Air travel : Implications for patients with pulmonary disease

DM Seminar presented by:

Dr. Vamsi Krishna

SR, Pulmonary medicine, PGIMER

Problems associated with Air Travel

Over 1 billion people air travel each year world over. Passengers traveling by air are exposed to following risks:

- Exposure to high altitude
- Risk of DVT
- Spread of Infectious diseases

Air travel : Pressurized cabins ?

- Commercial aircraft are not pressurized to sea level, but to a relatively modest intermediate cabin altitude.

  (fuel efficient for jet engines and avoids much turbulence)

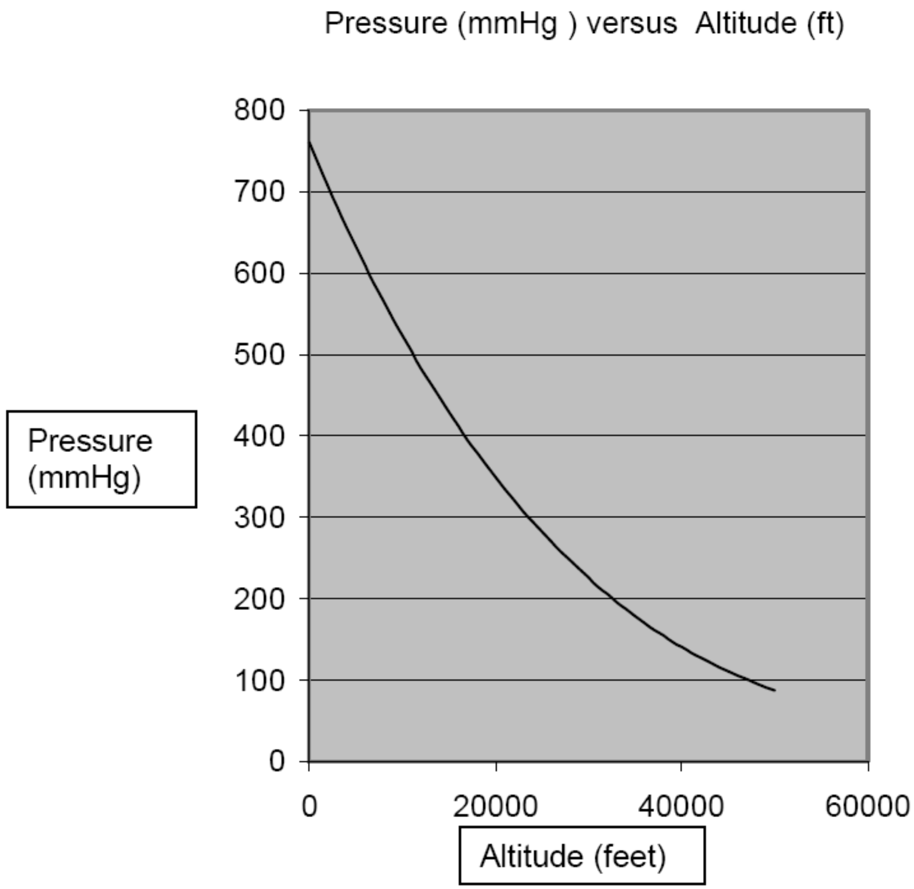
- Aircraft cabin altitude can thus approach 2438 m (8000 ft) while the aircraft is flying at 11582 m (38000 ft).

Cottrel JJ. Chest 1988;92:81-4

Effects of altitude on Oxygenation

- At altitude of 8000 ft, partial pressure of oxygen falls to a level, equivalent to breathing oxygen at FiO_2 of 15.1%

- In a healthy individual
  PaO_2 falls to 53-64 mm Hg
  SpO_2 falls to 85-91%



Magnitude of problem

- 5% of commercial airline passengers were ambulatory patients with some illness including chronic obstructive pulmonary disease (COPD)

Iglesias R. Aerosp Med 1974; 45: 204-206

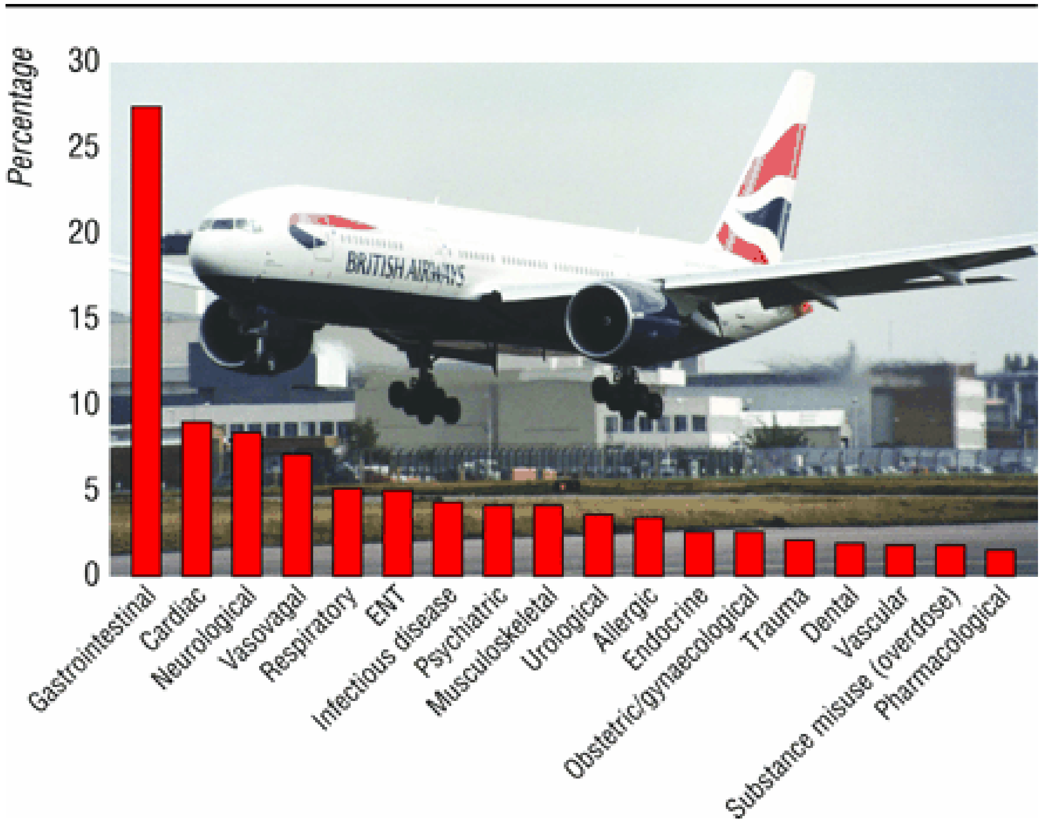
- 10.2% of in-flight medical emergencies calls were respiratory in nature.

Cottrel J.JAMA 1989; 262(12):1653-6

- 17% of respiratory in flight emergencies resulted in diversion of air craft and was 3rd most common cause.

Sirven JI. Neurology,2002;58:1739-44

Magnitude of problem



Dowdall N. BMJ 2000;321:1336-1337

Table 1—*Selected Surveys of In-Flight Medical Emergencies*

	Reference				
	61 (Speizer et al)	60 (Cummins and Schubach)	59 (Skjenna et al)	50 (Cottrell et al)	49 (Hordinsky and George)
Locus	Los Angeles	Seattle-Tacoma	Air Canada	United Air Lines	FAA
Period	10/1/85-3/31/86	9/1/86-8/31/87	1/1/88-12/31/88	7/1/86-6/31/87	8/1/86-7/31/87
No. of passengers ($\times 10^3$)	8,735	14,400	13,553	55,000	ns*
In-flight incidents, No. (%)	260 (0.003)	190 (0.001)	464 (0.003)	218 (0.0004)†	1,016†
Categories of incidents, No. (%)					
Cardiovascular	34 (13)	21 (20)	235 (50.6)	34 (15.6)	177 (17.4)
Respiratory	20 (7.5)	15 (7.9)	48 (10.3)	22 (10.1)	94 (9.3)
Neurologic	49 (18.8)	23 (12.1)	33 (7.1)	72 (33)	256 (25.2)
Gastrointestinal	69 (26.5)	28 (14.7)	59 (12.7)	ns*	109 (10.7)
Trauma	13 (5)	26 (13.7)	31 (6.7)	ns*	12 (1.2)
Other	76 (29.2)	60 (31.6)	58 (12.5)	90 (41.3)	368 (36.2)
Incidents/100,000 passengers	2.9	1.3	3.4	0.4	. . .
In-flight deaths, No.	7	0	2	3	9
Medical kit uses, No.	–	–	167	362	1,016

Gong H. Chest 1992;101;1104-1113

Clinical strategy

Aim :To maintain PaO_2 of >50 mm Hg during travel

↓

Target : High risk patients

↓

Preflight assessment of in-flight PaO_2

↓

Oxygen supplementation to needy

Preflight evaluation

Who should be evaluated ?

- Severe COPD or asthma
- Severe restrictive disease, especially with hypoxemia
- Cystic fibrosis
- Recent Pneumothorax

- Pre-existing requirement for oxygen or ventilator support

- History of air travel intolerance with respiratory symptoms (dyspnea, chest pain, confusion or syncope)

- Risk of or previous venous thromboembolism

- Conditions worsened by hypoxemia (cerebro vascular disease, coronary artery disease, heart failure)

- Cases of Tuberculosis

BTS 2004 recommendations

Preflight evaluation

History & examination

Spirometry

SpO2

ABG

Regression estimates of PaO2

Hypoxia Inhalation Test

6 minute walk test

Predicting PaO_2

- PaO2 of 68 or 72 at ground level predicts in cabin PaO2 of 50 and 55 respectively (making correction for FiO_2, assuming constant A-a gradient

- PaO2 at sea level alone as a predictor may misclassify many patients as A-a gradient and PaO2/ FiO2 ratios do not remain same at altitudes.

Chi-Lem G. Arch. Med Res 1998;29:57-62

Regression estimates of PaO_2

- 20.38- (3xaltitude) + 0.67x PaO_2 Ground (mmHg)

Henry J. Surg Gynecol Obstet 1973;136:49-53

- 22.8 – (2.74 x Altitude) + 0.68 x PaO_2 Ground (mmHg)
  Not dependant on spirometric values
  moderate COPD (FEV1 40%)

Gong H. Am Rev Respir Dis 1984; 130:980-986

- Eq 1: 0.410 x PaO_2 Ground (mmHg) + 17.652
- Eq 2: 0.519 x PaO_2 Ground (mmHg) + 11.855 x FEV1 (liters) – 1.760
- Eq 3: 0.453 x PaO_2 Ground (mmHg) + 0.386 x (FEV1% pred) +2.44
  Moderate COPD (FEV1 33%)
  Addition of spirometric values improve prediction

Dillard TA. Ann Int Med1989;111:362-367

Regression estimates of PaO_2

0.417(PaO2)+17.802	Rp – 0.756
0.294(PaO2)+0.086(FEV1%)+23.211	Rp – 0.804
0.245 (PaO2)+0.171(FEV1/FVC%)+21.028	Rp – 0.828
0.228 (PaO2)+20.098(FEV1/FVC)+22.258	Rp – 0.827

Addition of spirometric values improve prediction
Addition of more than one variable do not improve predictability much

Dillard TA. Chest 1995;107:352-7

Regression estimates of PaO_2

- No guidelines and recommendations on when and what formula to be used
- Some authors prefer use of regression estimate as first step and advice Hypoxia inhalation test, if PaO2 is (50 +/- 3) mm Hg

Hypoxia Inhalation Test

Breathing 15% O_2 by face mask/mouth piece
Breathing in a body box with 15% O_2
Breathing Nitrogen with venturi mask (35-40%)

↓

Monitor SpO_2 &
After 15-20 minutes measure PaO_2

Creates FiO_2 of 15%
Estimate in flight PaO_2
But flight duration and cabin conditions are not reproduced.

Hypoxia Inhalation Test (HIT)

- PaO2 levels measured by HIT correlated with PaO2 levels measured with hypobaric exposure of 8000 ft.

  Dillard TA. Chest 1995;107;352-357

- Results HIT correlated well with hypobaric exposure, but full equilibration took 20 minutes

  Naughton MT. Am J Respir Crit Care 1995;152:1956-60

Regression estimate Vs Hypoxia inhalation test Vs Hypobaric simulation

- Regression estimates – easy to calculate
  - require PaO_2, FEV_1 only
  - do not require special gases and equipment

- 15.1% HIT within 2 hrs of 8000 ft hypobaric exposure had higher accuracy than regression estimates

Naughton MT. Am J Respir Crit Care 1995;152:1956-60

- HIT performs as good as hypobaric simulation

Dillard TA. Chest 1995;107:352-7

50 meter walk test

- Inability to complete walk test or moderate to severe dyspnea (assessed by VAS) could implicate necessity for oxygen onboard.

BTS Recommendations 2002

- Equating MRC 3 or 4 at FiO_2 21% to MRC 5 at FiO_2 15%
- No studies to validate this test.
- Questionable utility.

Pulse Oximetry

- Preflight assessment:

  BTS recommendations incorporate SpO_2 into preflight assessment

  But confounded by smoking and transient hyperventilation

- Use in HIT:

  During acute hypoxia, pulse oximetry over-estimates PaO_2

  Currently use of pulse oximetry in HIT not recommended as it is not studied and validated

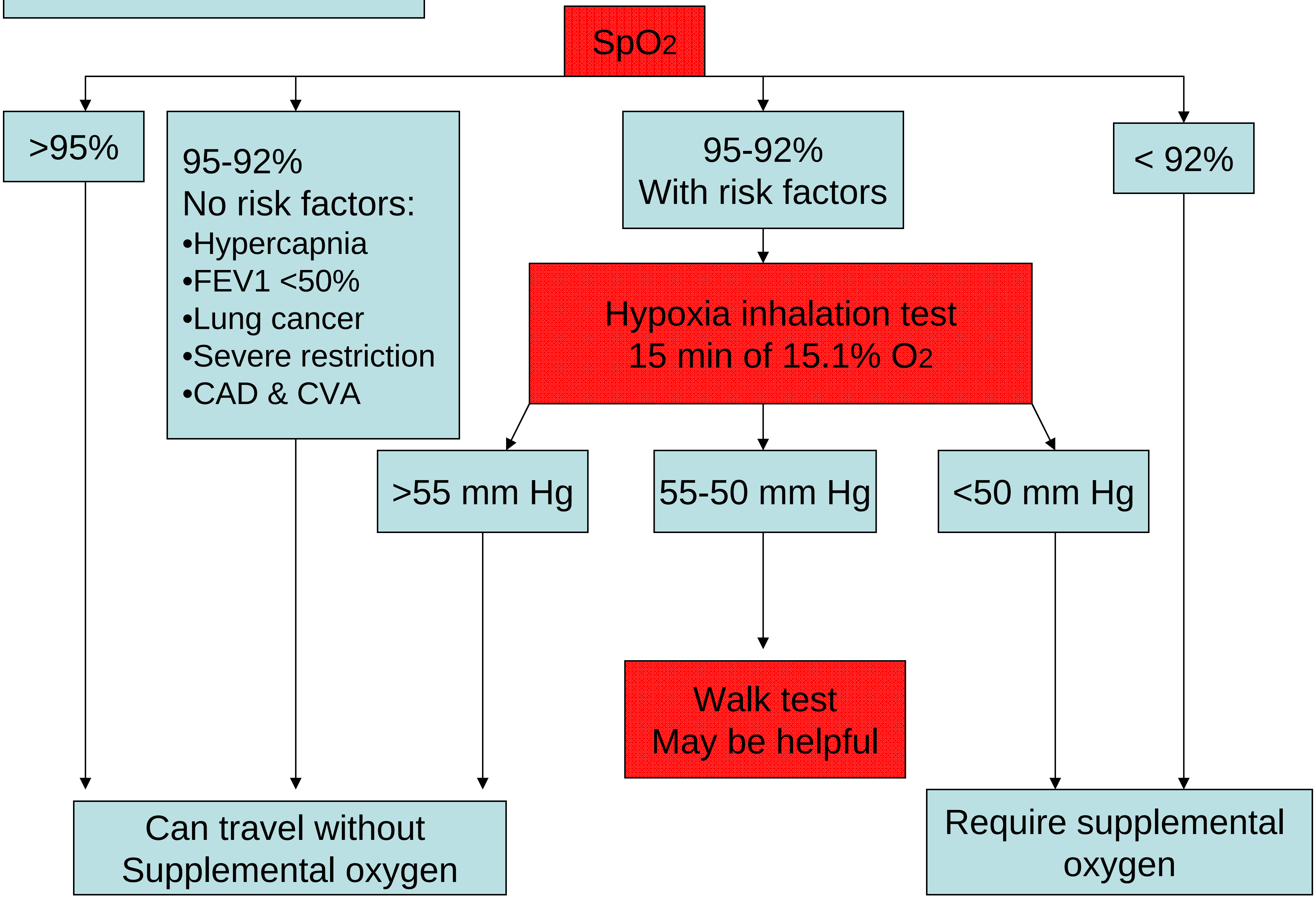
- In-flight monitoring:

  Studies suggest SpO_2 of >90% would maintain PaO_2 of >50 mm Hg

  Bendrick GA. Aviat Space Environ Med 1995;66:40-44

  But its routine use for self monitoring by patients not recommended

BTS Protocol

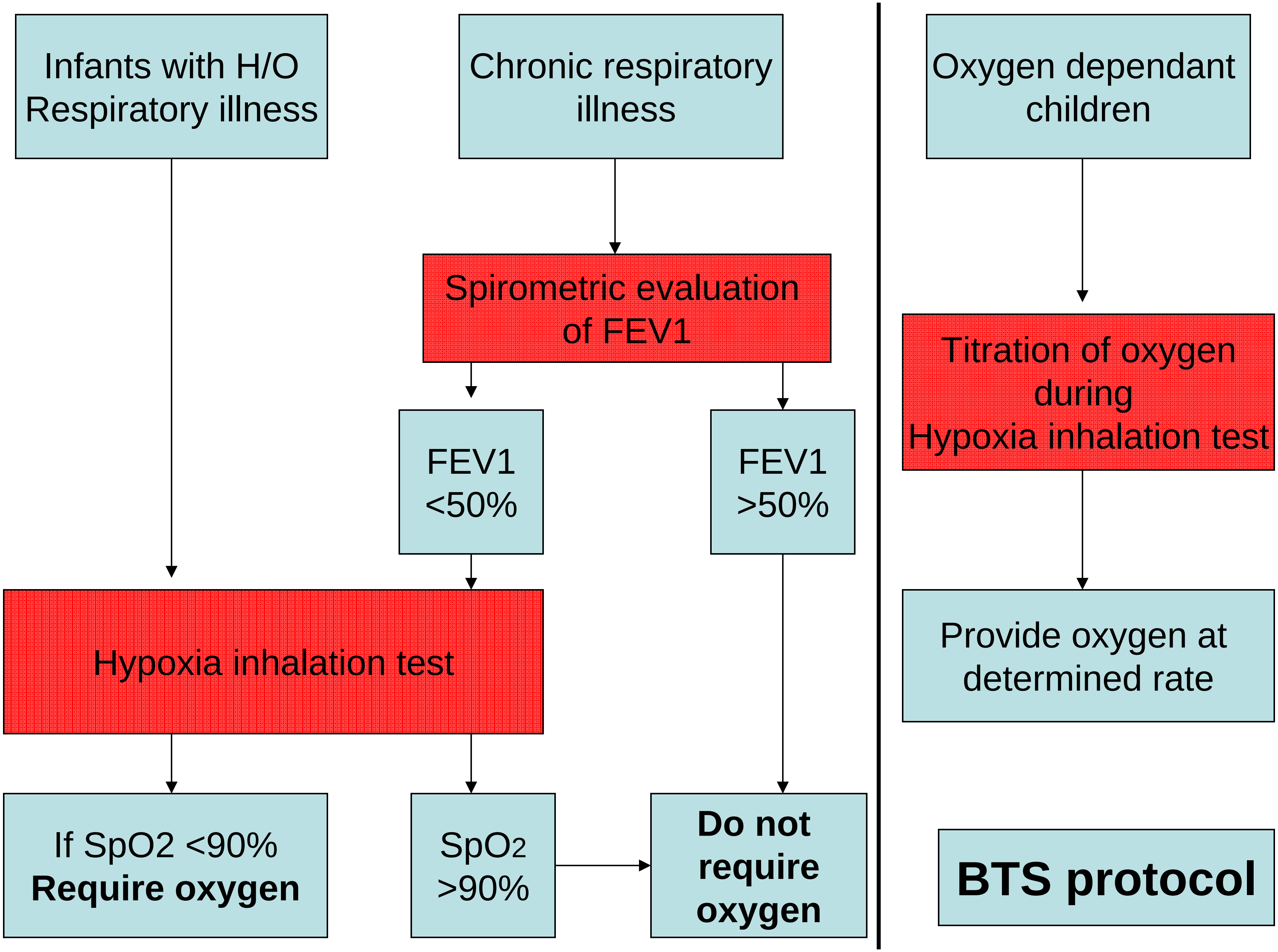


Pre flight evaluation in pediatric population

- Difficult to predict how an infant behaves in hypoxic environment.
  (presence of right to left shunt and fetal hemoglobin)

- Infants with respiratory disease in neonatal period and children with chronic respiratory diseases like cystic fibrosis should undergo pre flight evaluation.

- Young children and infants should undergo hypoxia inhalation test in body box



Infants with H/O Respiratory illness
Chronic respiratory illness
Oxygen dependant children
Spirometric evaluation of FEV1
FEV1 <50%
FEV1 >50%
Titration of oxygen during Hypoxia inhalation test
Hypoxia inhalation test
Provide oxygen at determined rate
If SpO2 <90% Require oxygen
SpO2 >90%
Do not require oxygen
BTS protocol

Preflight evaluation

- 24% of physicians measuring blood gas levels recommend in-flight oxygen when PaO_2 <7.3 kPa and 50% when PaO_2 is 7.3-8.0 kPa.
- 65% of physicians using spirometry recommend oxygen when the FEV1 is <40%
- 50% recommend oxygen when SaO_2 <90% , 33% when SaO_2 is 90-94%.
- 10% physicians use predictive equations.
- More than half of specialists but fewer than 10% general physicians perform hypoxic challenge tests

Coker RK. Eur Respir J 2000; 15: 128-130

Travel advice

Supplemental oxygen

- Supplementary oxygen is usually given at a rate of 2 -4 L/min.
- Given by nasal cannulae.
- In-flight oxygen need not be switched on until the plane is at cruising altitude, and may be switched off at the start of descent.
- For patients on oxygen at sea level, the rate should only be increased while at cruising altitude.

Supplemental oxygen

- Evaluation for oxygen requirement during HIT.

  2 l/min oxygen supplementation would suffice to maintain SpO_2 >90% in patients with severe obstruction and moderate restriction.

  Cramer D. Thorax 1996;51:202-203

- Empirical formulae:

  (FiO_2 x SBP) at ground = (FiO_2 x SBP) at altitude

Characters of 233 patients receiving In flight Oxygen

Gong jr. Chest 1992;101;1104-1113

Diagnostic categories	
COPD	104 (44.6)
Asthma	15 (6.4)
Interstitial lung disease	14 (6.0)
Cystic fibrosis	3 (1.3)
Neuromuscular disorder	7 (3.0)
Pneumonia (recent)	11 (4.7)
Pulmonary embolism	3 (1.3)
Pulmonary hypertension	6 (2.6)
Lung cancer	18 (7.7)
Other malignancy	9 (3.8)
Cardiac disorder	72 (30.9)
Seizure disorder	6 (2.6)
Preflight oxygen therapy	157 (67.4); 92 continuously 65 intermittently

General measures

- Carry well-filled reliever and preventer inhalers in their hand luggage
- Portable battery-operated nebulisers may be used at the discretion of the cabin crew.
- Spacers are as effective as nebulisers
- A full supply of all medication should be taken as hand luggage, preferably in the original packaging with pharmacy labels.

COPD

- 38% of patients with severe COPD had at least one airline trip within 2 year period.
- Only 27% of them consulted physician before trip
- 18.2% of them developed symptoms or signs during travel

Dillard TA. Arch Int Med 1991;151:1793-1795

- Mean fall of SpO2 in patients with severe COPD was 11% (94 to 83%)

Gong H. Am Rev Resp Dis 1984; 130:980-986

- Light exercise such as walking to bathroom with out supplemental oxygen could produce severe hypoxia and near syncope in patients with severe COPD.

Kramer.RA. Chest; 1995 108: 1292-96

- Risk of pneumothorax in relation to size of bulla not studied

Indications for Hypoxia inhalation test in patients with COPD

Comorbid disease that may be affected by hypoxaemia

Coronary artery disease
Congestive heart failure
Arrhythmias and other cardiac diseases
Cerebrovascular disease
Anemia
Seizure disorders and other neurologic diseases
Pulmonary vascular disease including pulmonary embolism

Symptoms manifested during prior air travel

Recovery phase after acute exacerbation

Tendency to hypoventilation with oxygen administration

Prediction of altitude $PaO_2 = 50 + 3$ mm Hg by regression equation

Reassurance before embarking on air travel

Management of stable COPD ATS 2004 guidelines

Bronchial Asthma

- Around one third of in-flight respiratory emergencies are ascribed to asthma.

  Cottrel JJ. JAMA 1989; 262: 1653-6

- Patients with severe asthma needs pre flight evaluation of supplemental oxygen.

- Patients are advised to carry inhalers and other regular medications in hand baggage.

- Spacers are as efficient as nebulisers in emergency

ILD

- Patients with moderate restriction (FEV1 50%), PaO_2 decreased from 10.4±1.6 kPa at sea level to 6.5±1.1 kPa at 8000 ft simulated altitude, and decreased further during light exercise (5.1±0.9 kPa).
- PaO_2 at this altitude correlated positively with sea-level PaO_2 and transfer factor of the lung for carbon monoxide and negatively with $PaCO_2$.
- PaO_2 increased to acceptable levels with an O2 supply of 2 L/min at rest and 4 L/min during 20 W exercise.

Christensen CC. Eur Respir J 2002;20:300-305

- Patients with severe restriction especially those with hypoxia should undergo pre flight evaluation.

BTS recommendations 2004

Cystic Fibrosis

- Patients with FEV1 <50% should undergo hypoxia inhalation test
- Patients with desaturation (SpO_2< 90%), should receive supplemental oxygen.
- Low cabin humidity could increase risk of bronchospasm and retention secretions with associated risk of atlectasis

OSA

- Patients should alcoholic beverages before and during the flight.

- Should carry dry cell powered CPAP machine

- Patients with significant de-saturation should use CPAP while sleeping onboard.

Patients on LTOT

- Should increase flow of oxygen
- No studies to show how much to be increased
- Titration at Hypoxia Inhalation Test is suggested
- Arrangements for oxygen in airport and transport to be arranged before hand

Ventilator dependant patients

- Should have an escort competent enough to change the tube, perform suctioning and do manual breathing.
- Carry an additional tracheostomy tube and battery driven suction machine
- Monitor cuff pressure (a little air needs to be removed during ascent and a little air be introduced on descent)

Pneumothorax

- Relative expansion of humidified gas =

$$\frac{\text{(initial pressure of the gas in the cavity at sea level – 47)}}{\text{(final pressure of gas in cavity – 47)}}$$

- Gas expansion with altitude is significantly greater than predicted by Boyle's law as applied to dry gas alone.

- The volume of gas in a non-communicating bulla/cavity will thus increase by 37.6% on ascent from sea level to 2438m (8000ft).

Pneumothorax

Current closed Pneumothorax	**Do not travel**
Spontaneous Pneumothorax treated By non-surgical means	•Safe after 1 week •Avoid air travel for 1 yr if secondary spontaneous
Spontaneous Pneumothorax treated By surgical means	Can travel safely
Traumatic Pneumothorax	Safe after 2 weeks After resolution

BTS recommendations 2004

Deep Vein Thrombosis

DVT

- Economy class syndrome, traveler's thrombosis, flight related DVT
- Hypotheses for increased risk include restricted mobility, seated position, dehydration and alcohol ingestion
- Compression of popletial veins against seat edge
- Decreased cabin pressure and hypoxia can decrease fibrinolytic pathway

Gertler JP.J Vasc Surg 1993;18:939-946

- Hypobaric environment leads to increased activated coagulation pathway

Bendz B.Lancet 2000;356:1657-58

DVT and PTE

- 75 % of post travel DVT were idiopathic against 38% in control group, suggesting air travel as an independent risk factor

  Emile F. Chest 1999;115:440–444

- Asymptomatic DVT occurs in nearly 10% of passengers

  Scurr JH. Lancet 2001; 357:1485-1489

- 11/61 deaths (in 3 yr duration) after arriving at Heathrow airport were due to PTE

  Sarvesvaran R. Med Sci Law 1986;26:35-38

- No increase in risk of DVT due to air travel (odds ratio of 1)

  Rodemil A. The Lancet 2000;352:1492-92

DVT

- Frequency of DVT was 1·0% (9/878, 95% CI 0·5–1·9), which included four cases of pulmonary embolism and five of deep venous thrombosis
- Low to moderate risk population

NZATT study. Hughes RA The Lancet 2003; 362:2039-2044

- LONFLIT 1 study showed zero incidence of DVT in low risk population against 2.8% in high risk population (H/O DVT, malignancy, coagulation disorder or large varicose veins) after 12 hr air travel

Belcaro G. Angiology 2001;52:369-74

- Incidence of DVT increases with distance traveled

<5000 km - 0.01 case/million
>5000 km - 1.5 case/million
>10,000 km - 4.8 case/million

Lapostolle F. N Engl J Med 2001;345:779-83

Prevention of DVT : Stockings

- Elastic stockings prevented DVT in healthy people traveling by air (no one wearing stockings developed DVT, 10% of control group developed Doppler proven DVT)

  Scurr JH. Lancet 2001; 357:1485-1489

- LONFLIT 2 : in high risk population (H/O DVT, malignancy, coagulation disorder or large varicose veins) showed, below knee stockings reduce incidence rate of DVT to 0.24% compared to 4.5% in controls (flight duration 12.4 hrs)

  Belcaro G. Angiology 2001;52:369-74

- LONFLIT 4 study showed reduced incidence of DVT in low and moderate risk population (0/184 Vs 6/188) in long duration flight (11-12 hrs) but no added advantage in short duration flights (7-8 hrs)

  Belcaro G. Angiology 2003; 54: 143-54

Graduated compression stockings

LONFLIT 4 :

- 20- 30 mm Hg at ankles

LONFLIT 5 *:

- Long haul flight in high risk patients
- Speicific “Scholl flight socks”
- DVT incidence was 6 times greater in control group compared to stockings users
- Pressure at ankle was 14-17 mm Hg

** Belcaro G. Clin Appl Thromb Hemost. 2003 Jul;9(3):197-201*

Aspirin and LMW Heparin

5/9 patients with DVT/PTE were receiving aspirin
NZATT study. Hughes RA The Lancet 2003; 362:2039-2044

LONFLIT 3 study:

- 300 High risk patients defined as prior DVT, a coagulation disorder, obesity or severely limited mobility, malignancy within the preceding 2 years, or large varicose veins

- **No Tt** Vs **Aspirin** Vs **LMW** heparin
- 4 cases Vs 3 cases Vs none

- Supports use of LMW heparin in high risk cases (p 0.02 when compared to controls)

Belcaro G. Angiology 2002; 53:1-6

Other modalities

LONFLIT – FLITE study:

- High risk group
- Flight duration 7-8 hrs
- Used profibrinolytic agent pinokinase (pine bark extract and Nattokinase, fermented soya extract)
- 0% in Tt group Vs 5.4% in placebo group

Belcaro G. Angiology 2003;54(5):531-9

BTS recommendations : Risk stratification

Slightly increased risk:
- >40 yrs
- Obesity
- Varicose veins
- Polycythemia
- <72 hours from minor surgery

High risk for DVT:
- Previous VTE
- Thrombophilia
- Within six weeks of major surgery
- History of previous stroke
- Malignancy

Moderately increased risk:
- Family history of VTE
- Pregnancy
- Post natal state
- Estrogen therapy
- Recent MI
- Limb paralysis
- Limb surgery or trauma

Prophylactic measures: BTS recommendations

All Passen.	Slightly increased risk	Moderate risk	High risk

- Avoid alcohol
- Patients not receiving supplemental oxygen should remain mobile
- Do leg exercises

- Avoid sleeping pills & Avoid sleeping for long periods
- Consider graduated compression stockings

- Graduated compression stockings
- Consider Preflight Aspirin

- LMW Heparin
- Anticoagulation to INR of 2-3

Spread of Infectious diseases

Tuberculosis

- Evidence of transmission was limited to crew members exposed to the index case for over 11 hours.

- Transmission was demonstrated only in a few passengers seated in close proximity to the index case, and only on a flight lasting more than eight hours.

Thomas AK.
N Engl J Med 1996;334:933-938

Tuberculosis

- Transmission of M. tuberculosis may occur during long (i.e. more than eight hours) flights, from an infectious source (a passenger or crewmember) to other passengers or crew members.
- Air travel does not carry a greater risk of infection with M. tuberculosis than traveling by rail, bus or attending conferences
- To date, no case of active TB has been identified as a result of exposure while on a commercial aircraft.

WHO: Tuberculosis and air travel: Guidelines 1998

Prevention of spread of Tuberculosis

- Non infectious cases only could fly in commercial air crafts:

  HIV negative patients who have completed two weeks of effective anti tuberculous treatment.

  HIV positive patients three smear negative sputum examinations on separate days or a single negative sputum culture result are required.

- In case of ground delays >30 mins, adequate ventilation should be provided

- There is no evidence that air recirculation facilitates transmission of tuberculosis

WHO: Tuberculosis and air travel: Guidelines 1998

Other diseases

- Epidemiological studies suggest measles and influenza could spread during air travel
- No evidence that aircraft cabin air recirculation increases the risk for URI symptoms in passengers traveling aboard commercial jets.

Jessica NZ. JAMA. 2002;288:483-486

Regression estimates of PaO_2

Equation	Observed PaO2	SE	SD
Gong et al	50.14	1.47	6.1
Henry et al	44.92	1.42	6
Dillard Eq 1	47.39	0.87	3.68
Dillard Eq 2	47.39	1.25	5.3
Dillard Eq 3	47.39	1.25	5.31
Predicted from HIT	47.39	1.48	6.27

Advanced lung disease

- 21 Patients with severe diseases being transported for lung transplantation and thrombectomy
- Oxygen supplementation, pulse oximeter monitoring and medical escort
- 20 patients reached destination safely (distance ranging from 2500 to 13,181 kms)
- Careful preparation, sufficient oxygen supply, oximetric monitoring, and medical escort, almost any patient with severe lung disease can travel by air to any necessary destination

Kramer MR. Chest, Vol 108, 1292-1296,