

Human Performance & Limitations - Module C — The Thin Air

Pressure, TUC & Decompression

Chapter 8 — What happens when the pressure fails: cabin pressurisation and the shrinking Time of Useful Consciousness, decompression, the bends, and the rules for blood donation and flying after diving.

BOOK

Human Performance & Limitations

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EXAM

DGCA CPL / ATPL — HPL

CHAPTER

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Plate 8.0 — When the pressure fails. At altitude the margin between control and unconsciousness is measured in seconds.

§ 16 Baroreceptor Reflex

WHAT IT IS

The baroreceptor reflex is the body's **automatic blood-pressure regulator**. Any change in your body's **demand for blood** can **trigger your baroreceptor reflex**. Specialised pressure-sensors ("baroreceptors") in the carotid arteries and aortic arch detect changes in BP and signal the brain to adjust heart rate and vessel diameter accordingly.

16.1 When the reflex fires — DGCA examples

For example, your body may need to adjust your blood pressure when you:

- **Change your body position, such as when you stand.**
- **See or experience something that frightens you.**
- **Switch from walking to running.**

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COCKPIT RELEVANCE

- **Postural changes:** standing up from a long sit (e.g. after a long flight, in turbulence, or after a low-blood-sugar moment) can cause transient hypotension → light-headedness. The baroreceptor reflex normally corrects this in 1–2 seconds.
- **Sudden fright / startle response:** pulls in adrenaline from the ANS (§7.4), spiking HR and BP. The baroreceptor reflex moderates this so you don't pass out from a hypertensive crisis.
- **Exercise & G-load:** from steady cruise to sudden manoeuvring, blood demand changes rapidly. The reflex keeps cerebral perfusion stable so you don't grey out.

A **well-conditioned, well-rested, well-hydrated** pilot has a sharper, faster baroreceptor reflex. A dehydrated or fatigued pilot's reflex is sluggish — which is one of several reasons hydration matters in long sectors and high-G ops.

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THE BARORECEPTOR REFLEX

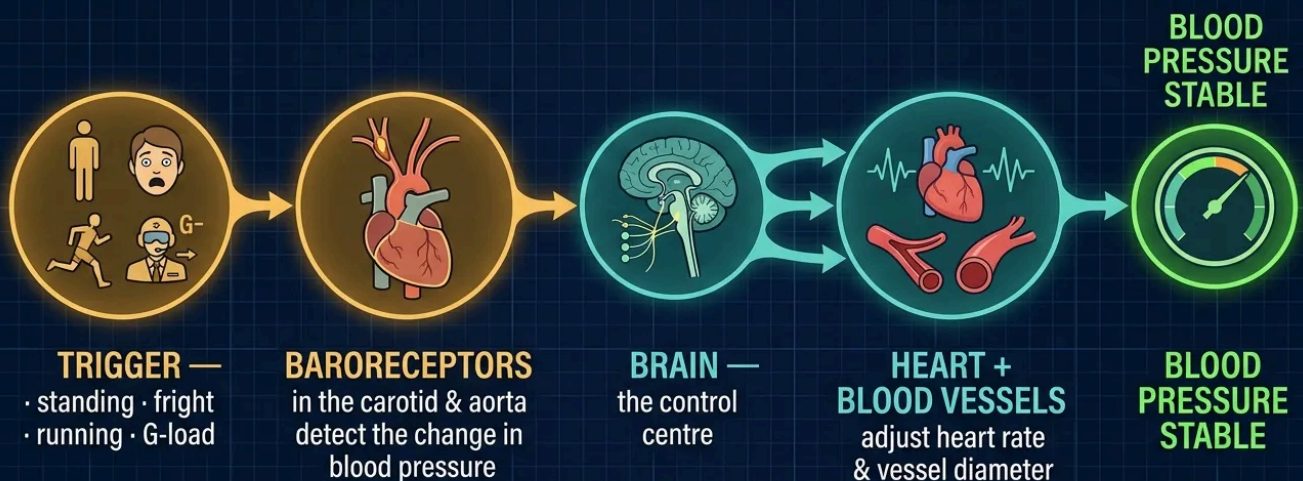


Figure 8.1 — The baroreceptor reflex: how the body senses and corrects a fall in blood pressure.

Donating Blood — the 48-hr rule

DGCA-QUOTED

In a **completely healthy individual**, the fluid reduction caused by donating **one unit of blood** is replaced within **several hours**. In some people, however, the loss of blood causes **disturbances to the circulation that may last for several days**.

While the effects at **ground level are minimal**, **flying during this period may entail a risk**.

THE DGCA RULE — EXACT PHRASING

Generally, active pilots should **NOT** donate blood, but if blood has been donated, they should wait at **LEAST 48 hours** before flying.

RECOMMENDED FOR ACTIVE PILOTS

DO NOT donate

IF DONATION HAS OCCURRED

Wait ≥ 48 hr

REASON

Circulatory disturbance

GROUND-LEVEL EFFECT

Minimal

WHY BLOOD DONATION INTERACTS DANGEROUSLY WITH FLIGHT

A single unit of blood (~450 ml) represents about **9 % of total blood volume** in an average adult. While the plasma volume is restored in hours, the **red blood cell mass** takes weeks to fully recover. Reduced RBC mass = reduced haemoglobin = reduced oxygen-carrying capacity = **anemic hypoxia (§10.3b)**. Add altitude (hypoxic hypoxia, §10.3a) and the two stack — exactly the same principle as smoker-at-altitude and alcohol-at-altitude in Part 4.

Cabin Pressurization & Time of Useful Consciousness (TUC)

18.1 What TUC / EPT is

DEFINITION — MEMORISE VERBATIM

Time of useful consciousness (TUC), also **effective performance time (EPT)**, is defined as the **amount of time an individual is able to function effectively (e.g., perform flying duties) in an environment of inadequate oxygen supply**.

It is the **period of time from the interruption of the oxygen supply** or exposure to an oxygen-poor environment **to the time when useful function is lost**, and the individual is **no longer capable of taking proper corrective and protective action**.

CRITICAL CONCEPT — TUC IS NOT TIME TO UNCONSCIOUSNESS

TUC is the time during which a pilot can still **do useful work** — don a mask, push a checklist, initiate descent. After TUC ends, the pilot may still be conscious for several more seconds, but is no longer **functional**. *This distinction is precisely why the DGCA emphasises "corrective and protective action" — the mask must be on the face before TUC expires.*

18.2 Why TUC Drops Sharply at Altitude

DGCA-QUOTED

At the higher altitudes, the **TUC becomes very short; considering this danger, the emphasis is on PREVENTION rather than CURE.**

Cabin pressurization eliminates many problems associated with high altitude flying, but it introduces other potential problems, the most important being the **risk of rapid decompression**.

WHAT DETERMINES TUC AFTER A RAPID DECOMPRESSION

The time of useful consciousness (TUC) following a rapid decompression depends on:

1. **Aircraft altitude,**
2. **The rate at which pressure falls,** and
3. **The level of physical activity of the individual at the time of the event.**

JET-TRANSPORT TUC REFERENCE VALUES

- At **typical jet transport aircraft altitudes (35,000 feet)** TUC will vary between **33 and 54 seconds**.
- Those average values can be expected to **drop by HALF at 40,000 feet.**
- This emphasizes the importance of **immediate availability of supplemental oxygen to crew members.**
- **RAPID DECOMPRESSION CAN REDUCE TUC BY HALF.**

18.3 TUC Master Table — Verbatim

This is the table you must memorise — both columns. Every DGCA HPL question on TUC is drawn from these figures.

Time of Useful Consciousness (TUC) by Altitude — DGCA Reference

Altitude (measured barometrically)	TUC (normal ascent)	TUC (rapid decompression)
FL180 (18,000 ft; 5,500 m)	20 to 30 minutes	10 to 15 minutes
FL220 (22,000 ft; 6,700 m)	10 minutes	5 minutes
FL250 (25,000 ft; 7,600 m)	3 to 5 minutes	1.5 to 3.5 minutes
FL280 (28,000 ft; 8,550 m)	2.5 to 3 minutes	1.25 to 1.5 minutes
FL300 (30,000 ft; 9,150 m)	1 to 2 minutes	30 to 60 seconds
FL350 (35,000 ft; 10,650 m)	30 seconds to 1 minute	15 to 30 seconds
FL400 (40,000 ft; 12,200 m)	15 to 20 seconds	7 to 10 seconds
FL430 (43,000 ft; 13,100 m)	9 to 12 seconds	5 to 6 seconds
FL500 (50,000 ft; 15,250 m)	8 to 10 seconds	5 seconds

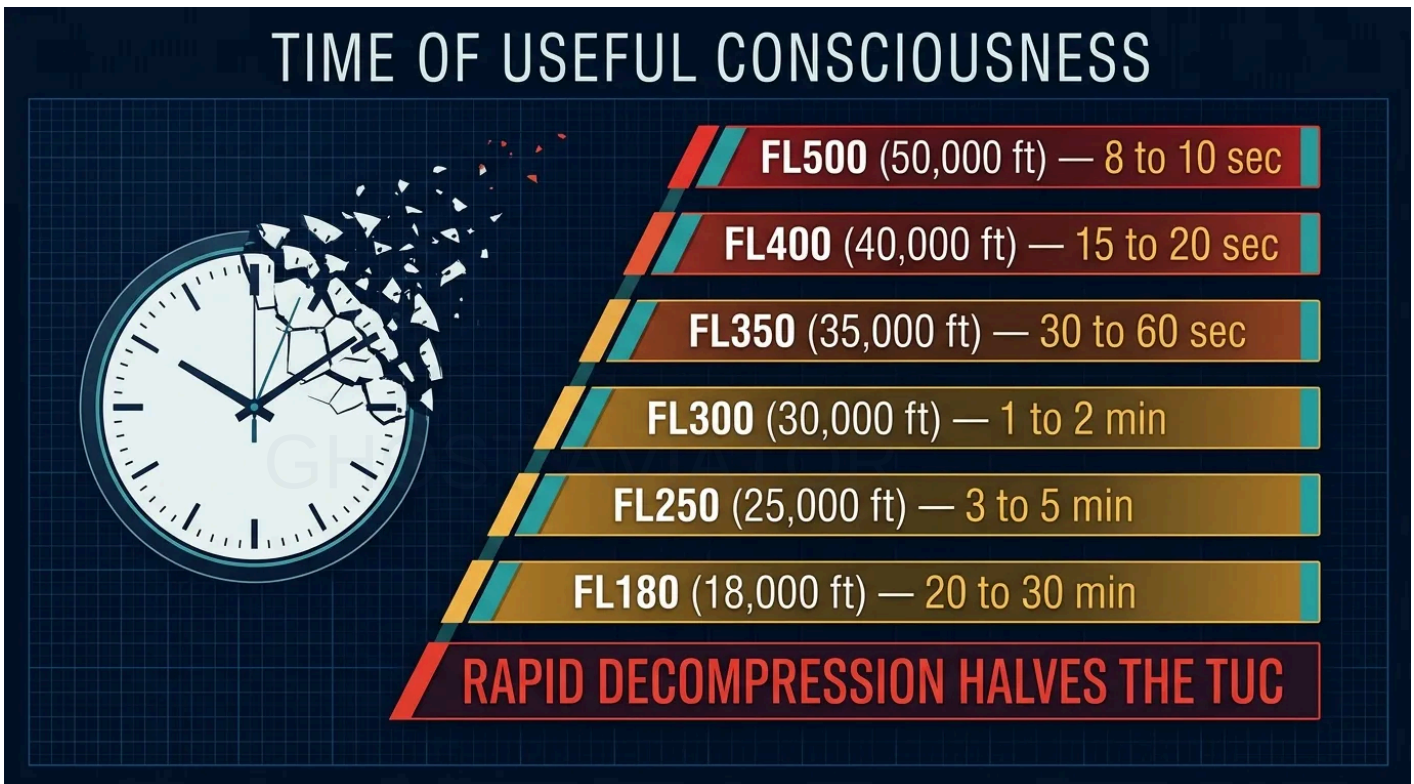


Figure 8.2 — Time of Useful Consciousness collapses with altitude: above FL250 it falls fast; by FL400 it is under 20 seconds.

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18.4 Rapid Decompression Halves TUC

THE "HALVING RULE" — DGCA-QUOTED

"Rapid decompression can reduce TUC by half."

Why? Because a rapid decompression doesn't just drop the pilot to ambient pressure — it actually **sucks oxygen out of the lungs into the cabin atmosphere** (Henry's law, in reverse). The pilot is left with **less oxygen in the bloodstream than the new ambient pressure alone would predict**.

33–54s TUC at FL350 (normal ascent)

½ Reduction after rapid decompression

7–10s TUC at FL400 (rapid decompression)

OPERATIONAL PILOT RESPONSE — THE DRILL

After a rapid decompression in a transport jet you have **seconds, not minutes**:

1. **Don oxygen masks** immediately — quick-don, regulator to EMERGENCY/100 %.
2. **Establish crew communication**.
3. **Initiate emergency descent** — target **10,000 ft** or MSA, whichever higher.
4. **Squawk 7700**, declare MAYDAY.

This drill is muscle-memory in transport flight training precisely because there is no time to think it through at FL350+.

§ 19

Decompression — Theory

DEFINITION

"Decompression" means the lowering of pressure.

19.1 The 8,000 ft "Maximum Comfort" Rule

DGCA-QUOTED

The maximum altitude without oxygen at which flying efficiency is not impaired is **8,000 feet**.

DGCA-QUOTED — FLIGHT RISK BELOW 10,000 FT

When flying at altitude below 10,000 feet, the risk of suffering from conditions related to decompression is low.

19.2 Atmospheric Pressure is Halved at 18,000 ft

NITROGEN SATURATION & PRESSURE FACTS

- At ground level, the body tissues are **saturated with nitrogen**, the inert gas which makes up **80 % of our atmosphere**.
- As the aircraft climbs, atmospheric pressure is reduced.
- By **18,000 ft ASL (5,486 m)** atmospheric pressure is HALVED.
- **Decompression sickness symptoms may develop at 18,000 ft and above.**
- Pilots flying aircraft with **unpressurised cabins at altitudes greater than 25,000 feet ASL (7,620 m)** may be subject to "the bends".

19.3 The Bends — Physiology of Nitrogen Bubbles

THE BOTTLE-OF-SODA MECHANISM — DGCA'S OWN ANALOGY

"The bends" condition is caused by **bubbles of nitrogen forming in the tissues because the ambient (atmospheric) pressure is less than the pressure at ground level**. (An example of this phenomenon is the **bubbles formed when a bottle of soda pop is opened**, and the pressure is reduced.)

The bubbles may:

- **Track into joint spaces** causing a **dull, sickening pain**.
- **More dangerously** they may be **released into the lungs or the brain**, giving rise to **chest pain and/or collapse**.

DECOMPRESSION — WHY BUBBLES FORM

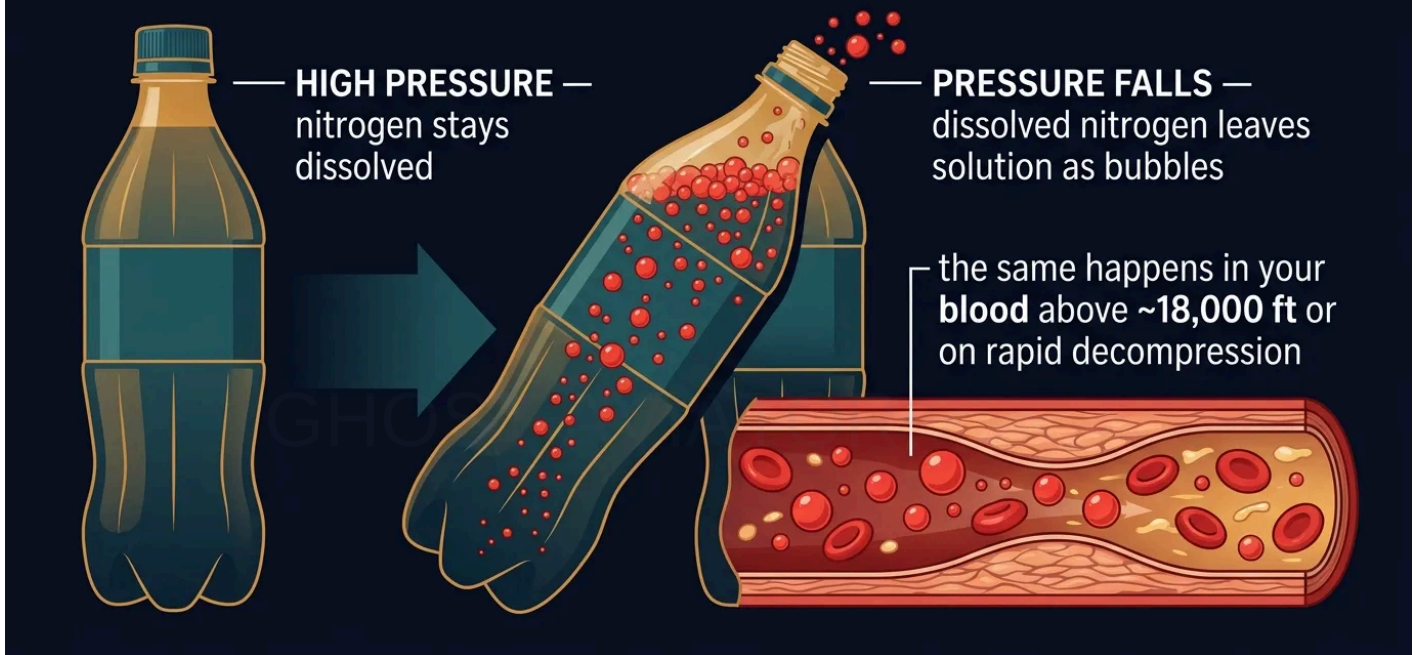


Figure 8.3 — When pressure falls, dissolved nitrogen leaves solution and forms bubbles in the blood and tissues.

19.4 Cabin Pressurization & Rapid vs Slow Decompression

HOW AIRLINE CABINS SOLVE THE PROBLEM

Airlines and high-performance aircraft have cabin pressurization systems to maintain an artificially "low altitude" within the cabin or cockpit. The pressurization of a commercial airliner flying at 30,000 ft maintains an internal cabin pressure equivalent to about 6,000 ft, with a maximum pressure of 8,000 ft.

FAST (Rapid) Decompression

A fast decompression is recognizable by:

- Mist in the cabin
- Blast towards the exterior of the aircraft
- Expansion of body gases
- Blast of air released violently from the lungs

SLOW Decompression

A slow decompression may be caused by:

- A slight air-tightness defect, or
- Bad functioning of the pressurization.

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Insidious onset — no warning blast, no mist, but cabin altitude creeps up over minutes. Detected via the cabin-altitude warning horn (typically at ~10,000 ft cabin altitude in transport jets).

19.5 Factors that Increase the Tendency to Develop the Bends

FIVE DGCA-QUOTED PREDISPOSING FACTORS

The tendency to develop the bends increases with:

1. **High rates of climb,**
2. **Age,**
3. **Obesity,**
4. **Physical activity,**
5. **Low temperatures.**

MAX ALTITUDE WITHOUT O₂ — NO IMPAIRMENT

8,000 ft

LOW DCS RISK BELOW

10,000 ft

ATMOSPHERIC PRESSURE HALVED AT

18,000 ft

UNPRESSURISED FLIGHT — BENDS THRESHOLD

> 25,000 ft

TYPICAL AIRLINER CABIN ALTITUDE

≈ 6,000 ft

MAXIMUM CABIN ALTITUDE

8,000 ft

N₂ % IN ATMOSPHERE

≈ 80 %

DCS RISK FACTORS COUNT

5

§ 20

Decompression Sickness (DCS)

DGCA-QUOTED INTRODUCTION

Without a cabin pressurization system, pilots and passengers in high flying aircraft would be exposed to high altitude, like hypoxia, low temperatures and Decompression Sickness/Illness.

20.1 Henry's Law Revisited — the underlying physics

HENRY'S LAW STATEMENT — VERBATIM FROM DGCA

Henry's Law explains the occurrence of decompression sickness. The principle that **at a constant temperature the concentration of a gas dissolved in a fluid with which it does not combine chemically is almost directly proportional to the partial pressure of the gas at the surface of the fluid.**

A rapid reduction in ambient pressure may cause the nitrogen in our blood to come out of solution as small bubbles leading to decompression sickness.

SYMPTOM LIST & THE "DELAYED ONSET" WARNING

Symptoms of decompression sickness are:

- Bends
- Chokes
- Skin manifestations
- Neurological symptoms
- Circulatory shock

Symptoms may appear several hours after the exposure.

20.2 Effects of Nitrogen Bubbles — Four Syndromes

The DGCA syllabus names **four specific syndromes** based on the tissue affected. Memorise the names and the body region.

Joints The BENDS

Joints: Bubbles in the joints cause **rheumatic-like pain**, called **the Bends**.

Classic shoulder & knee deep, dull ache — diver's bends, identical mechanism.

Skin The CREEPS

Skin: Nitrogen bubbles released under the skin cause **the Creeps**, a **sensation of movement under the skin**.

Linked to formication (§10.4) — the "ants crawling under the skin" feeling.

Respiratory System The CHOKES

Respiratory System: Shortness of breath and a feeling of burning, gnawing and piercing pain. Known as **the Chokes**.

Bubbles in pulmonary capillaries → ventilation/perfusion mismatch. Burning chest pain.

The Brain The STAGGERS

The Brain: Loss of mental functions and control of movement. Known as **the Stagers**.

Neurological DCS — confusion, ataxia, weakness, paralysis. Most dangerous form.

DCS Syndromes — quick-reference one-liner

Tissue	Syndrome Name	Symptom Type
Joints	The Bends	Rheumatic-like joint pain
Skin	The Creeps	Sensation of movement under skin
Respiratory System	The Chokes	Shortness of breath; burning, gnawing, piercing chest pain
The Brain	The Stagers	Loss of mental function & movement control

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20.3 Treatment of Decompression Sickness

DGCA-QUOTED FOUR-STEP TREATMENT

1. Keep patient warm and on 100 % Oxygen.
2. An immediate descent must be initiated.
3. Land as soon as possible.
4. Seek medical assistance immediately on landing.

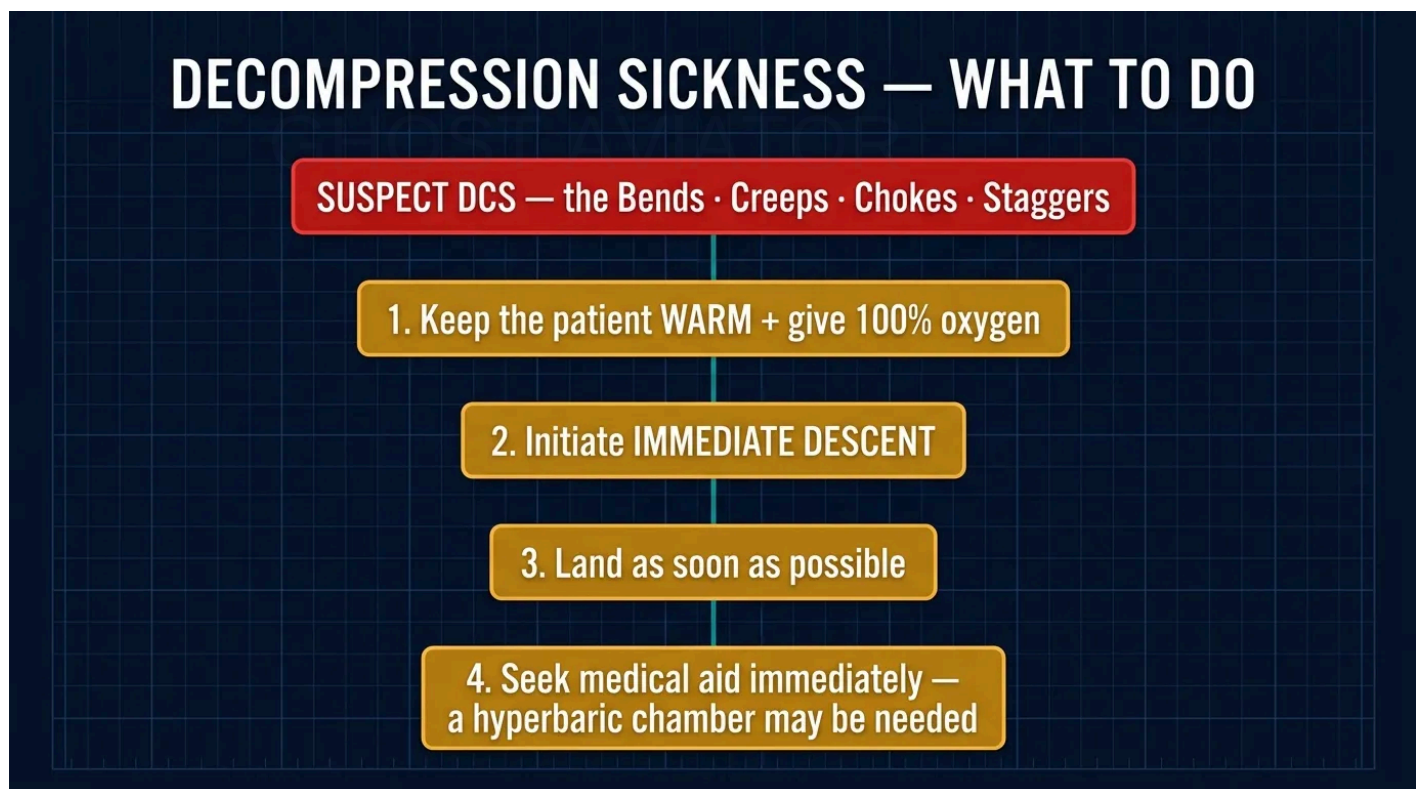


Figure 8.4 — Decompression sickness (the bends): the forms it takes and the response.

20.4 The 12-Hour No-Fly Rule After Rapid Decompression

DGCA-QUOTED

Do not fly for at least **12 hours** after experiencing rapid decompression even though you may be feeling fit.

WHY 12 HOURS?

DCS symptoms can be **delayed for several hours**. Feeling "fit" immediately after a decompression event does **not** mean nitrogen bubbles are not still forming or growing in tissues. The 12-hour pause allows the body to off-gas the residual nitrogen at normal pressure, much like a diver waiting before flying or driving up a mountain.

§ 21

Flying After Diving — the 24-hour rule

DGCA-QUOTED MECHANISM

Decompression sickness can occur when flying at low altitude in individuals who have been diving, using compressed air breathing apparatus shortly before flight at a depth of **30 feet or more**.

THE HARD RULE — MEMORISE VERBATIM

As a general rule, individuals should **NOT** fly within **24 hours** following diving and certainly not the same day.

30_{ft} Diving depth that creates DCS risk on flying

24_{hr} Minimum wait between diving & flight

15min – 12hr Symptom-onset window after surfacing

WHY DIVING + FLIGHT IS SO DANGEROUS — DGCA-QUOTED

Occasionally a "medical emergency" arises as a result of compressed-air diving, when a diver is in danger of developing **air-embolism (bends) at the surface altitude**, as a result of being unable to decompress before surfacing. In some of these cases **air-evacuation is the only feasible method of getting the patient to a decompression chamber in time to treat this condition**. Flight, however, should be at **the lowest possible altitude to avoid aggravating the condition**.

SYMPTOM ONSET TIMING — DGCA QUOTE

Symptoms and signs **usually appear within 15 minutes to 12 hours after surfacing**; but in severe cases, symptoms may **appear before surfacing or immediately afterwards**. **Delayed occurrence of symptoms is rare** (the source text terminates mid-sentence at the page break — continued in §21+).

FLYING AFTER DIVING

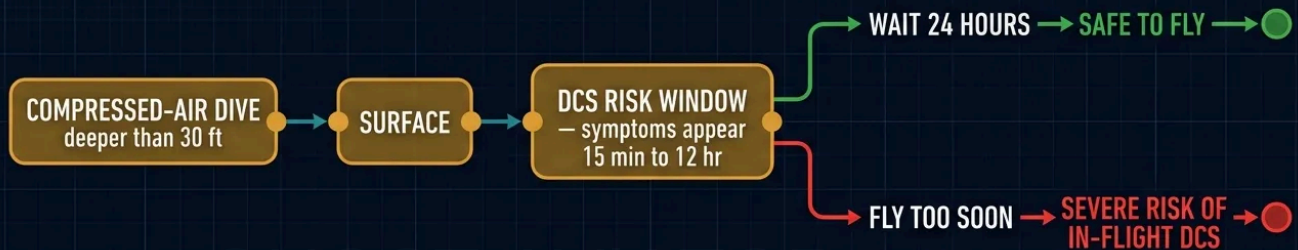


Figure 8.5 — Flying after diving: the wait times that keep dissolved nitrogen from bubbling at altitude.

CROSS-LINK RECAP — THE THREE "WAIT BEFORE FLYING" RULES

You now have three numbers in your head that the DGCA examiner loves to swap around:

- **Alcohol — bottle to throttle:** 24 hr (§14.1)
- **Blood donation:** 48 hr (§17)
- **Flying after diving:** 24 hr (§21)
- **Flying after rapid decompression:** 12 hr (§20.4)

Do not mix them up. Diving and alcohol share the 24-hour figure; donation gets the longest pause; rapid decompression "only" 12 — but with mandatory medical clearance afterwards.

PICKING UP THE BROKEN SENTENCE

The Part-5 text ended with "*Delayed occurrence of symptoms is rare...*" — the rest of the sentence (Part 6 source PDF page 22) reads: "...**but it does occur, especially if air travel follows diving.**"

In plain English: **even if a diver feels perfectly fine 24+ hours after surfacing, a subsequent flight can re-precipitate DCS symptoms.** This is because residual nitrogen still dissolved in slow-perfused tissues (fat, bone marrow) can come out of solution when the pilot enters the lower cabin pressure of a transport flight. *The 24-hour rule is a minimum, not a guarantee.*

◆ END OF CHAPTER 8 ◆

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