Decompression chamber test for aircrew evaluation

Wg Cdr PS Sodhi * Wg Cdr VV Joshi + Wg Cdr AK Sharma #

ABSTRACT:
The standard practice of evaluation of aircrew by a decompression chamber test following ENT surgery to check the patency of the Eustachian tubes and the integrity of the Tympanic membrane is reviewed. The relevant anatomy and pathophysiology of the Eustachian tube, the operational and technical capabilities of the Decompression Chamber and the chamber protocol being followed for evaluation of ENT cases is reviewed in terms of the physiological and operational requirements. The clinical guidelines for taking up Ear surgery cases for Decompression chamber test and the Teed's classification used in the determination of post-test fitness of the cases is also discussed. Unlike in the RAF, which has specified separate protocols for fast jets, multiengined (transport) aircraft and helicopters, we are using one standard protocol for all pilots and for the evaluation of paratroopers for free fall jumps (FFPT). The data of all ENT evaluations carried out at AFCME and No 1 AMTC between 1996 and Jul 2001 is analysed and presented. Total of 17% cases, who were declared clinically normal, failed to pass the Chamber test. The data of decompression chamber evaluation of clinically normal Army paratroopers for Combat Free Fall (CFF) duties is also presented. The limitation of the Decompression Chamber test for aircrew evaluation are deliberated upon with recommendations for the required amendments to the test protocol in the light of the present day operational requirements.

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KEY WORDS: Decompression Chamber Test, Barotrauma

Decompression Chamber (DC) test, also called as Ear Clearance test, is a means of reproducing the pressure changes in the middle ear, as seen during ascent and descent in an aircraft, in a controlled fashion under laboratory conditions using a DC. The use of this procedure allows the medical evaluators to study the structural integrity of the tympanic membrane as well as the function of the Eustachian tube on exposure to the simulated pressure changes. With this, the efficacy of any surgical procedure carried out in the middle ear in particular

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as well as in other ENT disabilities in general, could be assessed in the aviator's operating environment. Perhaps, more importantly, this testing provides reassurance to the aviator and the medical evaluator that the disease condition has been successfully treated and would not exacerbate in the aviation environment. This paper discusses the Decompression Chamber test in all its perspectives.

**Decompression Test Protocols**

Each decompression test is conducted according to standard procedures as laid down in Air Force Order (AFO) 08/91 and is shown in Fig.1 [1]. Aviators who tolerate it without discomfort and / or objective signs of barotrauma are considered fit for flying duties.

In the IAF, the profile used for the Decompression Chamber test includes an ascent from ground level to 10000 ft at the rate of 3000 ft/min and then descent back to ground level at 3000 ft/min. Teed's classification is used in the evaluation of the tympanic membrane. The classification is based on the auroscopic appearance of the tympanic membrane and is as follows:

- **Teed I**: Erythema of the handle of Malleus
- **Teed II**: Erythema of the entire drum
- **Teed III**: Haemorrhage into the substance of the Tympanic membrane itself. These appear as bright red patches on the drum
- **Teed IV**: Deep blue - black appearance of the drum indicating blood filling the middle ear. The ear drum may or may not be ruptured.

Indian Air Publication 4303 specifies that the chamber test is required to be carried out for fighters and transport aircraft as required [2]. However, there are no separate aircraft stream wise protocols being followed at present.

In the RAF it is now an established routine that all aviators with history of barotrauma, chronic sinusitis, surgery of the middle ear etc are subjected to Decompression chamber test and must pass the test before their flying category is restored. Table 1 and Fig 2, 3 and 4 show the standard test profiles being currently used in the RAF. One of the three standard decompression profiles is used. These are in the order of decreasing severity for fast jets, multi-engine (transport) aircraft and helicopters. The optional 6000 ft/min ascents and descents are usually carried out, although it is not necessary for helicopter aircrew to pass this part of the profile. Each profile is designed to test the aviator's tolerance to pressure changes of increasing severity. The changes in pressure needed to simulate the changes in cabin altitude are effected by means of a decompression chamber [3].

**Selection of Patients**

In all aviators who have had an ENT surgical procedure carried out or have had an episode of middle ear disease must be subjected to a decompression chamber test, so that the response to actual pressure changes may be ascertained. The DC test has been recommended in tympanoplasty (types I and II), myringoplasty, minor ossiculoplasty not involving Stapes and in simple mastoidectomy prior to reflighting [4].

*Ind J Aerospace Med 45(2), 2001*
Fig 1: DC Test Protocol (IAF) (AFO 08/91)

Fig 2: DC Test Protocol (RAF) (Fast Jet Aircraft)
Decompression chamber test for aircrew evaluation: Sodhi PS et al

It is mandatory that sufficient time elapses after the surgical procedure before the individual is subjected to the Decompression Chamber test. The recommended time intervals, which must elapse after some common surgical procedures before subjecting to the DC test, are as follows [2]:

(a) Tympanoplasty : 01 Year
(b) Myringoplasty : 06 months
(c) Myringotomy : 03 months
(d) Simple Mastoidectomy: 03 months

The aviator is observed in a ground category for this period. Moreover, the following conditions should be fulfilled prior to subjecting the pilot to the DC test at the end of the above-mentioned periods:

(a) Complete resolution of symptoms.
(b) Should not be on any medication.
(c) Clinical evaluation reveals no abnormality of the tympanic membrane and a functional Eustachian tube.
(d) Should have an acceptable audiogram
(e) Should have a normal Tympanogram.

Tympanometry has been identified as a reliable method of evaluating tympanic membrane compliance and the Eustachian tube patency [5]. Since in aviation, the patency of the Eustachian tube plays a pivotal role in pathophysiology of Barotrauma, it is pertinent that the aircrew before being subjected to DC test has a normal Tympanogram.

Materials and Methods

Technical description of Decompression Chamber [6]

The Decompression chamber at No 1 AMTC is of 1971 vintage. The relevant technical capabilities of the 1 AMTC chamber are shown in Table 2.

Profile of Ear Clearance Test

Each decompression test was conducted in accordance with AFO 08/91 (Fig.1). For post surgical cases, a decompression test with progressively severe ascent and descent rates were used. All the clinical cases were given tests individually. The first test was usually started at the rate of 500 ft/min. The patient was constantly asked for development of any symptoms during the test and examined auroscopically after the test. Thereafter, if the patient was asymptomatic with no objective evidence of barotrauma, he was then subjected to rates of 1000 ft/min, 2000 ft/min and finally 3000 ft/min. The patient is examined after every test. The maximum altitude in all the tests was maintained at 10000 ft. Individuals who cleared the test with 3000 ft/min ascent and descent rates without discomfort and/or objective signs of barotrauma were considered fit for flying duties.

Patients / Subjects

(a) ENT Cases: The percentage distribution of the various types of ENT cases subjected to the Decompression test between Jan 1996 to Jul 2001 is shown in Table 3. The clinical diagnosis of these ENT cases was as follows:

(i) Ear Disorders (Surgical): 04 cases of Myringoplasty and 02 cases of tympanoplasty

*Ind J Aerospace Med 45(2), 2001*
Table 1. Decompression Chamber Test Protocol Followed in RAF [4]

<table>
<thead>
<tr>
<th>Fast Jet Aircraft</th>
<th>Multiengined (transport/reconnaissance) and propeller aircraft</th>
<th>Helicopter</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Ground level to 10,000 ft at 2000 ft / min</td>
<td>• Ground level to 10,000 ft at 2000 ft / min</td>
<td>• Ground level to 10,000 ft at 2000 ft / min</td>
</tr>
<tr>
<td>• 10,000 ft to 2000 ft at 2000 ft / min</td>
<td>• 10,000 ft to 2000 ft at 2000 ft / min</td>
<td>• 10,000 ft to 2000 ft at 2000 ft / min</td>
</tr>
<tr>
<td>• 2000 ft to 20,000 ft at 4000 ft / min</td>
<td>• 2000 ft to 20,000 ft at 4000 ft / min</td>
<td>• 2000 ft to 10,000 ft at 4000 ft / min</td>
</tr>
<tr>
<td>• 20,000 ft to 2000 ft at 4000 ft / min</td>
<td>• 20,000 ft to 2000 ft at 4000 ft / min</td>
<td>• 10,000 ft to 2000 ft at 4000 ft / min</td>
</tr>
<tr>
<td>• 2000 ft to 25,000 ft at 6000 ft / min</td>
<td>• 2000 ft to 25,000 ft at 6000 ft / min</td>
<td>• 2000 ft to 10,000 ft at 6000 ft / min (optional)</td>
</tr>
<tr>
<td>• 25,000 ft to 10,000 ft at 10,000 ft / min</td>
<td>• 25,000 ft to ground level at 6,000 ft / min</td>
<td>• 10,000 ft to ground level at 6000 ft / min (optional)</td>
</tr>
<tr>
<td>• 10,000 ft to ground level at 6000 ft / min</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Technical Description of Decompression Chamber

<table>
<thead>
<tr>
<th>Sr No</th>
<th>Attribute</th>
<th>Capability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Dimension</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Length</td>
<td>5000 mm</td>
</tr>
<tr>
<td></td>
<td>Volume</td>
<td>2200 mm</td>
</tr>
<tr>
<td>2.</td>
<td>Air Capacity</td>
<td>5.3 m³</td>
</tr>
<tr>
<td>3.</td>
<td>Motor Power Ventilator</td>
<td>900 m³</td>
</tr>
<tr>
<td>4.</td>
<td>Max Speed of Ascent</td>
<td>0.37 Kw</td>
</tr>
<tr>
<td>5.</td>
<td>Max Speed of Descent</td>
<td>16000 ft / min</td>
</tr>
<tr>
<td>6.</td>
<td>Max Low Pressure</td>
<td>16000 ft / min</td>
</tr>
<tr>
<td>7.</td>
<td>Max time of Ascent for 760 to 8 mm Hg</td>
<td>8 mm Hg</td>
</tr>
<tr>
<td>8.</td>
<td>Max time of Descent from 8 to 760 mm Hg</td>
<td>1 min</td>
</tr>
<tr>
<td>9.</td>
<td>Accuracy</td>
<td>5 mm Hg</td>
</tr>
</tbody>
</table>

Ind J Aerospace Med 45(2), 2001
Decompression chamber test for aircrew evaluation: Sodhi PS et al

Table 3: Clinical Distribution of Disabilities (n= 39*)

<table>
<thead>
<tr>
<th>Disability Type</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ear Disorders (Surgical)</td>
<td>15.4</td>
</tr>
<tr>
<td>Ear Disorders (Non-Surgical)</td>
<td>28.2</td>
</tr>
<tr>
<td>Other ENT Disorders (Surgical)</td>
<td>23.1</td>
</tr>
<tr>
<td>Other ENT Disorders (Non-Surgical)</td>
<td>20.5</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>12.8</td>
</tr>
</tbody>
</table>

Note: Some of the cases had more than one disability

Table 4: Stream wise distribution of DC Test Cases (n= 28)

<table>
<thead>
<tr>
<th>Aircraft Stream</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fighters</td>
<td>42.8</td>
</tr>
<tr>
<td>Transports</td>
<td>17.8</td>
</tr>
<tr>
<td>Helicopters</td>
<td>25</td>
</tr>
<tr>
<td>Navigators</td>
<td>7.2</td>
</tr>
<tr>
<td>Civil Aviation</td>
<td>7.2</td>
</tr>
</tbody>
</table>

Table 5: FFPT Assessment: % Unfit (n= 626)

<table>
<thead>
<tr>
<th>Year</th>
<th>Number evaluated</th>
<th>% Unfit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996</td>
<td>111</td>
<td>3</td>
</tr>
<tr>
<td>1997</td>
<td>47</td>
<td>10.6</td>
</tr>
<tr>
<td>1998</td>
<td>121</td>
<td>4</td>
</tr>
<tr>
<td>1999</td>
<td>127</td>
<td>17</td>
</tr>
<tr>
<td>2000</td>
<td>139</td>
<td>19</td>
</tr>
<tr>
<td>Up to Jul 2001</td>
<td>81</td>
<td>23.5</td>
</tr>
</tbody>
</table>

*Note: Some of the cases had more than one disability
Fig 3: DC Test Protocol (RAF)
(Multiengine Transport/Reconnaissance & propeller aircraft)

Fig 4: DC Test Protocol (RAF)
(Helicopter)

Ind J Aerospace Med 45(2), 2001
Decompression chamber test for aircrew evaluation: Sodhi PS et al

(ii) Ear Disorders (Non-Surgical): 05 cases of CSOM and 05 cases of Otitic Barotrauma

(iii) Other ENT Disorders (Surgical): 02 cases of Chronic Maxillary Sinusitis with antral polyp, 02 cases of Fronto-Maxillary Sinusitis, 01 case of bilateral Ethmoidal polyp and two of deviated nasal septum (DNS).

(iv) Other ENT Disorders (Non-Surgical): Allergic Rhinitis, Sinusitis and Fracture Nasal bone.

(v) Miscellaneous: Two cases of scarred and retracted tympanic membrane, one case each of Sensory Neural Hearing Loss, Migraine and a case who had symptoms of ear ache in flight with no objective findings on clinical examination.

(b) Free Fall Para Troopers (FFPT) Evaluation:

Army paratroopers reporting for determination of fitness for combat free fall (CFF) duties were subjected to the decompression chamber test in accordance with AFO 08/91. All these subjects were clinically normal. These subjects were required to undergo 2 types of tests. The first one being standard Decompression test (Ear clearance test) to check for the patency of the Eustachian tube described earlier. The second test was given only if the Ear clearance was satisfactory. In this test effects of Hypoxia were demonstrated by exposing the subjects to altitude of 30000 ft, with the ascent and descent rates being 3000 ft/min as in the ear clearance test.

Results

ENT cases

(a) The mean age of the aircrew evaluated with DC test at AFCME and No. 1 AMTC, between Jan 1996 to Jul 2001 was found to be 31.0 years (SD ± 7.0 years) with a range of 20 to 54 years. (n = 28) The aircraft stream wise distribution is shown in Table 4.

(b) A total of 41 tests were given for ENT evaluations of cases in this period. Failure in the decompression chamber test occurred on 07 occasions (17%).

(c) 85.7% cases cleared the test in their first attempt. 04 cases, which required multiple tests prior to re-flighting were as follows:

(i) Secretary Otitis Media - Failed on two occasions
(ii) Post Myringoplasty CSOM - Failed on three occasions
(iii) Scarring of Tympanic Membrane for Eustachian tube assessment - Failed once
(iv) Otitic Barotrauma with Chronic Fronto-Maxillary sinusitis - Failed once

FFPT Evaluation

The mean age of the soldiers evaluated for FFPT was 25.3 years (SD ± 2.4 years) with a range of 22.3 - 29.8 years. (The intake criterion for FFPT course is age less than 30 years) The year wise percentage of cases declared unfit in the DC test are shown in Table 5 and Fig 5. It is brought out that 8 cases (4 in 2000 and 4 in 2001) were declared unfit after the Hypoxia indoctrination test (max

Ind J Aerospace Med 45(2), 2001
altitude 30000 ft) despite being fit in the standard ear clearance test. Only 02 cases developed Sinus barotrauma (< 1%) while the rest had features of Otitic barotraumas.

Discussion

It is now an established routine that all aviators with history of barotraumas, chronic sinusitis, surgery of the middle ear and any other significant ENT disability must pass a decompression test before their flying category is restored. Similar routine is also being followed in the major Air Forces of the world.

The distribution of the cases evaluated by DC test in last 5 years shows that ear disabilities and non-ear ENT disabilities form absolutely equal distribution of the total cases (43.6% each). Moreover, non-surgical ear disorders are slightly more than any other types of ENT disability (28.6%). Establishing the functional integrity of the Tympanic membrane and the Eustachian tube on exposure to simulated pressure changes has long been recognised to be an important aspect of refightining.

A total of 41 tests were given for ENT evaluation of cases in this period. Failure in the decompression chamber test occurred on 07 occasions (17%) despite normal clinical status or ground. This amplifies the importance of the test in considering refightening an aircrew with ENT disability.

The analysis of repeated failure to clear the DC test has brought out that repeated failures are observed in ear disabilities especially those affecting the middle ear. One of the cases of Post Myringoplasty CSOM failed to pass the test on three occasions despite normal pre-test clinical examination including tympanometry. The other cases, which failed the test, were one case each of Secretory Otitis Media, Scarring of Tympanic Membrane for Eustachian tube assessment and a case of Otitic Barotrauma with Chronic Fronto-Maxillary sinusitis.

42% of all the cases evaluated were from the fighter stream. The problem of ear clearance is obviously more in the more agile fighter aircraft, which is probably reflected in this data also.

The FFPT evaluation data has shown an increasing positivity over the years. There is no satisfactory explanation for this finding. Some of the subjects passed the standard ear clearance test of 10000 ft altitude but developed barotrauma in 30000 ft hypoxia test (ascent / descent rates in both tests being 3000 ft/min) This indicates that duration of exposure could also play a role in barotrauma. The implication of this finding is discussed further in the limitation of the present standard protocol.

Limitations of Decompression Chamber Test

(a) Limitations of Protocol. It may well be that our test parameters are less stringent and that some of the aviators who clear the test could develop symptoms while flying. The following issues need further consideration:

(i) The barometric pressure changes to which the aircrew of the modern military aircraft may be exposed are of a different order compared...
to those experienced by aircrew or passengers aboard a commercial airliner or transport aircraft. Most modern commercial airliners have a pressurization system that restricts the cabin altitude to a maximum of 6000 - 7000 ft. During descent from altitude, the phase of flight when otitic or sinus barotraumas is most likely to occur, the cabin pressurization system in these aircraft generally restricts the rate of pressure change to the equivalent of 300 - 500 ft/min. In most modern military combat aircraft, the cabin altitudes often rise to over 20,000 ft and the rate of change of cabin altitude frequently exceeds 4000 ft/min, and occasionally even 10,000 ft/min. The maximum descent rates are experienced by the aircrew in the following conditions:

(a) Instrument Descents (Below 10000 ft)
(b) Steep Dive for bombing (Above 10000 ft)

(ac) Emergency descents in explosive decompression (up to 10000 ft only)

The rates of descent in instrument descents (at low altitudes), commonly experienced in some of the fighter aircraft of IAF are as follows (4):

MiG 21 Series : 8000 ft/min
Jaguar / Mirage 2000 : 6000 ft/min
Kiran Jet Trainer Aircraft : 4000 ft/min
HPT-32 Piston Trainer Aircraft : 1200 - 2000 ft/min

Thus it is clear that the protocol followed by us for the DC test is less stringent than that experienced in most fighter and jet trainer aircraft currently in used in IAF.
Decompression chamber test for aircrew evaluation: Sodhi PS et al

(ii) The paratroopers are subjected to
descent rates of > 10000 ft/min while taking part
in free fall jumps. (The terminal velocity at sea level
is 10200 ft/min and is higher at higher altitudes)
[7].

(iii) The time duration of exposure to
pressure changes in descent is another factor
which requires due consideration. As brought out
earlier, FFPT evaluation has shown that a few
soldiers who clear the ear clearance test 10000 ft
max altitude (exposure time 3.3 minutes), develop
barotrauma in the Hypoxia indoctrination test while
descending from simulated altitude of 30000 ft to
ground level at descent rates of 3000 ft/min
(exposure time 10 minutes). Thus, the time of
exposure plays a role in development of signs of
Barotrauma and should be incorporated in the
testing protocol. This issue is further substantiated
by the fact that the RAF protocol for DC test
includes descent from altitude of 25000 ft.

(b) Limitations of Decompression Chamber

(i) Although the chamber itself can provide
rates of ascent and descent at 16000 ft/min, the
instruments to monitor the rate of ascent and
descent has a max gradation of 4000 ft/min. Hence
rates more than these can only be simulated
approximately with its inherent hazards.

(ii) The inherent lag and inertia of the
chamber system is significant and often the rate
of change of ascent and descent takes a long time
to settle to the desired value of 3000 ft/min. In a
short test of about 3 minutes (for max altitude of
10000 ft), the chamber actually ascends or
descends at rates of 2000-4000 ft/min for a
relatively significant period than when used for
higher altitude tests with longer net duration. This
approximation is another factor to be borne in mind
in the conduct of the DC test.

(c) Improvements in Post-test evaluation

The Tympanometric evaluation of the patients
is usually being done prior to subjecting to the
DC test. However, no Tymanometry is being done
after the test. The fitness / unfitness is determined
purely by presence or absence of symptoms and
objectively by auroscopic examination of the
Tympanic membrane. Rao and Chatterjee in a
limited study have brought out that in the patient
in whom mild post-test barotrauma developed,
there were discernable changes in the peak and /
or middle ear pressure readings of the post-test
Tympanogram [8]. These authors have recommended studies on larger number of subjects,
which needs to be carried out. Hence, it is felt that
a comparison of post-test follow up Tympanogram
with the pre-test will serve as an additional
objective diagnostic tool for evaluation of subjects.
Thus a Tympanogram immediately after the DC test
is recommended.

(d) Non surgical ENT cases with short
duration of illnesses

It is very probable that not all the aircrew
cases with history of ENT disorders undergo the
recommended DC test. This includes those cases
in whom the disease process is controlled within
a short time (below 21 days) and their flying fitness
is then given locally itself. It is possible that such
an aviator may get recurrent bouts of the same
disease, each controlled with medications, but still
never be tested by a DC test due to local non-
availability of the chamber. In such cases,
possibility of barometric changes precipitating a new episode of clinical disease also exists and should be kept in mind by the treating Medical Officers. It is hence felt that any aircrew who have a recurrent ENT problem, how so ever minor, should be evaluated at an ENT center and followed up by an Ear clearance test.

Conclusions and Recommendations

The Decompression test as a methods of determining aircrew fitness after an ENT disability is based on strong physiological fundamentals and must be done on all the possible cases with suspected damage to the middle ear and Eustachian tube. Medical Officers in the field should be vigilant in cases with recurrent ENT symptoms and consider the option of DC testing in doubtful cases. The test protocol being followed has scope for improvements, as discussed, in the light of changing aviation scenario.

References