declared fit to fly dual-control aircraft only. Of 16 patients (2 ears: 1 line pilot and 1 cabin crewmember), 2 were declared unfit to fly because of persistent dizziness identified with vestibular tests. However, these events were not caused by a perilymph fistula.

Of the five fighter pilots (seven ears), three were declared fit to fly without restriction and two were declared fit to fly dual-control aircraft only. One fighter pilot, who underwent surgery on both ears, was able to resume combat aircraft activity. However, certain types of maneuvers, such as "dogfighting," during which the subject is subjected to rapid

Table I. Summary Table.

EARS	GENDER	BIRTH YEAR	JOB	YEAR OF SURGERY	AGE AT THE TIME OF SURGERY	PRE-OP MHL (DB)	POST-OP FOLLOW-UP (yr)	FLIGHT APTITUDE	MHL DEROGATION (Db)	CURRENT MHL (Db)	CURRENT AGE (yr)	FOLLOW-UP (yr)
1	M	1953	LP					Derogation	25	40	55	17
2	M	1961	LP	2003	42	55	5	Derogation	20	25	47	10
3	M	1946	LP					Derogation	45	45	62	25
4	M	1969	LP					Fit to fly		25	39	6
5	F	1973	CC	2005	32	55	3	Derogation	25	25	35	13
6										35	35	10
7	F	1966	CC					Fit to fly		20	42	8
8	F	1975	CC	2003	28	50	1	Unfit to fly	Vertigo	25	33	5
9	F	1972	CC	2002	30	50	6	Derogation	20	25	36	12
10	F	1966	CC	2006	40	45	2	Derogation	35	35	42	7
11	M	1948	LP					Fit to fly		35	60	29
12										40	59	13
13	M	1961	PP					Derogation	40	55	47	17
14	M	1966	FP	2004	38	50	4	Dual-control	15	15	42	7
15	F	1961	LP	2002	41	60	6	Derogation	20	20	47	11
16	M	1971	LP	2006	35	45	2	Derogation	15	15	37	5
17	M	1949	LP	2002	53	60	2	Unfit to fly	Vertigo	45	59	8
18	M	1962	LP	2006	44	45	2	Derogation	30	30	46	15
19				2004	41	45	4		25	25	45	15
20	M	1946	FP	1996	50	60	9	Derogation	15	15	62	14
21										40	61	10
22	M	1957	FP					Fit to fly	35	35	51	0
23	M	1959	LP					Fit to fly		35	49	12
24	F	1954	CC					Fit to fly		25	54	3
25										35	53	11
26	F	1965	CC					Fit to fly		35	43	4
27	M	1958	LP	2004	46	35	4	Derogation	2015	20	50	8
28	M	1959	FP	2001	42	45	7	Derogation	15	20	49	13
29				2000	40	30	8		15	15	48	13
30	M	1958	FP	1997	39	50	10	Dual-control	30	30	50	18
31	M	1964	Nav	1999	35	70	9	Derogation	35	30	44	15
32	M	1977	Nav					Unfit to fly	Vestibular areflexy	25	31	1
33	M	1958	LP					Derogation		20	50	5
34				2004	45	55	3		20	15	49	19
Mean					40.1	50.3	4.8		25.5	28.7	47.4	11.1

FP: Fighter pilot; CC: Cabin crew; LP: Line pilot; Nav: Navigator; PP: Private pilot.

Table II. Patient Categories.

		FIGHTER PILOT		LINE PILOT		CABIN CREW		PRIVATE PILOT		NAVIGATOR		TOTAL	
		EARS	PATIENTS	EARS	PATIENTS	EARS	PATIENTS	EARS	PATIENTS	EARS	PATIENTS	EARS	PATIENTS
Stapes surgery		5	4	8	7	4	4	0	0	1	1	18	16
No Surgery		2	1	7	5	5	3	1	1	1	1	16	11
Total	Ears	7		15		9		1		2		34	
	Patients		5		12		7		1		2		27

changes in altitude and repeated, significant load factors, were prohibited (**Table IV**).

Stapes surgery appeared to slow cochlear damage, which then evolved in a manner similar to that of healthy ears. The resumption of aviation activity had no impact on hearing and the surgery also halted the progression of the disease, including bone conduction impairment. Thus, the risks of resuming the aviation activity described above could be applicable to 24 of the 27 aircrew members with otosclerosis in our series. To date, no flight incidents have been reported.

DISCUSSION

The aircrew population analyzed in this study had a lower incidence of otosclerosis (nearly 0.025%) than the overall population (0.1 to 2%).[2] Perhaps this incidence level is the result of the initial medical selection. Additionally, the study population was predominantly men; the male:female sex ratio in this study was 2.4, which differs from the expected ratio of 0.5.[2] This difference was expected given the characteristics of the study population. The percentage of female fighter and transport pilots in the French army is 2.3%.[8] The disease progressed more rapidly in the women than in the men, especially at low frequencies. This pattern is consistent with the usual description of more rapid hearing deterioration among women.[2]

In nonoperated patients (civilian and military), fitness to fly is determined by European legislation.[1] Audition needs to be minimally disturbed and is primarily assessed using pure tone audiometry.[18] When tested using a pure-tone audiometer, the hearing loss at 500, 1000, and 2000 Hz should not be more than 35 dB or more than 50 dB at 3000 Hz in either ear. If these standards are exceeded, even at a single frequency, the applicant must "demonstrate satisfactory functional hearing ability."[1] Functional hearing is evaluated using speech audiometry in noise (65 dB). During functional speech in noise, under professional conditions, experienced staff members achieved excellent levels of discrimination of information, despite the degradation indicated by classical vocal audiometry tests, highlighting the importance of expertise in speech audiometry in noise in this context. Such results indicate that an individual who has been designated unfit for flying duties can nonetheless resume their duties via the waiver process.

When compared with the results for the healthy ears, the sensorineural hearing loss observed at high frequencies in our series does not appear to be specific to otosclerosis (nonsignificant difference). This can perhaps be explained as the result of the combination of chronic and acute acoustic trauma suffered on the tarmac as a result of aviation-related activities. However, bone conduction impairment cannot be eliminated as a frequently bilateral pathology. Over an average disease course of 9 yr, there is a loss of bone conduction mainly at medium frequencies in comparison to healthy ears. This difference is not significant at 4000 Hz and most likely originates from chronic noise exposure.

Our series shows that the unfitness to fly imposed by stapes surgery plays an important role in therapeutic decision making. As we have seen, patients prefer to postpone potential surgery and remain fit for as long as possible. Indeed, our series studied aviation professionals who are highly experienced in the communication aspect of their specialty. Thus, in the same way that presbycusis is masked by the cognitive aspect of hearing, the functional hearing of aircrew members remains excellent for a long time, even more so than that of healthy, but less experienced, pilots.

This essential feature is, of course, considered in the waiver decision: the three nonoperated patients who were declared unfit to fly during a routine visit but were granted a waiver had a mean MHL of 47 dB. Even a patient with an MHL of 55 dB (ear no. 13) was authorized to continue flight activity. Tests of professional speech audiometry in noise also yield excellent results and can provide additional evidence to be reviewed when authorizing fit-to-fly status.

Table III. Development of the Frequency-By-Frequency Hearing Loss and the Average Gain in Terms of Audiometric Pre- and Postoperative Air-Bone Gap (diff ABG).

AIR CONDUCTION (Hz)	250	500	1000	2000	3000	4000	6000	8000
Average	2.7	2.6	2.2	2	1.9	2.1	2.3	2.1
Female	3.7	3.4	2.9	2.8	2.2	2.4	2.5	2.5
Male	2.4	2.4	2	1.6	1.7	1.9	2.3	0.19
t-test (*P*)	0.001	0.001	0.01	0.001	>0.05	>0.05	>0.05	0.05
diff ABG	28	24	26,1	15,3	13,6	10,6		

Table IV. Summary of Fitness-To-Fly Decision.

	FIT TO FLY	WAIVERS	WAIVERS WITH RESTRICTION	TOTAL WAIVERS	UNFIT TO FLY	TOTAL
Stapes surgery	0	12	2	14	2	16
No surgery	7	3	0	3	1	11
Total	7			17	3	27

Theoretically, in this disease, stapedial otosclerosis serves a protective role against inner ear barotrauma.[19] Deafness protects individuals from excessive sounds and hearing may actually improve in noise (Willis' paracusis). All this confirms the legitimate possibility of maintaining fitness to fly, as hearing is still functional. Monitoring must be increased and performed twice a year to detect rapid changes or bone conduction impairment.

For the patients who underwent stapes surgery, it was more difficult to assess sufficient fitness when a pilot was referred for otosclerosis. The opening on the labyrinth and the pressure changes caused by aviation activity pose a significant theoretical risk of barotrauma of the inner ear and perilymph fistula facilitated by the footplate opening. For these reasons, stapes surgery was initially considered a final indication against flight fitness. However, in 1998, Thiringer and Arriaga published a series of 16 U.S. Air Force pilots who were declared fit to fly after stapedectomy.[19] Although the texts have not been modified, since then, a declaration of fitness with a waiver became possible after surgery.[5,13]

For example, we consider the case of a line pilot (ears no. 18 and 19) who had his initial visit in September 1990 and quickly experienced progressive conductive hearing loss with a normal eardrum (Table I). The results of his speech discrimination in noise test allowed for the maintenance of fitness until March 2004. He underwent the first stapes surgery in September 2004 on the left ear. His flight fitness with a waiver was judged to be adequate in April 2005, but the development of hearing loss in the right ear led to further flight unfitness in March 2006. The right ear was operated on in September 2006. The patient was declared fit to fly with a waiver in May 2007 (**Fig. 1**).

We propose a framework for determining whether an aircrew member is fit to fly after surgery for otosclerosis, under certain conditions and security guarantees, with or without restrictions, based on several factors. Audition is required to be minimally disturbed and the conservation of good speech discrimination in silence and in noise needs to be verified. In our series, it appeared that surgery slowed cochlear damage, which then developed in line with that of healthy ears, except for 4000 Hz. Hearing loss was more prevalent at 4000 Hz, which could be the result of the operative sectioning of the tendon of the stapes muscle, which abolishes the protective effect of the acoustic reflex.

Preoperative bone conduction loss may result in bone conduction impairment, but can also be associated with some cochlear reserve.[20] The average difference between frequencies, however, tends to improve, especially at the higher frequencies (2000 and 3000 Hz) that can precisely measure the cochlear reserve.

Balance needs to be good, i.e., no trouble reported, no spontaneous nystagmus on the videonystagmography recording, no postural deviation, a normal head-shaking test, and normal condition-5 and condition-6 scores on the computerized dynamic platform posturography.[9] These tests aim to study the possible impact of surgery on vestibular function and to identify a possible perilymph fistula (CT-scan, VEMP threshold).[19] There were 2 patients (2 ears) out of 16 who were declared unfit to fly because of persistent dizziness, illustrating that the surgery carries the risk of complications beyond the common functional discomfort that may affect flight fitness.

The operative report is also an essential to evaluating the surgical technique used and the quality of the piston. Fitness-to-fly determinations should consider which technique was used to reduce the risk of complications. Gierek et al. followed patients who underwent surgery over a 20-yr period and concluded that there was no difference in terms of results, complications, and quality of life between stapedectomy and stapedotomy.[3] In 1998, Shea et al. published their experience with 40 yr of stapes surgery and approximately 14,449 stapedectomies.[15] It appeared that the postoperative air-bone gap at 500, 1000, and 2000 Hz was less than 10 dB at 1 yr and 5 yr after surgery in 95% of cases, and 30 yr after surgery in 62.5% of cases.

Thus, in the literature, the results of both surgical techniques appear identical, both functionally and in terms of complications. The technique seems irrelevant in terms of obtaining excellent results in the vast majority of cases.[16,17,21] If we look at the risk of prosthesis dislocation upon exposure to load factors during flight, theoretically, stapedotomy seems more secure than stapedectomy because it includes two effective anchor points. However, despite the lack of significant differences between the techniques, some additional surgical techniques deserve to be discussed.

Surgical microburs are sometimes blamed for intraoperative sound trauma, represented by a loss in bone conduction. Yavuz et al. found the same results in terms of gain and complications in a series of 71 ears operated on with a microdrill and 52 ears operated on using calibrated trephines.[22] No increase in cochlear lesions was mentioned when microburs were used.

The laser allows for multiple completely atraumatic procedures. The CO_2 laser allows for a calibrated stapedotomy, but carries a risk of damage to the facial canal. Furthermore, its axis of operation is not always able to vaporize the branches of the stapes.

The diode laser can be guided by microsuction and vaporizes the bony structures that comes in contact with the fiber, which simplifies the crurotomy. Nguyen et al. reported functional outcomes similar to those of other techniques, but with a lower risk of footplate fracture.[11] In our series, we noted two cases of delayed postoperative transient facial palsy that recovered fully after 3 mo. If caloric nerve irritation is implicated, the time-to-onset argues in favor of viral reactivation (e.g., Herpes, VZV).[10]

The piston has mass and is therefore subject to acceleration, with a theoretical risk of accidental dislocation during hard acceleration. Massey et al. found an air-bone gap closure of less than 10 dB in 86% of cases with a Teflon piston compared with 71% with a titanium piston.[7] Additionally, the density of titanium is $5\ g \cdot cm^{-13}$; thus, Teflon, whose density is only $2.15\ g \cdot cm^{-13}$, is preferred in aerospace applications.

The length and diameter of the piston can influence the functional outcome or the risk of perilymph fistula. Portmann et al. studied the distance between the incus and the plate.[12] In

	Mr D.(Ears 18 and 19)						1962		Line pilot											
Years	1990	1991	1992	1993	1994	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007			
Air conduction																				
																	sept-06	Beginning	pre-op	Evolution	Evolution (dB/year)
250	15	20	25	40	40	40	45	40	35	45	50	50	55	50	55	55	30	20	55	35	2,3
500	10	20	20	30	30	40	30	30	40	35	40	40	50	45	45	40	30	20	40	20	1,3
1000	15	20	30	20	20	30	35	30	30	35	30	30	40	40	20	45	30	20	45	25	1,7
2000	10	10	10	15	15	15	20	20	20	25	35	35	35	35	35	35	20	10	35	25	1,7
3000	10	10	10	20	20	20	25	25	30	25	35	35	30	30	30	35	20	10	35	25	1,7
4000	10	15	15	25	25	20	25	30	30	35	40	40	35	40	35	35	30	15	35	20	1,3
6000	10	10	10	15	15	25	20	20	20	20	25	25	30	30	35	25	30	10	25	15	1
8000	10	10	15	20	20	15	20	20	20	20	20	20	25	20	30	25	30	10	25	15	1
															sept-04						
250	15	20	25	40	35	40	40	43	40	45	55	55	65	60	40	35	20	20	60	40	2,9
500	15	20	20	30	30	35	30	30	45	50	15	50	55	55	35	25	15	20	55	35	2,5
1000	10	15	20	30	30	35	35	35	35	45	15	45	40	40	20	15	25	15	40	25	1,8
2000	10	10	10	10	10	20	15	20	30	40	35	40	40	40	25	25	30	10	40	30	2,1
3000	10	10	10	20	15	20	25	30	35	30	25	30	40	35	25	25	20	10	35	25	1,8
4000	10	10	15	20	25	25	35	35	45	40	45	45	50	40	35	45	25	10	40	30	2,1
6000	10	10	15	25	20	25	20	20	25	30	30	30	40	40	35	30	35	10	40	30	2,1
8000	10	10	10	10	15	10	20	20	25	30	20	35	30	30	35	35	45	10	30	20	1,4
Bone conduction																					
																		pre-op ABG	post-op ABG	diff ABG	
250	10	10	10	25						20			20		20	20	15	35	15	20	**-5**
500	5	10	10	15						20			25		20	20	20	20	10	10	**0**
1000	5	5	20	10						15			20		15	20	20	25	10	15	**0**
2000	10	10	10	10						20			35		25	25	20	10	0	10	**-5**
3000	10	10	10	10						10			25		20	20	15	15	5	10	**-5**
4000	5	10	10	10						10			30		20	20	25	15	5	10	**5**
																		pre-op ABG	post-op ABG	diff ABG	
250	10	10	10	25						10			20	20	15	15	15	40	25	15	**-5**
500	10	10	10	15						15			20	20	15	20	15	35	20	15	**-5**
1000	10	5	15	15						10			10	10	10	10	20	30	10	20	**0**
2000	5	10	10	10						15			30	30	20	25	25	10	5	5	**-10**
3000	10	10	10	10						10			20	20	15	10	15	15	10	5	**-5**
4000	10	10	10	10						10			30	30	15	15	20	10	20	-10	**-15**

Fig. 1. Example of Mr. D., line pilot (ears no. 18 and 19). AC = air conduction; BC = bone conduction; ABG = audiometric air-bone gap.

one out of two cases, the distance was 4.25 mm and the authors proposed the systematic use of a 4.75-mm piston. Marches et al. studied the piston diameter in stapedotomy[6] and found that the use of a 0.6-mm diameter piston versus a 0.4-mm diameter one provided better air conduction, mainly at the speech frequencies. However, Shabana et al. did not find any significant difference in terms of functional outcomes or bone conduction impairment with the use of either a 0.4- or a 0.6-mm piston.[14]

Thus, the functional results of atraumatic laser stapedotomy seem to argue for its use in the aviation aircrew population. Using a Teflon piston with a diameter of 0.4 mm or 0.6 mm and a length of 0.5 mm longer than the distance between the incus and the footplate seems to guarantee optimal results with limited risks related to aviation activity.

A postoperative CT scan of the petrous bones is usually used to assess the correct length of the piston and the absence of excessive protrusion in the vestibule, which is the potential cause of dizziness. This imagery confirms the correct position of the piston.[4] In our series, the CT scan was conducted between 3 and 6 mo postoperatively.

Thiringer et al. also proposed the use of the systematic achievement test altitude chamber.[19] The protocol used by the U.S. Air Force comprises a rise in altitude and then a return to the surface. The test then continues with a free-fall test from a height of 42,000 to 25,000 ft (12,801 to 7620 m). A rapid decompression test is then conducted by imposing a rapid transition from an altitude of 8000 ft to 22,000 ft (2438 to 6706 m). Finally, perilymph fistula is tested for by having the patient breathe into a depressurized mask at an altitude of 43,000 ft (13,106 m). This test has the advantage of putting the patient in exceptional situations and it ascertains the reliability and the tightness of the prosthetic fit.

However, this test is not without risks to the ear that was operated on and it seems ethically questionable to perform an examination that may lead to deafness. The same can be said for the centrifuge test, which does not subject the ear to acceleration in limited directions, but also does not reflect the brutality and rapid changes of direction imposed by aerobatic activity or dogfights.

Two tests provide interesting possibilities for assessing the risk of accidents or incidents related to aviation activity. The first is set in a real-life situation that occurs naturally after the waiver, but may be limited initially and reassessed after a certain number of hours to gradually raise restrictions. The second is the development of a professional audiometric test. This test could be performed in noise and would then address both the characteristics and utilization of the semantic content of the noise.

In conclusion, there is a risk to the vestibulocochlear system with aviation activity. Prior to surgery, otosclerosis serves a protective role in the inner ear (other than the associated risk of bone conduction impairment) and hearing stays functional for a longer period of time. Stapes surgery theoretically results in increased sensitivity to pressure changes and the risk of perilymph fistula and intense vertigo in flight. The sectioning of the tendon of the stapes muscle also renders the acoustic reflex response to a sometimes intense sound exposure ineffective in subjects during their work. Otosclerosis has long been synonymous with the cessation of aviation activity for aircrew members.

When an aircrew member is referred for otosclerosis, their flight fitness is determined on the basis of their auditory and balance status and the follow-up examination of these findings. In our series, only 3 aircrew members out of 27 did not obtain waivers for flight fitness. The few published studies on the resumption of flight in patients who have undergone surgery and our recent experience in France with similar waivers in commercial and military aviation suggest stapes surgery may allow for a safe recovery of aviation activity under certain conditions and after relevant vestibulocochlear assessment.

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