Pulmonary Considerations For Air Travel

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Disclosures

Dr. Mohr has no financial or commercial conflicts of interest related to this presentation

Learning Objectives

- Upon completion of this learning activity participants should have:
- A basic understanding of the physiological stresses of commercial air travel
- A basic understanding of the effects of these stresses on various pulmonary disease states
- Awareness of specific guidelines for air travel of patients with chronic pulmonary illnesses


ANTI-ICE
START
IAS/MACH
231
HDG
360
VERT SPD
+2400
ALT
06200
Speed Hold Selector (231 knots)
OGY
0414.0
313
CRS 000
ILGA
110.50
DME ----
113.90
DME ----
TAT +14c
1.04
1.04
1.04
1.04
EPR
24.1
24.1
24.1
24.1
N1
330
330
330
330
EGT
DOWN
GEAR
TOTAL FUEL
243.8 LBS x 1000

INTRODUCTION

- More than 4 billion people travel on commercial aircraft each year
- In the United States alone:
  - 80% of all adults have flown at least once
  - > 1 billion passengers in 2019

- Commercial air-travelers include:
  - Individuals of all ages (infants to elderly)
  - Individuals with a wide variety of medical conditions

- For most passengers air-travel is uneventful
- Some passengers may experience significant physiological stress during flight:
  - Elderly patients
  - Cardiopulmonary disease

- In order for physicians to properly evaluate and advise patients prior to air travel they must have:
  - A basic understanding of the physiological stresses of commercial air travel
  - A basic understanding of the effect of these stresses on various cardiopulmonary disease states
  - Awareness of specific guidelines for air travel of patients with chronic illnesses


SOMETHING TELLS ME WE MIGHT NEED A DOCTOR ON THIS FLIGHT!
Winnett

IN-FLIGHT MEDICAL PROBLEMS

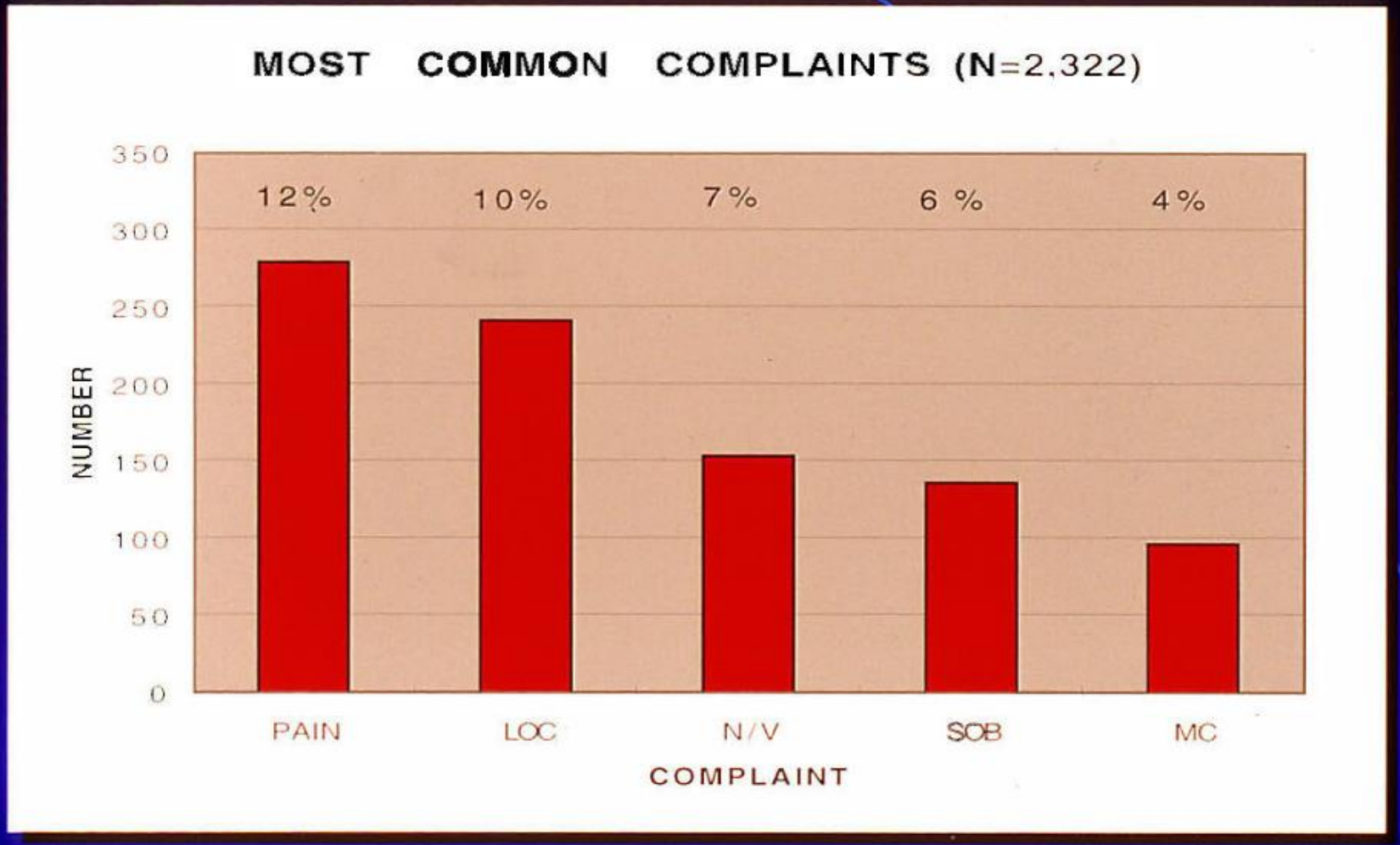
- The exact incidence of in-flight medical problems is unknown with certainty:
  - No uniform method of reporting
  - No systematic method of recording

IN-FLIGHT MEDICAL PROBLEMS

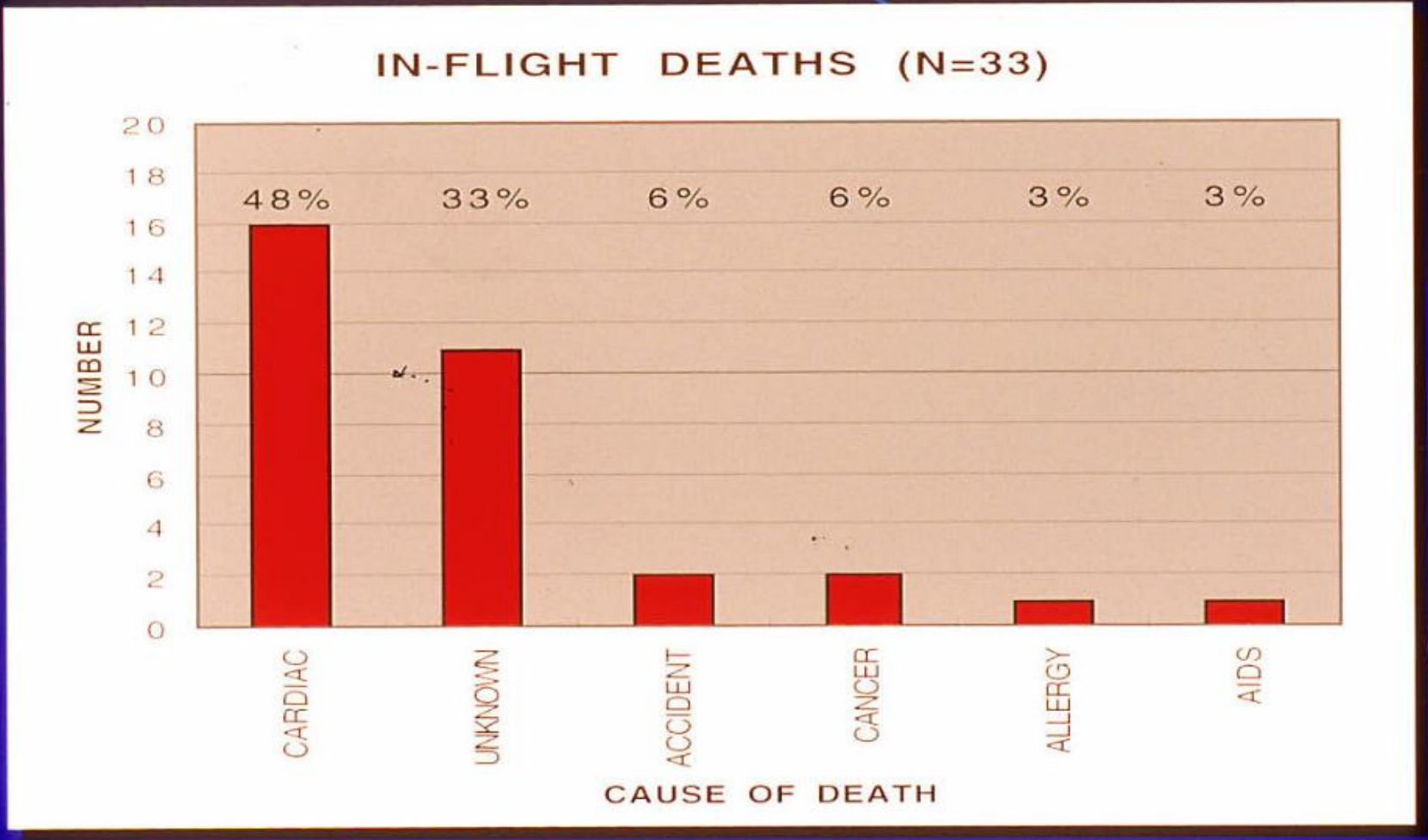
- 1986-1988: FAA required all U.S. carriers to report every case in which the on-board medical kit was used
- Report published in 1991:
  - 900 million passengers
  - On board medical kit used 2,322 times
  - 33 deaths

Hordinsky and George FAA AM-91/2 1991

IN-FLIGHT MEDICAL PROBLEMS
(HORDINSKY & GEORGE FAA AM-91/2 - 1991)



IN-FLIGHT MEDICAL PROBLEMS
(HORDINSKY & GEORGE FAA AM-91/2 - 1991)



Pre-Flight Screening

- History- comorbidities, any recent exacerbation, previous flying history, duration of the planned flight, altitude of the destination.
- Physical Examination,
- Spirometry
- Pulse oximetry at rest
- Arterial blood gas confirmation (if hypercapnia is suspected).

PRE-FLIGHT MEDICAL SCREENING

[Gong et al. Chest 1993 (104): 788]

- 1,115 patients referred by a single U.S. airline for pre-flight medical evaluation in 1991
- 42.7 million passengers flew on this airline during this same period of time

PRE-FLIGHT MEDICAL SCREENING

[Gong et al. Chest 1993 (104): 788]

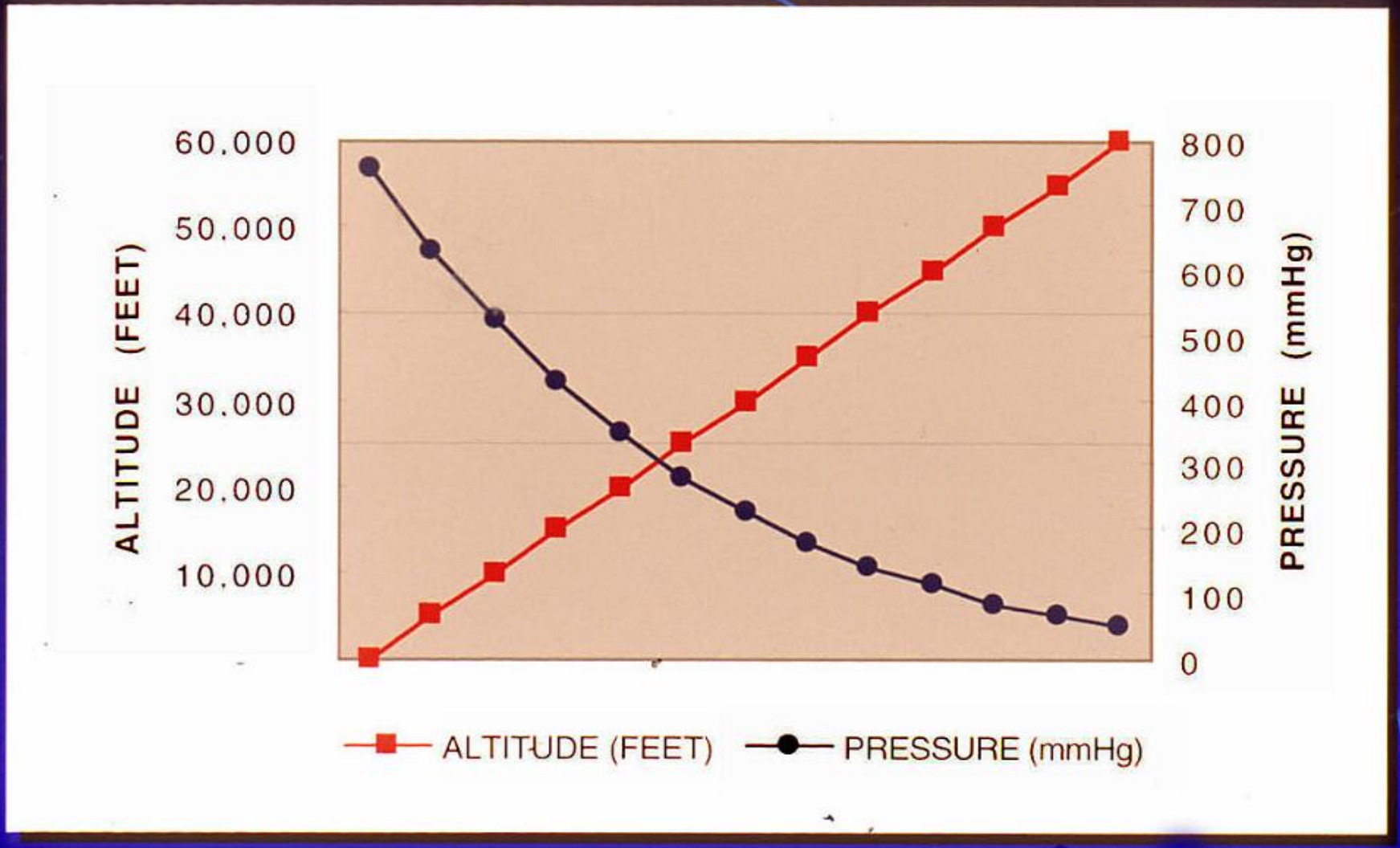
- 1,011 patients cleared to fly
  - 92% of patients evaluated for O_2
  - All patients who required O_2 actually received it in flight
- 104 patients not cleared to fly
  - Unstable medical condition
  - Violation of policy (e.g. IV therapy)

PRE-FLIGHT MEDICAL SCREENING

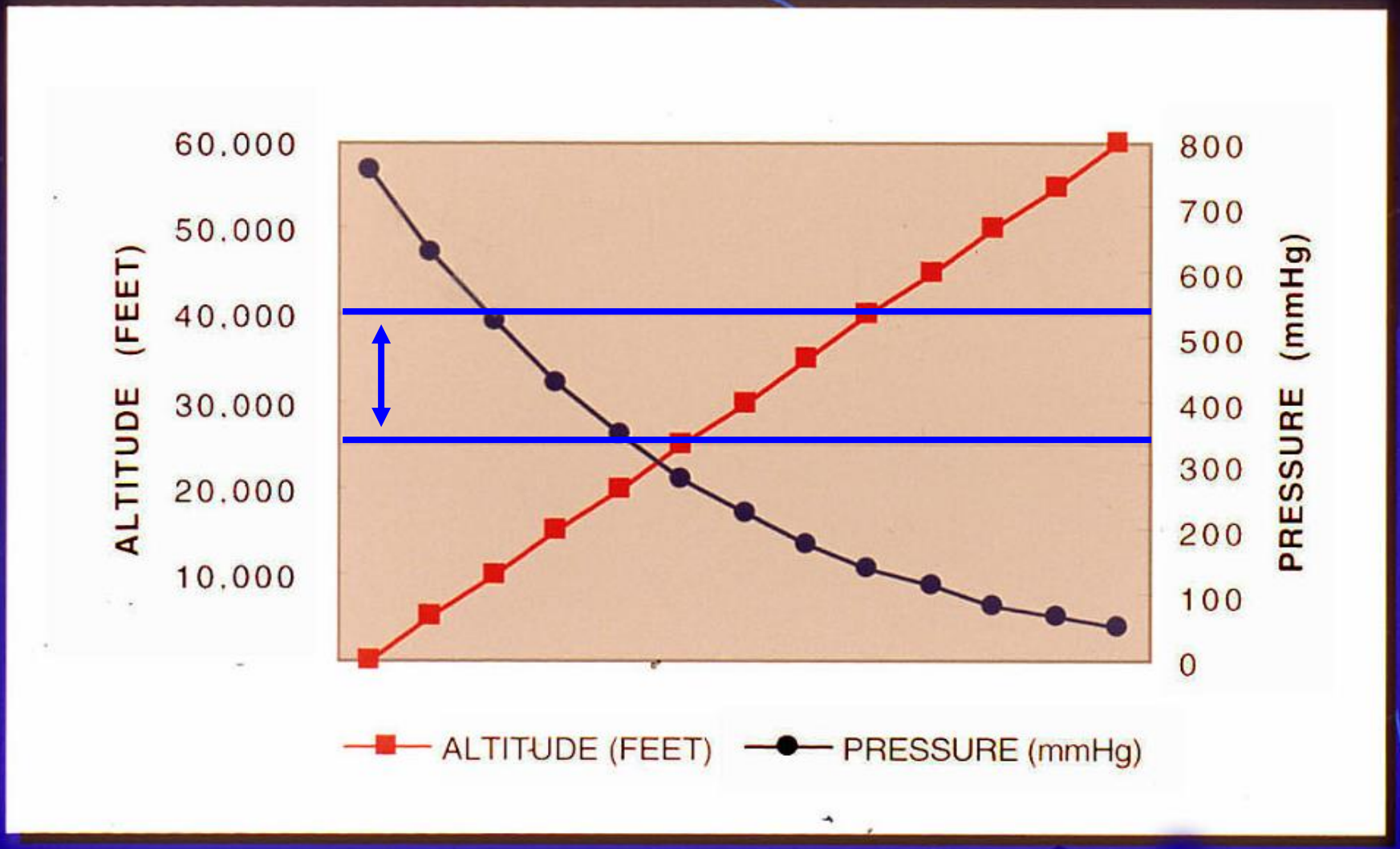
[Gong et al. Chest 1993 (104): 788]

None of the 1,011 screened patients cleared to fly experienced in-flight medical problems

BAROMETRIC PRESSURE AT VARIOUS ALTITUDES

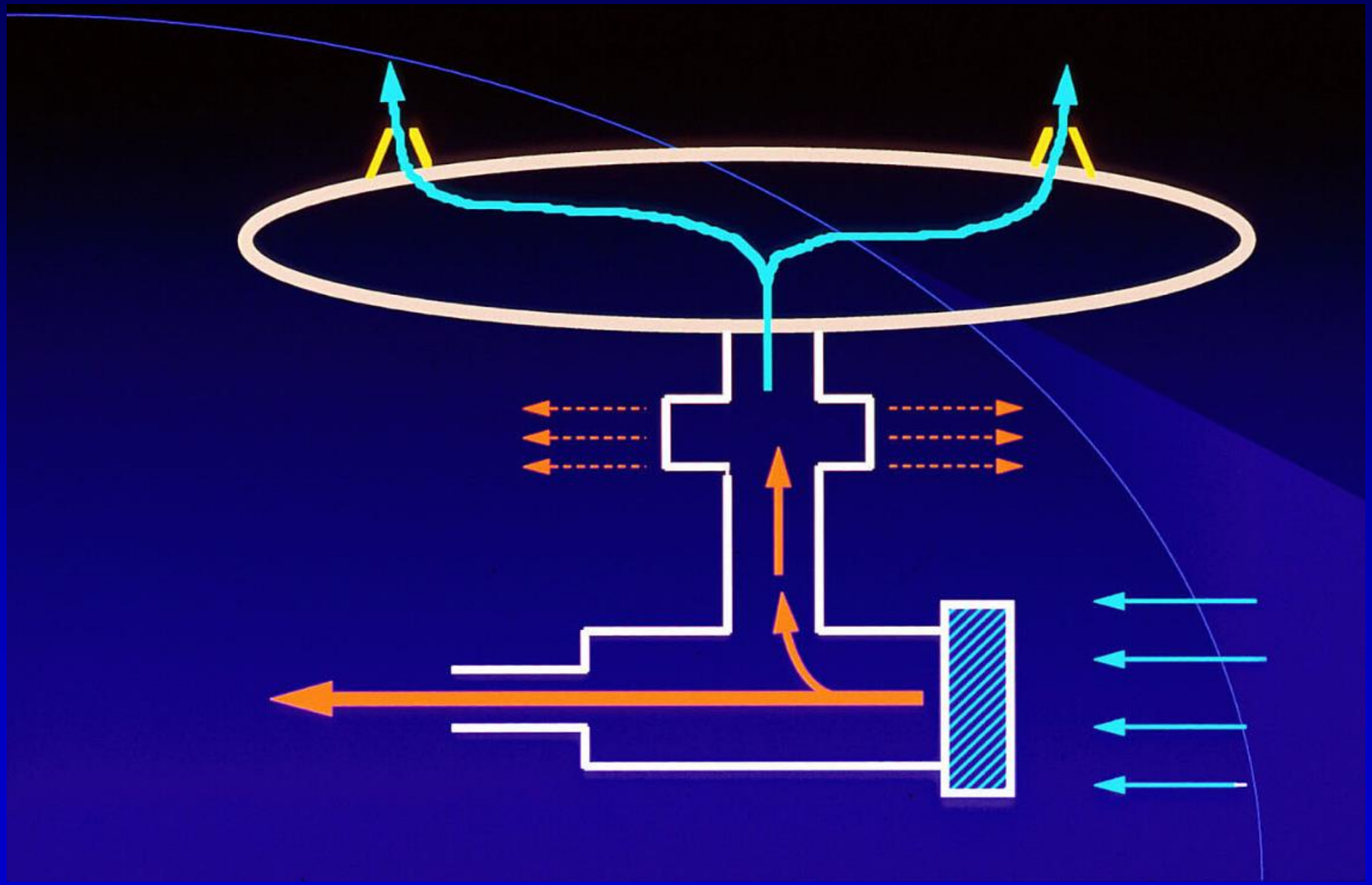


BAROMETRIC PRESSURE AT VARIOUS ALTITUDES



External P_iO_2 and P_aO_2 at Cruising Altitude

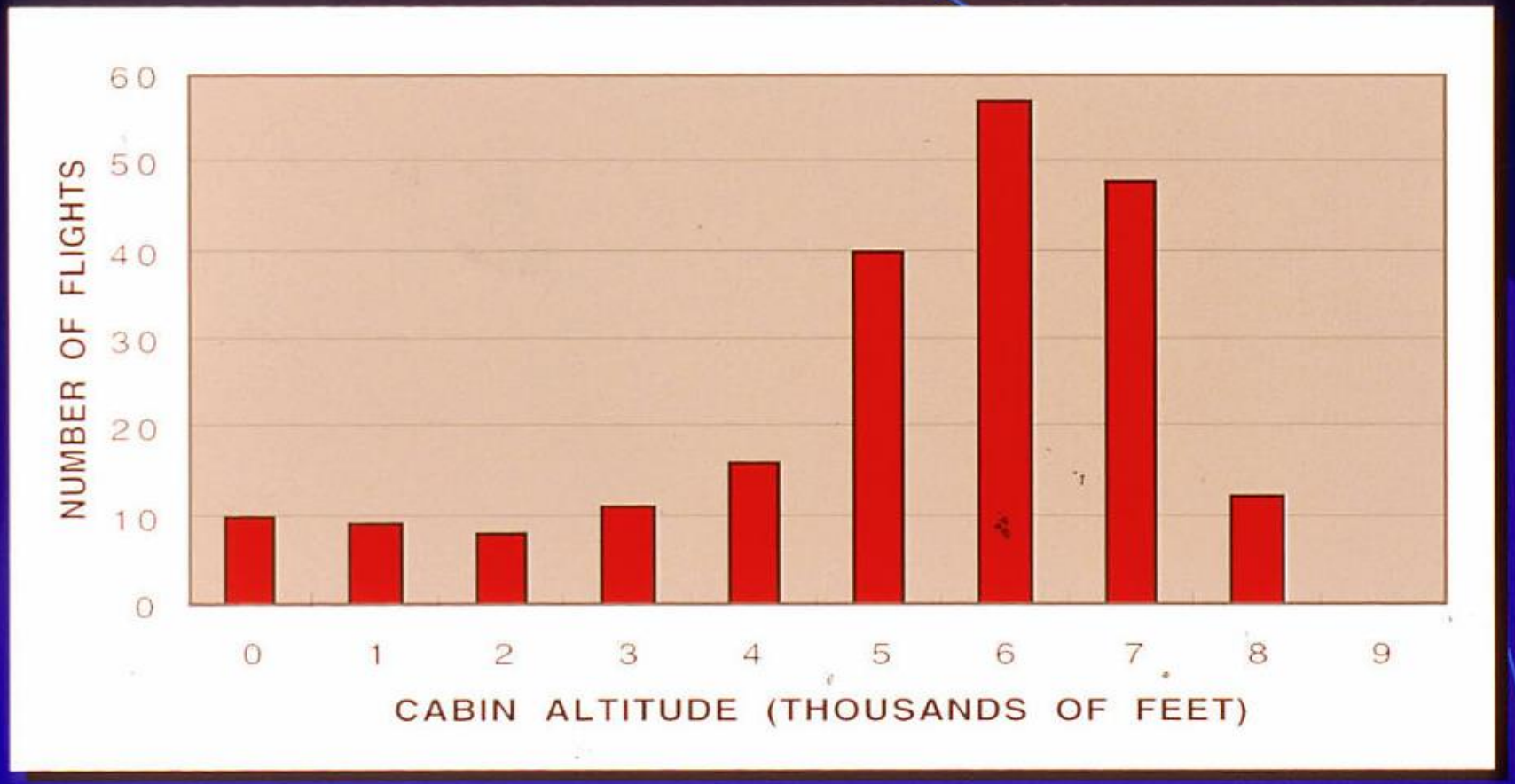
Altitude (feet)	**P_iO_2**	**P_aO_2**
25,000	55 mmHg	35 mmHg
40,000	30 mm Hg	18 mmHg



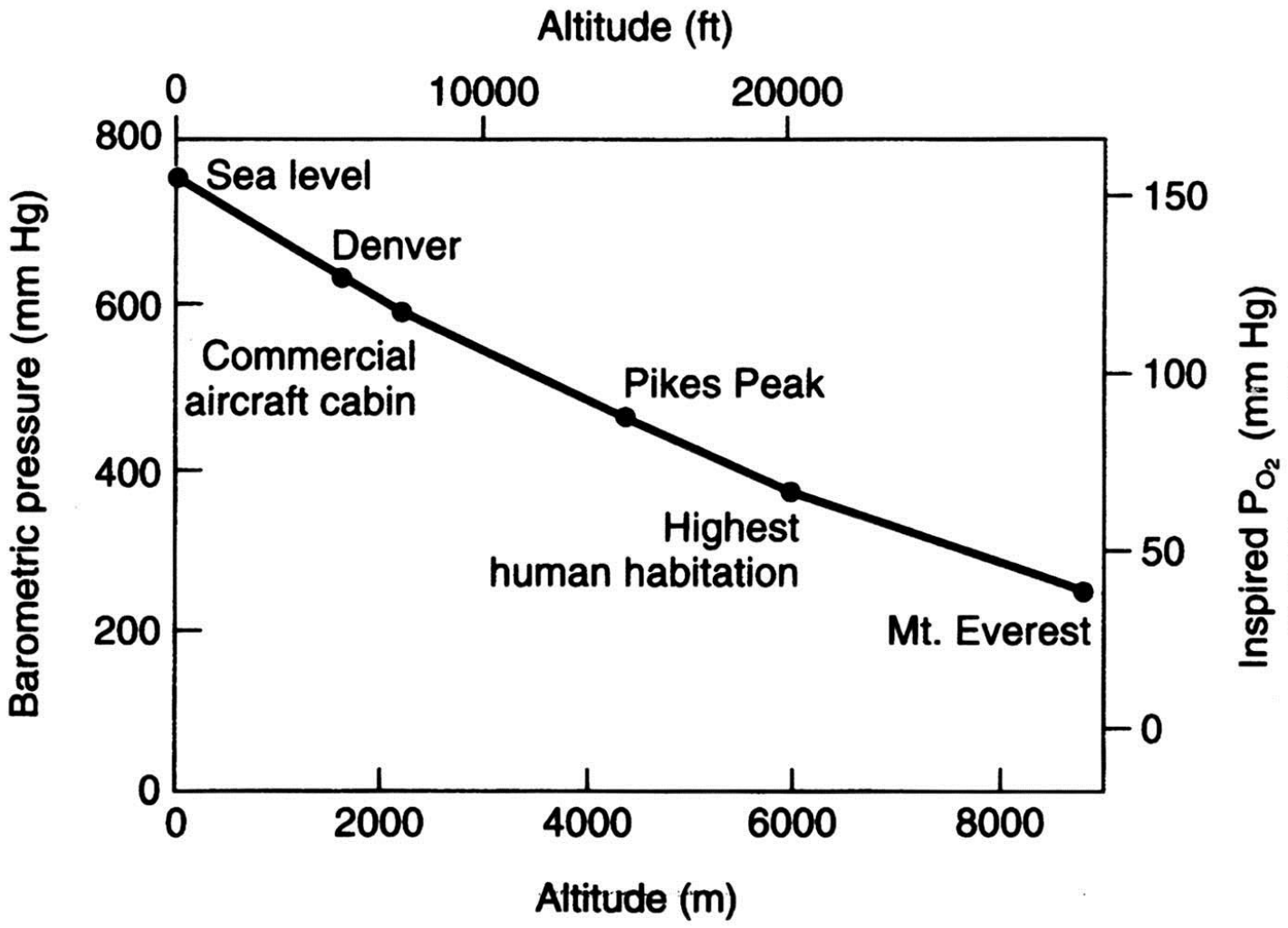
The mean cabin altitude for a pressurized commercial airliner at cruising altitude is about:

1. Sea level
2. 2,500 feet
3. 4,500 feet
4. 6,500 feet

CABIN ALTITUDES ON COMMERCIAL FLIGHTS



COTRELL, JJ. CHEST 1988; 93: 81-84

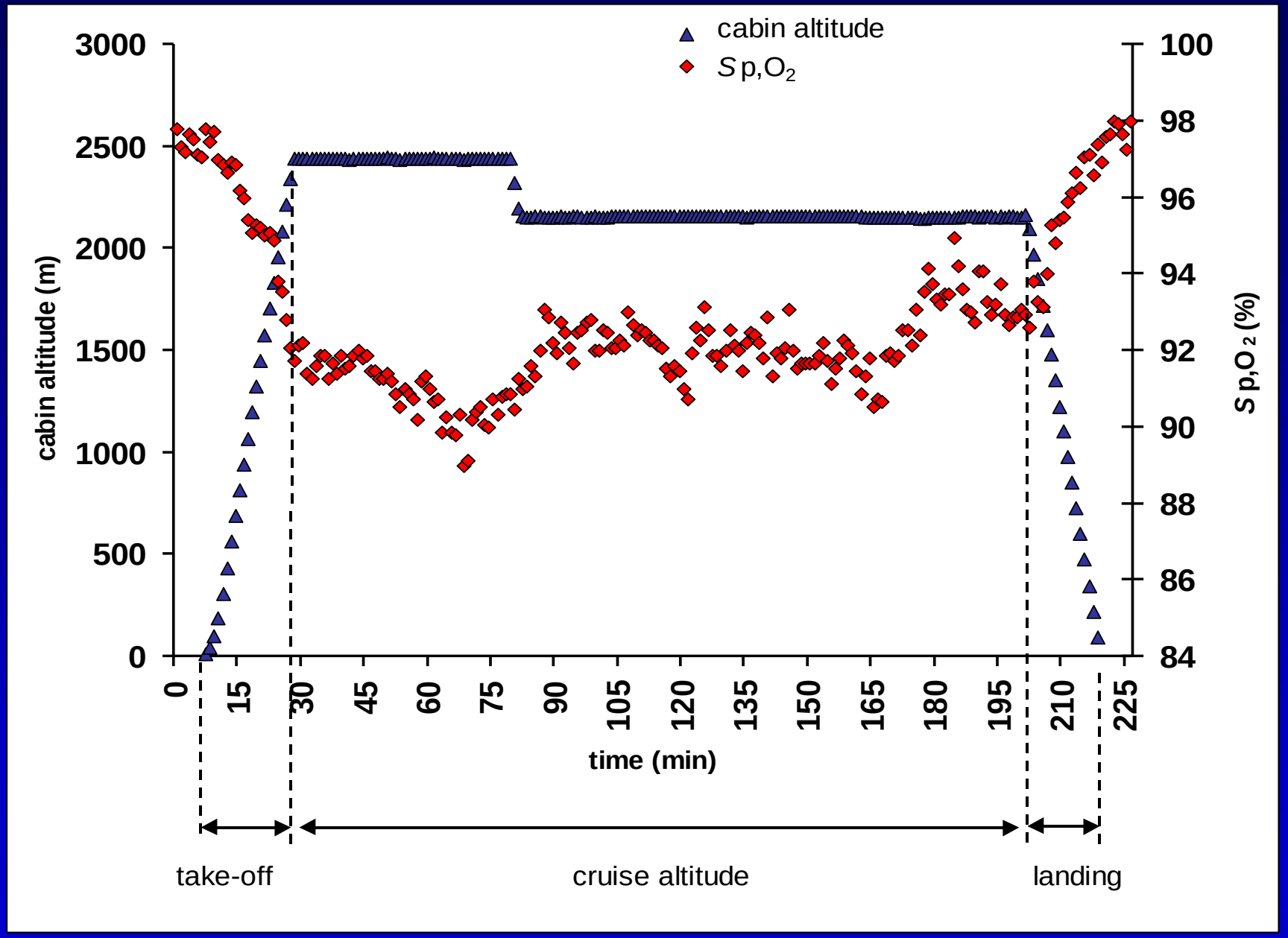

Altitude (ft)
0
10000
20000
800
600
400
200
0
Barometric pressure (mm Hg)
Sea level
Denver
Commercial aircraft cabin
Pikes Peak
Highest human habitation
Mt. Everest
150
100
50
0
Inspired P_{O_2} (mm Hg)
0
2000
4000
6000
8000
Altitude (m)

In healthy individuals, the arterial P_aO_2 in a commercial airliner at cruising altitude is about:

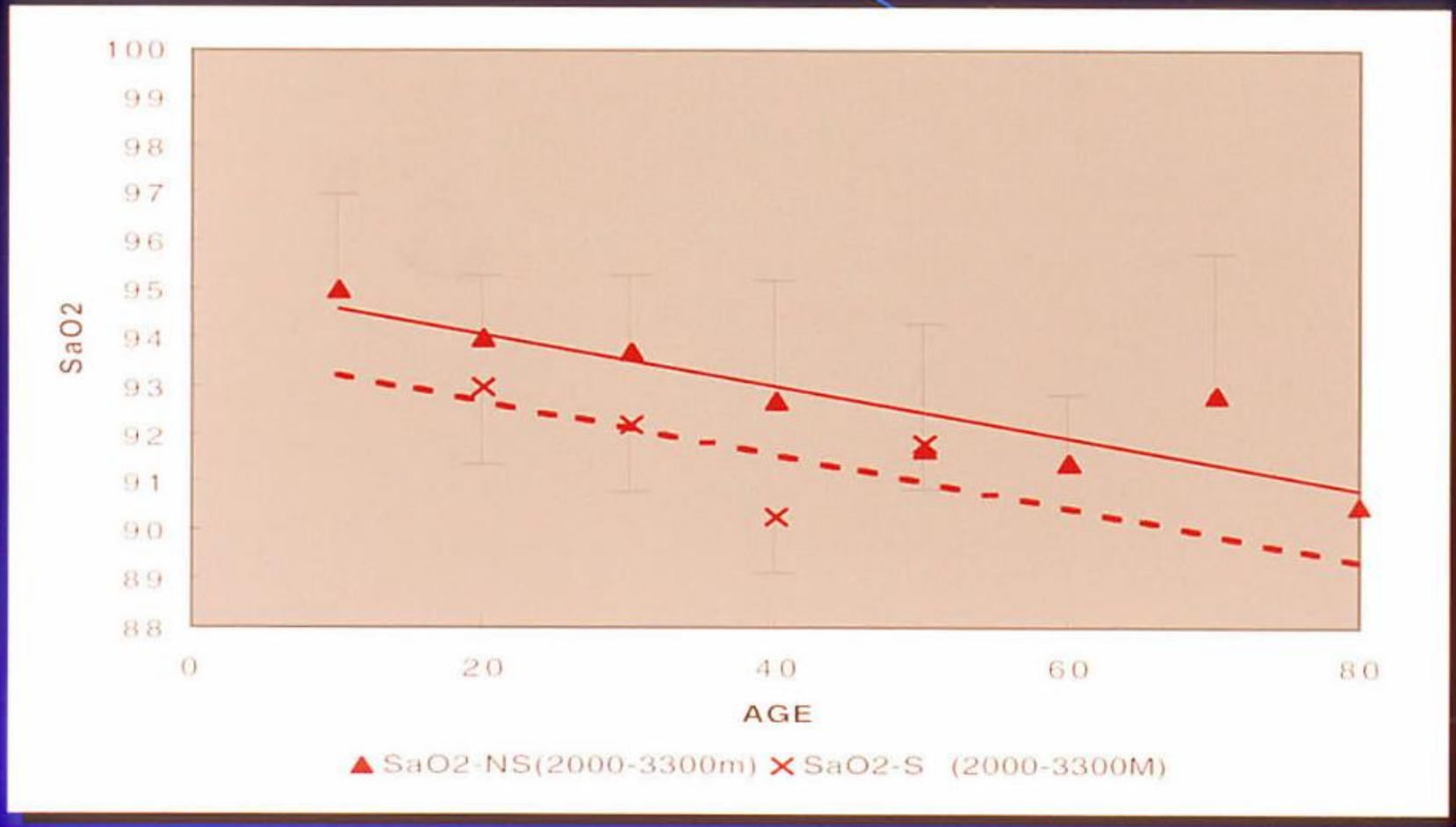
1. 90-95 mmHg
2. 85-90 mmHg
3. 75-85 mmHg
4. 55-75 mmHg

Cabin P_iO_2 and P_aO_2 at Cruising Altitude

Altitude (feet)	**P_iO_2**	**P_aO_2**
5,000	120 mmHg	75 mmHg
8,000	108 mm Hg	55 mmHg


cabin altitude
Sp,O2
3000
2500
2000
1500
1000
500
0
cabin altitude (m)
100
98
96
94
92
90
88
86
84
Sp,O2 (%)
0
15
30
45
60
75
90
105
120
135
150
165
180
195
210
225
time (min)
take-off
cruise altitude
landing

AGE RELATED S_aO_2 AT 2000-3300 METERS SMOKERS VS. NON-SMOKERS



SOSKUTY 1991

MAJOR CONSIDERATIONS

- Baseline P_aO_2 – at ground altitude
- Functional severity of the disorder
- Degree of reversibility
- Pulmonary and respiratory muscle reserve – to sustain increased $\dot{V}$

Which of the following identifies a COPD patient to be at high risk for respiratory decompensation during air travel:

1. D_LCO less than 70 percent predicted
2. FEV_1 less than 60 percent predicted
3. Maximum voluntary ventilation (MVV) less than 40 liters/minute
4. History of hyperventilation syndrome

COPD

- Predictors of poor tolerance
  - Dyspnea on mild exertion
  - Predicted in-flight P_aO_2 < 50 mmHg
    - Estimation from data in literature
    - Equations
    - Nomogram
  - MVV < 40 L/min
  - CO_2 retention

COPD

- Recommendations:
  - Supplemental in-flight O_2 (2-4 liters/min)
    Goal: to maintain in-flight P_aO_2 > 50 mmHg
  - If already on O_2 – increase flow by 33%

The AMA Council of Scientific Affairs recommends that supplemental oxygen be provided during air travel if the pre-flight PaO_2 at or near sea level is:

1. < 80 mmHg
2. < 75 mmHg
3. < 70 mm Hg
4. < 65 mm Hg

COPD

AMA Council of Scientific Affairs Recommendation:

If the preflight P_aO_2 is < 70 mmHg at or near sea level, provision should be made for supplemental oxygen

Lyznicki et al. Aviat Space Environ Med 2000; 71: 827-831

COPD

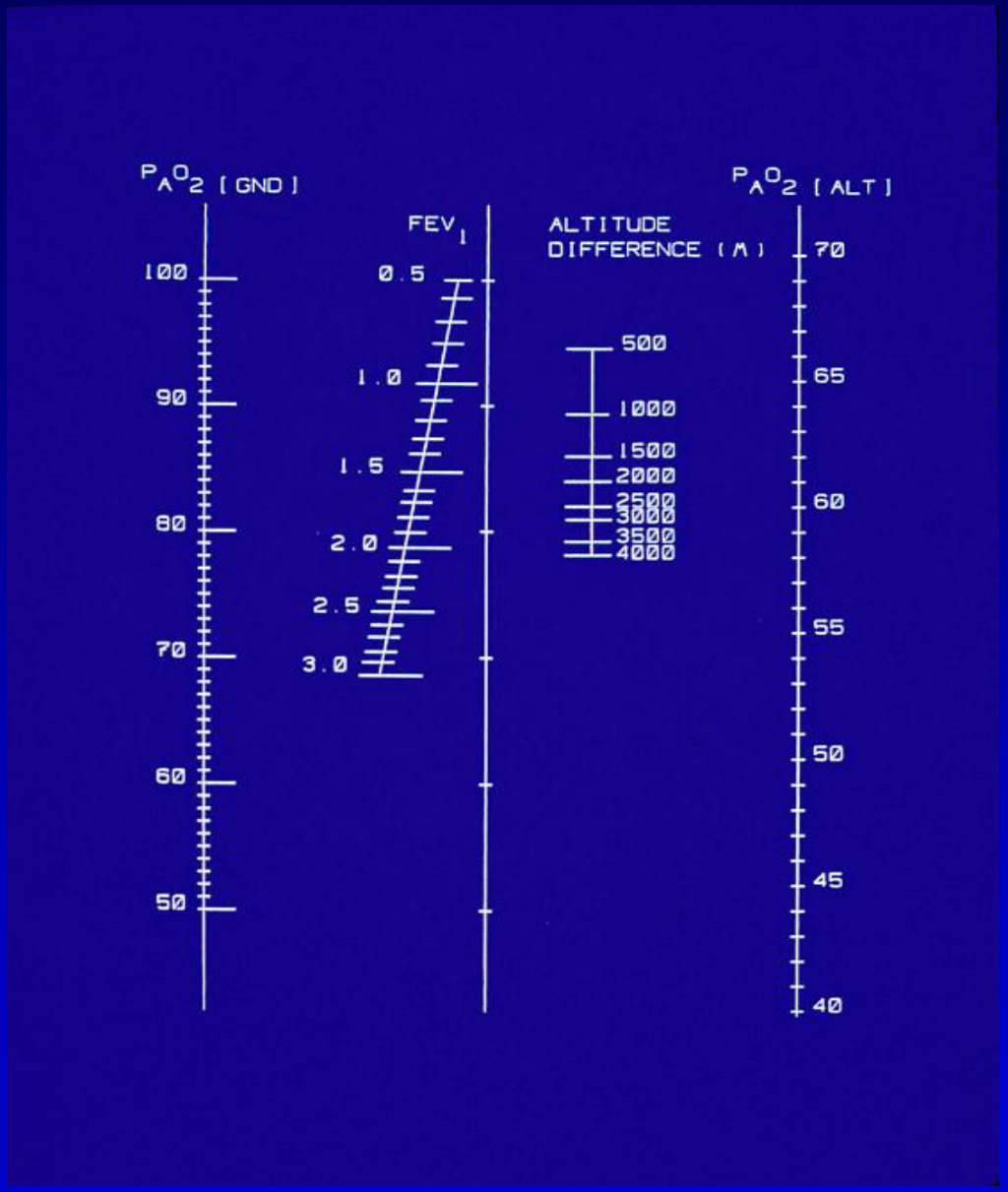
- Schwartz et al (Ann Int Med, 1984)
  - Ground P_aO_2 < 67 mmHg is a predictor of in-flight P_aO_2 < 50 mmHg
- Gong et al (Am Rev Resp Dis, 1984)
  - Ground P_aO_2 < 72 mmHg correlates with a P_aO_2 < 50 mmHg at 8,000 feet

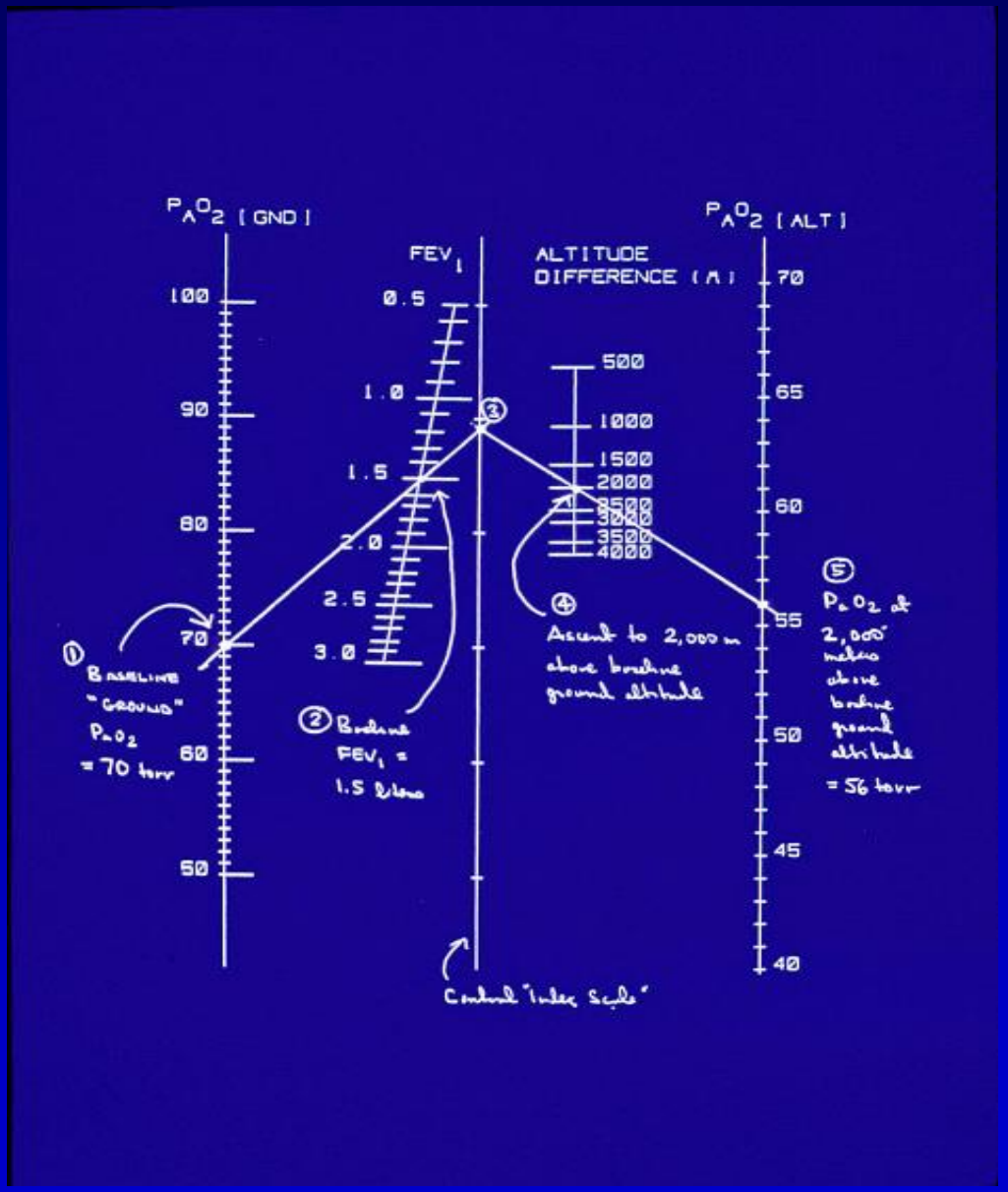
COPD

- PREDICTION OF P_aO_2 AT MODERATE ALTITUDES

$$P_aO_{2\,[ALT]} = 0.19\,(FEV1 * P_aO_{2[GND]}) - 11.51[\ln(MA-GA)] + 123.17$$

$$r^2 = 0.99 \qquad p=0.01$$


P_AO_2 [GND]
100
90
80
70
60
50
FEV$_1$
0.5
1.0
1.5
2.0
2.5
3.0
ALTITUDE DIFFERENCE (M)
500
1000
1500
2000
2500
3000
3500
4000
P_AO_2 [ALT]
70
65
60
55
50
45
40


P_AO_2 [GND]
P_AO_2 [ALT]
FEV_1
ALTITUDE DIFFERENCE (A)
100
90
80
70
60
50
0.5
1.0
1.5
2.0
2.5
3.0
500
1000
1500
2000
2500
3000
3500
4000
70
65
60
55
50
45
40
① Baseline "ground" P_AO_2 = 70 torr
② Baseline FEV_1 = 1.5 liters
③
④ Ascent to 2,000 m above baseline ground altitude
⑤ P_AO_2 at 2,000 meters above baseline ground altitude = 56 torr
Control "index scale"

ASTHMA

- Severe – poorly controlled
  - Should not fly
- Recent Hospitalization
  - Wait until entirely stable for 1-2 weeks after discharge
- Stable – well controlled
  - Can generally fly safely

ASTHMA

- All patients with asthma who fly should:
  - Continue usual medications
  - Carry all prescribed medication with them on the airplane
  - Carry a course of oral steroids with them on the airplane

Restrictive and Interstitial Lung Disease

- **Predictors of poor tolerance:**
  - Dyspnea on exertion
  - O_2 desaturation with mild exercise
  - P_aO_2 < 70 mm Hg at or near sea-level
  - P_aO_2 < 50 mmHg at altitude
  - Moderate to severe impairment of D_LCO

Restrictive and Interstitial Lung Disease

- **Recommendations:**
  - Supplemental in-flight O_2 (2-4 liters/min)
    Goal: to maintain in-flight P_aO_2 > 50 mmHg
  - If already on O_2 – increase flow by 33%

Restrictive and Interstitial Lung Disease

Prediction of P_aO_2 at 8,000 feet

$$P_aO_2 \text{ (8,000 feet)} = 0.74 + (0.39 \times [P_aO_2 \text{ sea level}]) + (0.33 \times [\text{TL,co \% predicted}])$$

P_aO_2 (8,000 feet) is the estimated arterial oxygen tension at 8,000 feet in kPa;

[P_aO_2 sea level] is the baseline arterial oxygen tension at sea level in kPa

[TL,co% predicted] is the percentage of the predicted diffusion capacity for carbon monoxide at sea level.

Christensen CC, Ryg MS, Refvem OK, et al. Effect of hypobaric hypoxia on blood gasses in patients with restrictive lung disease. Eur Respir J 2002; 20:300-305

Altitude Simulation Tests

- **Hypobaric Chamber**
  - Can simulate a variety of altitudes and duration of hypoxia, depending upon capabilities of the chamber
  - Measure arterial blood gasses before and at the end of chamber study
  - Most commonly used in research

Altitude Simulation Tests

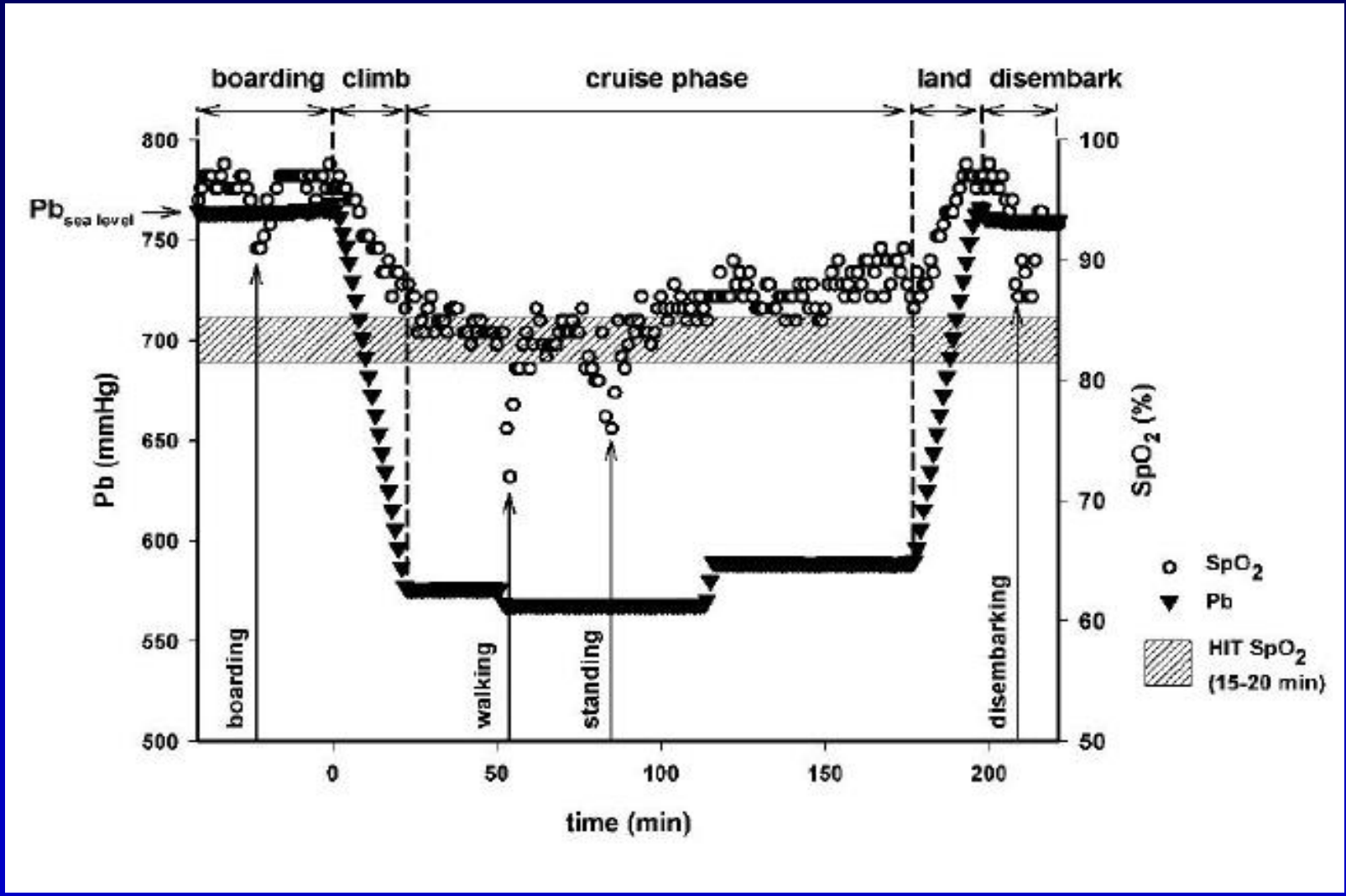
- **Hypoxia Altitude Simulation Test**
  - 15% O_2 for 20 minutes simulates an altitude of 8,000 feet
  - Measure arterial blood gasses and SpO_2 before and after 20 minutes of exposure to the hypoxic gas mixture

Altitude Simulation Tests

- **Hypoxia Altitude Simulation Test**
  - If PaO_2 is > 55 mmHg after 20 minutes, supplemental oxygen is not needed.
  - If PaO_2 is < 50 mmHg after 20 minutes, supplemental oxygen is recommended.

Altitude Simulation Tests

- **Hypoxia Altitude Simulation Test**
  - If PaO_2 is between 50 and 55 mmHg after 20 minutes:
  - If SpO_2 < 85%, supplemental oxygen is recommended.
  - If SpO_2 on 6-minute walk test < 85%, supplemental oxygen is recommended
  - Clinical judgment



Kelly P, Swanney M, Seccombe L, et al. Air travel hypoxemia versus the hypoxia inhalation test in passengers with chronic obstructive pulmonary disease. Chest; April 2008

Which condition is an absolute contraindication for commercial air travel:

1. BOOP
2. Severe pulmonary hypertension
3. Chronic hypersensitivity pneumonitis
4. Pleural effusion

PULMONARY HYPERTENSION

- Mild or asymptomatic PH (Class I&II)
  - Thorough pre-flight medical evaluation
  - May fly without supplemental O_2
  - Continue usual medications
- Mildly symptomatic PH (Class III)
  - Supplemental O_2
- Severe or symptomatic PH (Class IV)
  - ***Absolute contraindication*** to air travel

IN-FLIGHT OXYGEN

- Airline-Provided Oxygen
  - Logistically challenging
  - Patients are not permitted to carry their own O_2 cylinders aboard commercial aircraft
  - Most airlines will provide in-flight O_2 to passengers with an O_2 prescription from a physician – at least 48 hours in advance
  - Airlines will not provide O_2 while passengers are on the ground or changing planes

IN-FLIGHT OXYGEN

- Portable Oxygen Concentrators
  - 2005 FAA Rule allows (but does not require) airlines to permit passengers to carry approved portable O_2 concentrators aboard commercial aircraft
  - 5 portable O_2 concentrators are currently approved by the FAA
  - Most airlines will permit portable O_2 concentrators

Airsep Lifestyle Portable

IN-FLIGHT OXYGEN

- Portable Oxygen Concentrators
  - Each airline has its own policies about what type of portable concentrators they will allow aboard aircraft
  - Physicians need to coordinate with the airline and provide an O_2 prescription at least 48 hours in advance of flight
  - Patient needs to carry a copy of the O_2 prescription with them during travel

IN-FLIGHT OXYGEN

- Portable Oxygen Concentrators
  - Some airlines charge fees for passengers to carry portable concentrators aboard
  - Patients need to have a sufficient number of batteries for the length of the flight
  - Most airlines will charge a fee for providing extra batteries during a flight

PHYSICIAN'S STATEMENT FOR AIR TRAVEL
PORTABLE OXYGEN CONCENTRATOR

Pursuant to Federal Aviation Regulations, a customer who would like to use a portable oxygen concentrator unit on board an airline must obtain a written statement from his or her physician answering the questions listed below.

Customer Information

This document is to remain in your personal possession and must be presented to airline representatives upon request. This document will not expire but must be available for every flight. Any changes in oxygen requirements such as a revised flow rate will require an updated statement.

You are responsible for ensuring that your unit is in good condition and free from damage or excessive wear and tear.

You are responsible for traveling with a sufficient supply of batteries to last the entire journey, per your oxygen requirements, including the duration of the flight, all ground time (before and after flight and during connections) and for unexpected delays. All batteries must be transported in carry-on (not checked) baggage and must be packed in a manner that protects them from damage or short circuits. Your portable oxygen concentrator, as well as the baggage containing the batteries, is exempt from the normal carry-on limitation of two pieces plus a personal item.

To be completed by physician:

Patient's Name: _____ Date: _____

Does the user of the device have the physical and cognitive ability to see, hear, understand, and take appropriate action in response to the device's aural and visual cautions and warnings?
Yes _____ No _____
If not, the customer must travel with someone who is capable of performing these functions.

Passenger is using the Sequal Eclipse Portable Oxygen Concentrator
Pulse Flow Mode _____ Continuous Flow Mode _____ *(please check one)*

Is oxygen use medically necessary for continuous use during taxi, take-off, landing, and during flight?
Yes _____ No _____

In the event of a flight connection, will oxygen be required while on the ground?
Yes _____ No _____

Pressurized aircraft cabin altitude equals 8,000 feet above sea level. Recognizing the possible changes in cabin pressure during flight, the patient's required oxygen flow rate during flight is _____ LPM.

Physician's Name: _____

Telephone: _____

Signature: _____

How long after resolution of a pneumothorax should a patient wait before traveling by commercial aircraft:

1. Five days
2. Two to three weeks
3. One month
4. Two to three months

PNEUMOTHORAX

- Any evidence of pneumothorax
  - ***Absolute contraindication*** for air travel
- After successful drainage or resolution
  - Wait 2-3 weeks before flying
  - F/U CXR recommended before flying

Bullous Emphysema - Pneumothorax

Wait one year after resolution of bullous rupture pneumothorax before flying

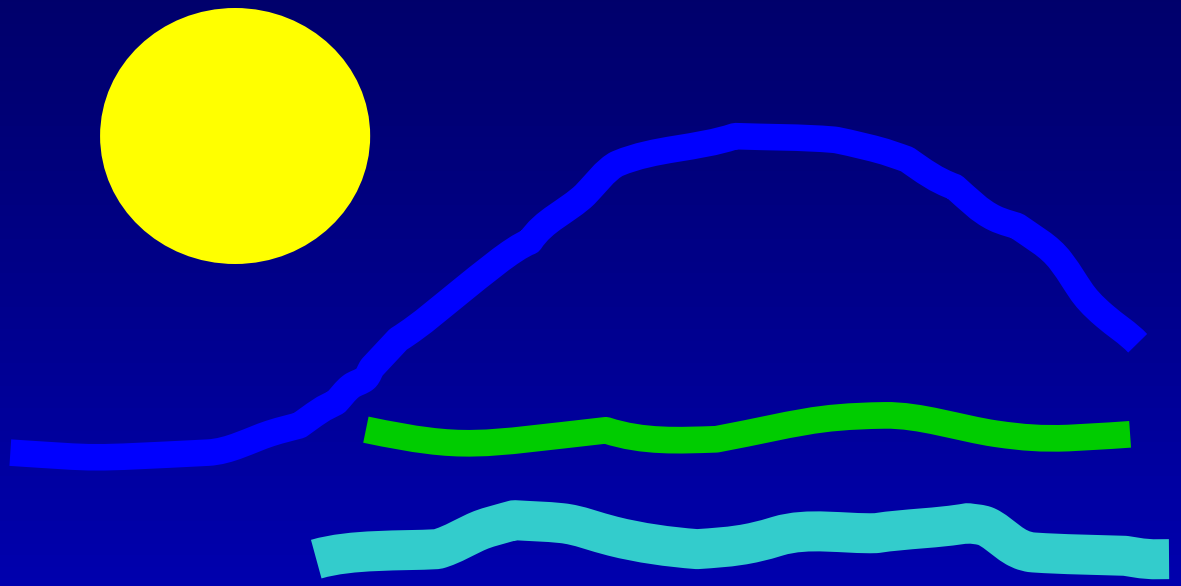
British Thoracic Society 2011

LAM – Chronic Pneumothorax

- 8/204 patients with LAM had chronic pneumothorax and traveled by commercial airline to the study center
- Pneumothoraces had been present for about 2.2 ± 0.3 years (range, 1-4.5 years) prior to study enrollment
  - 2/8 patients had previously undergone a pleurodesis
- The pneumothoraces did not increase significantly during observation period of 4.4 ± 0.4 years (80-107 mL)
- No adverse consequences related to air travel occurred

Taveira-DaSilva AM, et al. Chest . 2009 ;136 (3): 665 – 670
Currie GP et al. Thorax. 2007;62*187-189.


DE-ICE
ON
OFF
NORM
START/IGN
NORM
START
AUTO
START
OFF
FUEL
X FEED
LEFT
RIGHT
F/D
ON
OFF
A/T ARM
L
R
OFF
CRS
357
HDG
025
BC
IAS\MACH
137
ALT
02300
VS
00000
AP
NAV
HDG
APR
SPD
MCH
ALT
LVL
V/D
AVNCS
OFF
TAT +08C
1.16
1.16
EPR
AUTOBRAKE 1
ON
49.34
49.34
N1
FLAPS
30
422.2
422.2
EGT
TOTAL FUEL 076.2
LBS X 1000
PITCH TRIM
L AILERON R
L RUDDER R
IRID
LIGHTS
BCN
NAV
ON
ON
LAND
STRB
TAXI
ON
ON
OFF
OFF
OFF
AUTOBRAKE
OFF
RTO
MAX
UP
LANDING GEAR
ON
NAV
GPS
ND
EICAS
EICAS 2



Thank You !

Supplemental Material

- Venous Thromboembolic Disease
- Respiratory Infections

DEEP VENOUS THROMBOSIS

- Intravascular stasis
  - Sitting immobile
  - Legs crossed
- Endothelial damage
  - Compression of lower extremity veins by edge of the seat
- Increased coaguability
  - Fluid shifts with edema of feet and ankles
  - Hemoconcentration

DEEP VENOUS THROMBOSIS

- Exact incidence of DVT related to air travel is unknown
- Multiple anecdotal reports:
  - Honolulu hospital: 44 patients admitted with DVT shortly after arriving by air over a 6 year period
  - Auckland area hospitals: 8-10% of all cases of DVT over 2 year period related to long haul flights

DEEP VENOUS THROMBOSIS

- **Ferrari et al. Chest 1999; 115:440**
  - Long distance travel by air or surface transport associated with increased risk of DVT (OR=4.0)
- **Samma et al. Arch Int Med 2000; 169:3415**
  - Long distance air travel associated with an increased risk of DVT (OR=2.3)

DEEP VENOUS THROMBOSIS

- **Lapostolle et al. NEJM 2001; 345: 779**
  - Long distance air travel associated with increased risk of pulmonary embolism:
    - > 6,200 miles – 4.8 cases / million
    - > 4,500 miles – 2.7 cases / million
    - > 3,100 miles – 1.5 cases / million
    - < 3,100 miles – 0.01 cases / million

DEEP VENOUS THROMBOSIS

- **Bulletin of WHO 2002; 80: 403**
  - A link probably exists between air travel and DVT
  - The exact risk of DVT related to air travel is not quantifiable because of a lack of data, but is likely to be small
  - The risk of DVT is probably greater in passengers who have an underlying risk factor

DEEP VENOUS THROMBOSIS
PREVENTIVE MEASURES (ASMA)

- **Do not place baggage under seat**
- **Exercise legs at regular intervals**
  - Stretching / flexing
  - Walk around cabin once an hour
- **Do not use hypnotic drugs**
  - Unrecognized leg compression
  - Muscle relaxation – promotes venostasis
- **Drink fluids before and during flight**
- **Avoid alcohol – a vasodilator**

Which patients should receive DVT prophylaxis with LMWH prior to commercial air travel:

1. Patients with homozygous sickle cell disease
2. Patients with active malignancy
3. Patients with a history of multiple deep venous thromboses
4. Patients with COPD

DEEP VENOUS THROMBOSIS
PREVENTIVE MEASURES

- **High Risk Patients: Sub-Q LMWH 2 to 4 hours before departure**
  - History of previous DVT
  - History of previous DVT
  - Known malignancy
  - Leg immobility
- **Very High Risk Patients: Warfarin or abandon trip**
  - History of multiple DVTs
  - History of multiple episodes of pulmonary embolism

DEEP VENOUS THROMBOSIS
PREVENTIVE MEASURES

All patients at high and very high risk of DVT during air travel should wear graduated compression stockings in addition to chemopophylaxis with LMWH or warfarin.

RESPIRATORY INFECTIONS

- Known infections transmitted during air-travel are:
  - Measles
  - Smallpox
  - Tuberculosis
  - Influenza
  - SARS

RESPIRATORY INFECTIONS

- Risk factors for the transmission of infections during air-travel include:
  - Age and type of aircraft
    - Extent of air recirculation / rate of exchange
    - Presence of HEPA filters (99% of particles > 0.3 μ)
  - Duration of flight
  - Proximity to index case
  - Infectiousness of index case

PNEUMONIA AND URI

Patients with pneumonia or upper respiratory infection should not fly until the infection is clinically resolved and there is evidence of satisfactory exercise tolerance*

* Walk 50 yards without significant dyspnea, normal six minute walk test, or climb one flight of stairs without significant dyspnea

WHO TB RECOMMENDATIONS

- Patients with tuberculosis should not travel until they are non-infectious.
- Physicians should notify their health authority of any patient with confirmed or suspected TB who has traveled by air in the past three months.
- Health authorities should promptly notify the airline of any patient with confirmed or suspected TB who has traveled on a flight of 8 hours or longer in the past three months.