PHYSIOLOGY OF ONE LUNG VENTILATION

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VMCH&RI

INTRODUCTION

- OLV is used in thoracic anaesthesia to describe the ability to ventilate one lung and intentional collapse of lung on the operative side.
- It complicates anaesthetic mgt.
- Haemodynamic stability and oxygenation to be maintained.
- To protect the dependent lung from contamination- patient in LDP
- Less retraction so less lung trauma
- Shorten the duration of surgery
- Perfusion continuously, so shunt

OBJECTIVES

1) Indications for OLV
2) Physiological Changes in LDP & OLV
3) Mgt of complications of OLV
4) Various techniques

Indications for OLV

- Lung protection
- Improving surgical access
- Intensive care ventilation – Differential lung ventilation in ill patients with two ventilators

I) Absolute

- Isolation of both lungs

a) Infection like lung abscess

b) Pulmonary Hge

- Differential ventilation

I) Broncho pleural fistula

II) Broncho pleuro cutaneous fistula

III) Tracheo bronchial disruption

IV) Giant unilateral lung cyst.

- Unilateral broncho pulmonary lavage

I) Pulmonary alveolar proteinosis

II) Rarely to asthma & cystic fibrosis

Relative

1. High priority
    a) Thoracic aortic aneurysm
    b) Pneumonectomy
    c) Upper lobectomy
    d) Thoracoplasty
2. Low Priority
    a) Oesophageal resection
    b) Mid or lower lobectomy
    c) Removal of totally occluded chronic pulmonary emboli.

Physiology of OLV

- Thoracic surgery presents unique set of physiological problems for anaesthesiologist
- Need for special considerations :

1. Physiological derangements by LDP
2. Opening the chest
3. OLV

Lateral Decubitus Position (LDP)

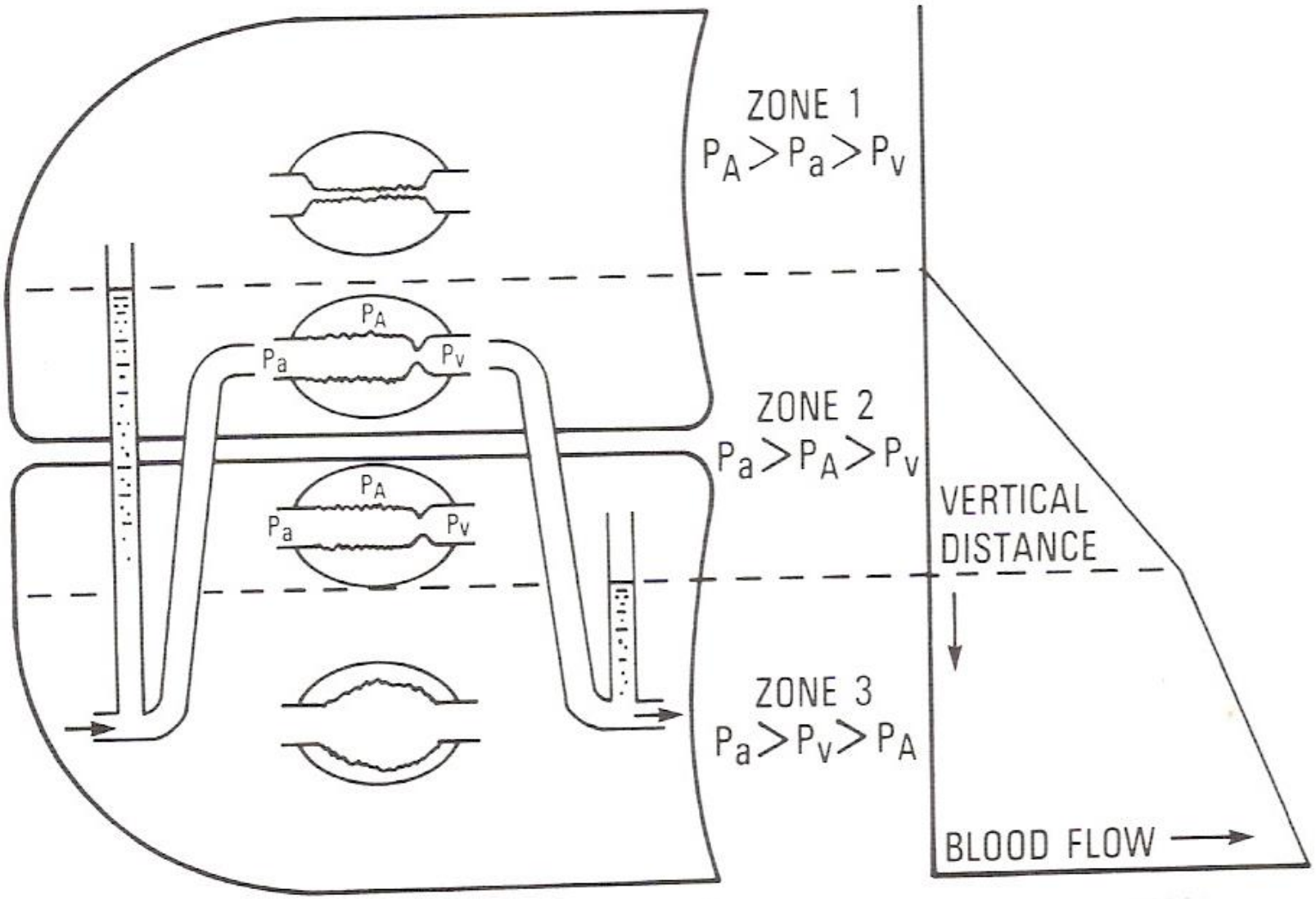
- Optimal access for most operations on lung, oesophagus & great vessels
- Alters V/Q relationship
- Further aggrevated by GA,MV,NMB & opening the chest
- In vertical position V & P increase towards the base.
- P > V – slight mismatch

Apex more ventilated than perfusion(V/Q > 1) & alveoli at base better P than V (V/Q < 1)

Zone I PA > Pa > Pv

Zone II Pa > PA >Pv

Zone III Pa>Pv > PA

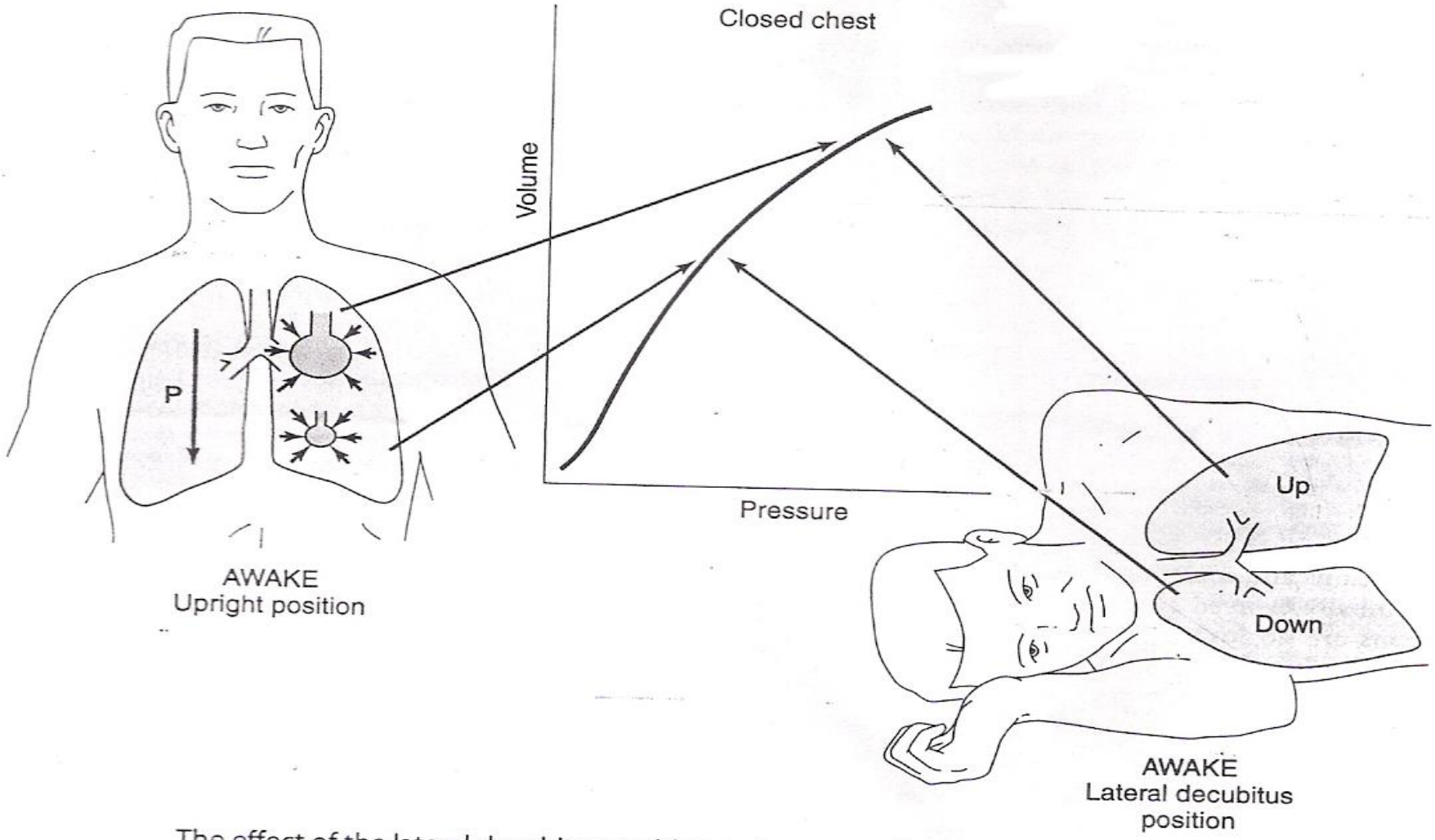

ZONE 1
$P_A > P_a > P_v$
P_A
P_a
P_v
ZONE 2
$P_a > P_A > P_v$
P_A
P_a
P_v
VERTICAL DISTANCE
ZONE 3
$P_a > P_v > P_A$
BLOOD FLOW

Awake Pt in LDP – closed chest

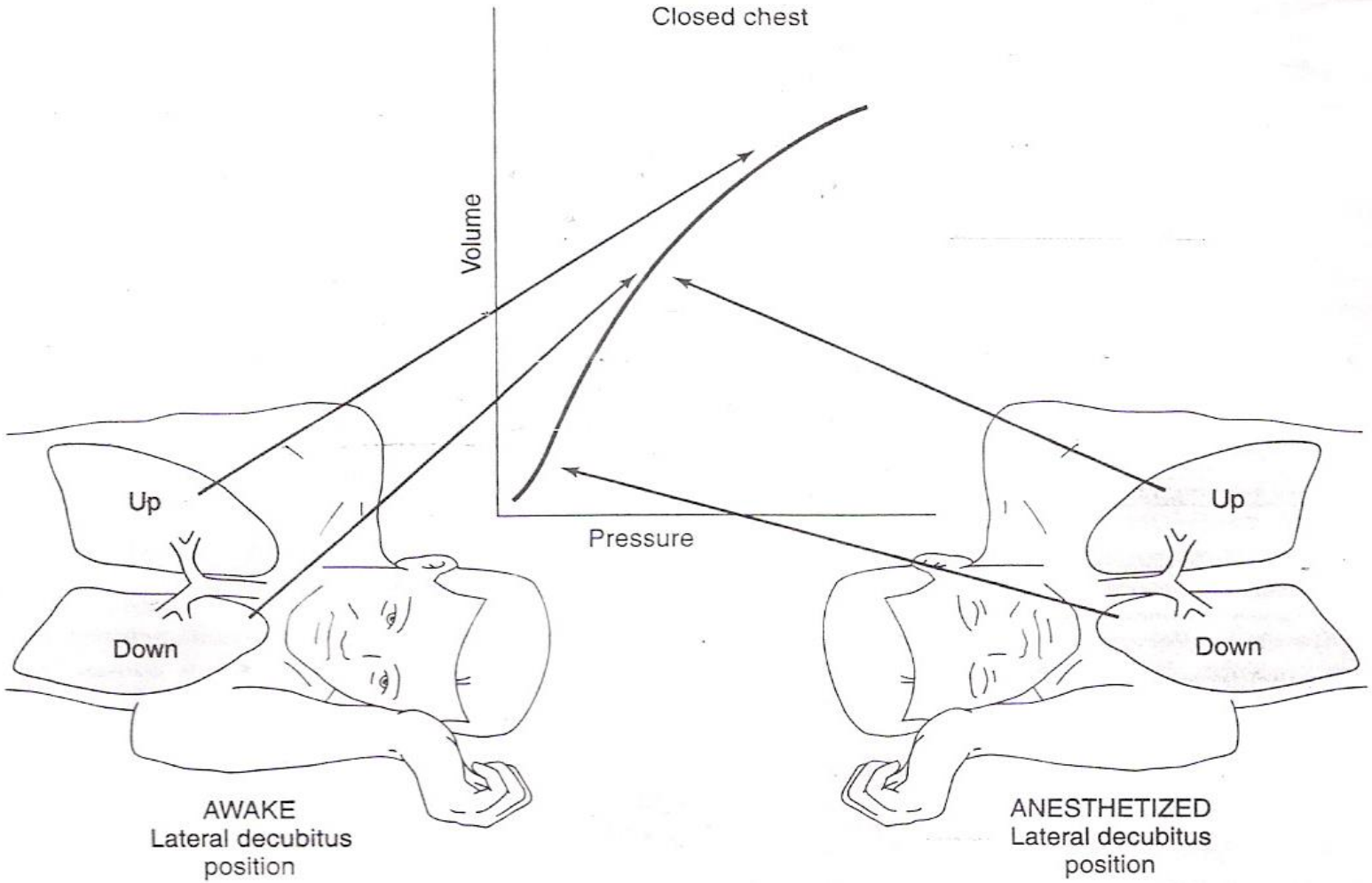
- When supine pt assumes LDP, V/P is preserved during spontaneous ventilation
- Lower lung more perfused & more ventilated than UL,more P because of gravity

Ventilation

1) Lower diaphragm pushed into chest high & contracts more – so more ventilation
2) V/Q is not altered
3) As perfusion increases V/Q ratio decreases from NDL to DL in upright & supine position



The effect of the lateral decubitus position on lung compliance.



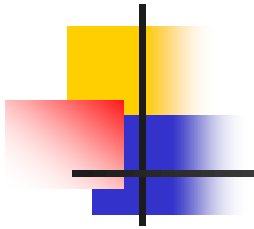
The effect of anesthesia on lung compliance in the lateral decubitus position. The upper lung assumes a more favorable position and the lower lung becomes less compliant.

Anaesthetised Pt in LDP – closed chest

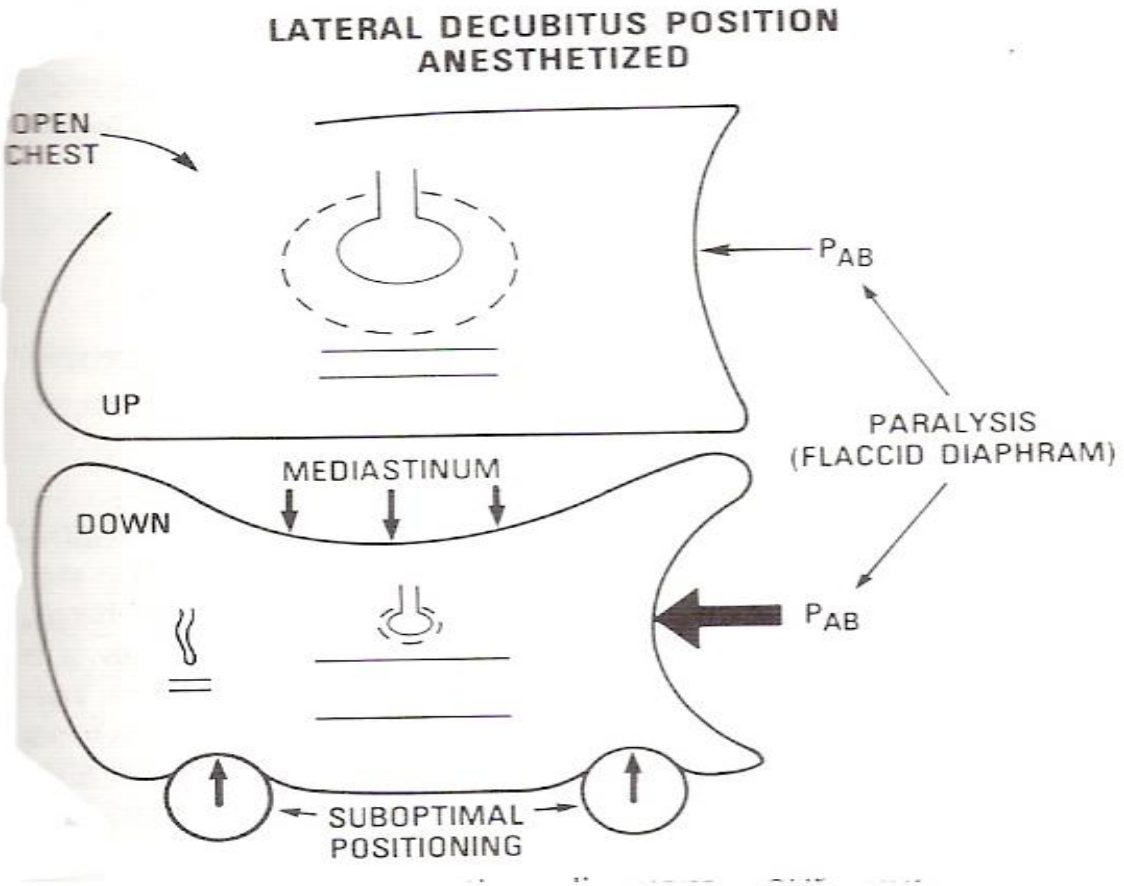
- No difference in blood flow in LDP

<u>Differences in ventilation</u>

1. Decrease in FRC with induction of GA moves the UL to favourable of compliance curve. LL to least compliance curve.
2. If the pt is paralysed, high curved diaphragm not exist
3. Mediastinum rest upon LL & impedes expansion & FRC
4. Sub optimal position compress LL



- Weight of the abdominal contents pushed cephalad impedes LL expansion.
- In short NDL is well ventilated but poorly perfused.
- DL well perfused but poorly ventilated. So V/Q mismatch.


LATERAL DECUBITUS POSITION
ANESTHETIZED
OPEN CHEST
UP
P_{AB}
PARALYSIS
(FLACCID DIAPHRAM)
MEDIASTINUM
DOWN
P_{AB}
SUBOPTIMAL
POSITIONING

Open Chest

- When chest is opened negative pleural pressure is lost & so as elastic recoil of lung - >collapse on that side in LDP
- Result in paradoxical respiration & mediastinal shift
- Progressive hypoxaemia & hypercapnia
- Overcome by IPPV during GA & thoracotomy

Anaesthetised, Open Chest paralysed pt in LDP

- No change in blood flow
- But paralysis causes change in V in LDP – weight of abdominal contents press greatest in DL. In awake pt active tension of diaphragm overcomes wt of ab.contents
- During IPPV passive diaphragm moves better in UL & so more V where there is least perfusion & vice versa

Problems

- V/Q mismatch -> Greater ventilation & less perfusion in NDL, but less V & greater P in DL
- Mucociliary clearance impeded and with high FIO2 & absorption atelectasis
- Leads to shunt flow & large (PA-Pa)O2

ONE LUNG ANAESTHESIA

1. If two lung ventilation produces partial shunt in in DL, OLV leads to large shunt(20-30%)
2. P(A-a)o2 increases –hypoxaemia
3. Elimination of CO2 is not affected provided MV is maintained

BLOOD FLOW TO NDL

- Blood flow to NDL is reduced due to HPV
- Factors inhibiting HPV and worsens Rt to Lt shunt:
- A.Very high or very low PA pressure
- B.Hypocapnia
- C.High or very low mixed venous Po2
- D.Vasodilators-NTG,SNP,Ca channel blocker
- E.Inhalation Anaesthetics

- Mechanical obstruction to blood flow:Gravity,surgical interference,pre existing disease of the lung.
- If NDL is severely diseased fixed reduction in blood even pre operatively,so collapse does not cause increase in shunt
- Ligation of pulmonary vessels during resection decrease blood flow
- Pts with normal lungs have higher shunt in OLV
- HPV-Increase in PVR,diverts blood from NDL to DL.Improvement in O2 due to HPV is beneficial if %of lung is30-70%.Reduced blood flow to 20-30%of CO as against 40-50% without HPV

BLOOD FLOW TO DL

- Factors that decrease blood flow to ventilated lung is also detrimental
- Counteract the effect of HPV by indirectly increase the blood flow to collapsed lung.Factors are
- A.High mean airway pressure in DL due to high PEEP,high peak inspiratory pressure and hyperventilation
- B.Low FIO2-HPV in ventilated lung
- C.Vasoconstrictors-more effect on normoxic vessels
- D.Intrinsic PEEP

VENTILATION IN OLA

- It is not only NDL contributes to decrease in V,the ventilation DL is not 100% effective
- Ventilation will be suboptimal for reasons already mentioned-V/Q mismatch.This requires DL ventilation to be optimally managed
- OLV causes hypoxia once the lung is collapsed.True Rt to Lt shunt because of continuous perfusion to NDL
- The Rt lung receives 55%Co.If it gets collapsed a shunt of 55%-but it is not so,because

a.NDL receives 10% reduction in blood flow due to gravity.

b.HPV-so obligatory shunt to DL during OLV is 20-30%

- V/Q mismatch in DL is due to
- 1.Effect of positioning
- 2.Accumulation of secretions
- 3.Absorption atelectasis due to high FIO2
- 4.Hypoventilation

Techniques of Lung Separation

I) Bronchial Blocking

a) Craford's tampon
b) Magils blocker
c) Thomson blocker
d) Forgarty embolectomy catheter
e) Folleys catheter
f) Pulmonary catheter

II) Combined endotracheal tube with bronchial blocker

1) Macintosh Leatherdale tube with blocker
2) Sturts-beacher tube with blocker
3) Univent endotracheal tube with sliding blocker

III) Single lumen endobronchial tubes

1) Machrays tube
2) Gordon-Green tube
3) Macintosh Leatherdale tube
4) Vellacott's tube
5) Green's tube

6) Brompton tube
7) Wilson tube

IV) Double lumen endobronchial tube

1) Carlen's tube (Left)
2) White's tube (Right)
3) Bryce Smith Right & Left tube
4) Robertshaw Left & right tube
5) Disposable PVC tubes

HISTORY

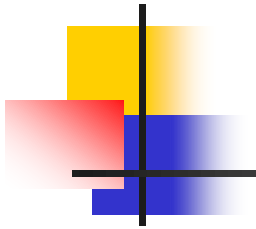
- First report in 1931
- 1.To prevent spillage
- 2.For broncho spirometry

Carlens introduced DLT in 1949

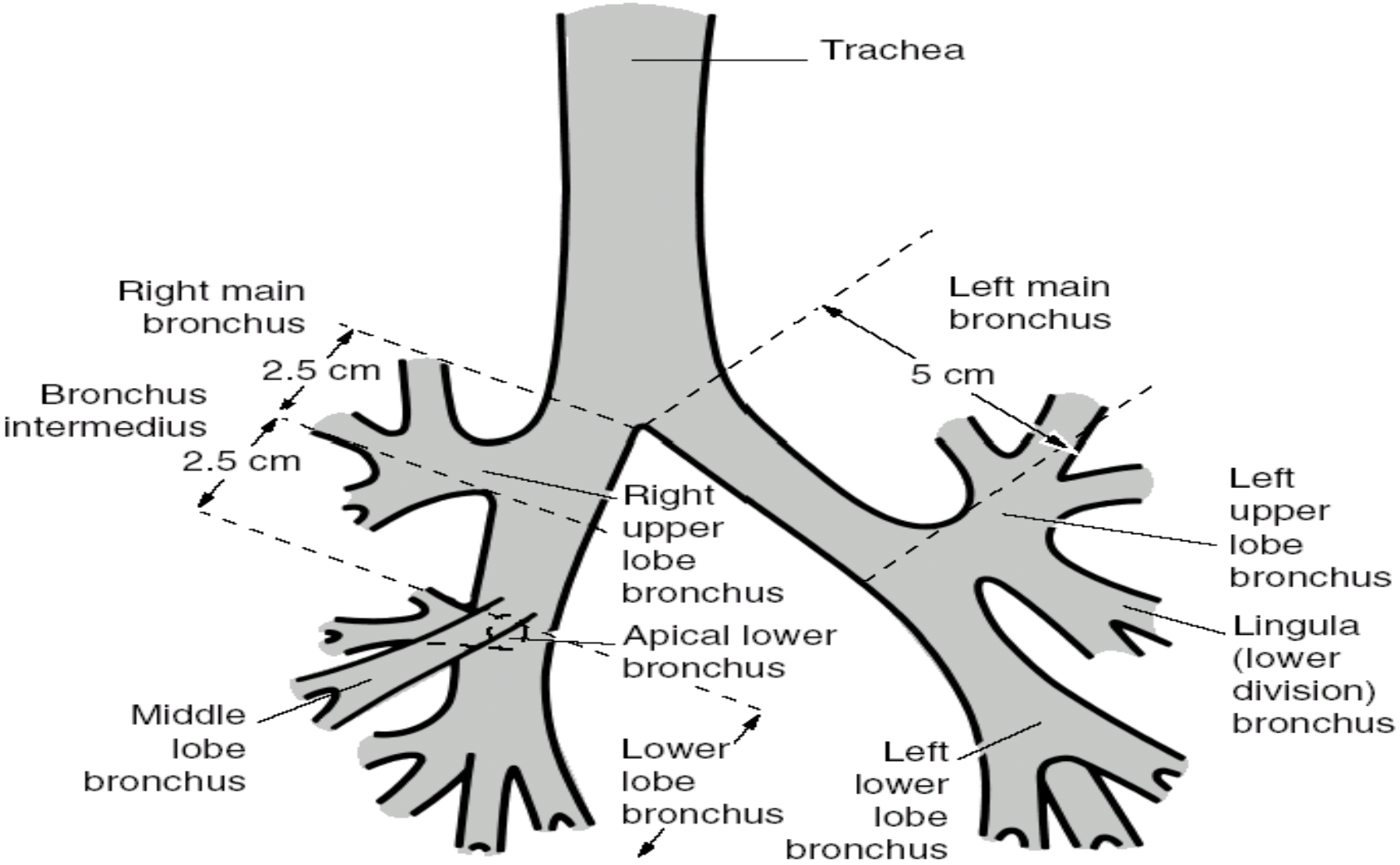
ONE LUNG VENTILATION

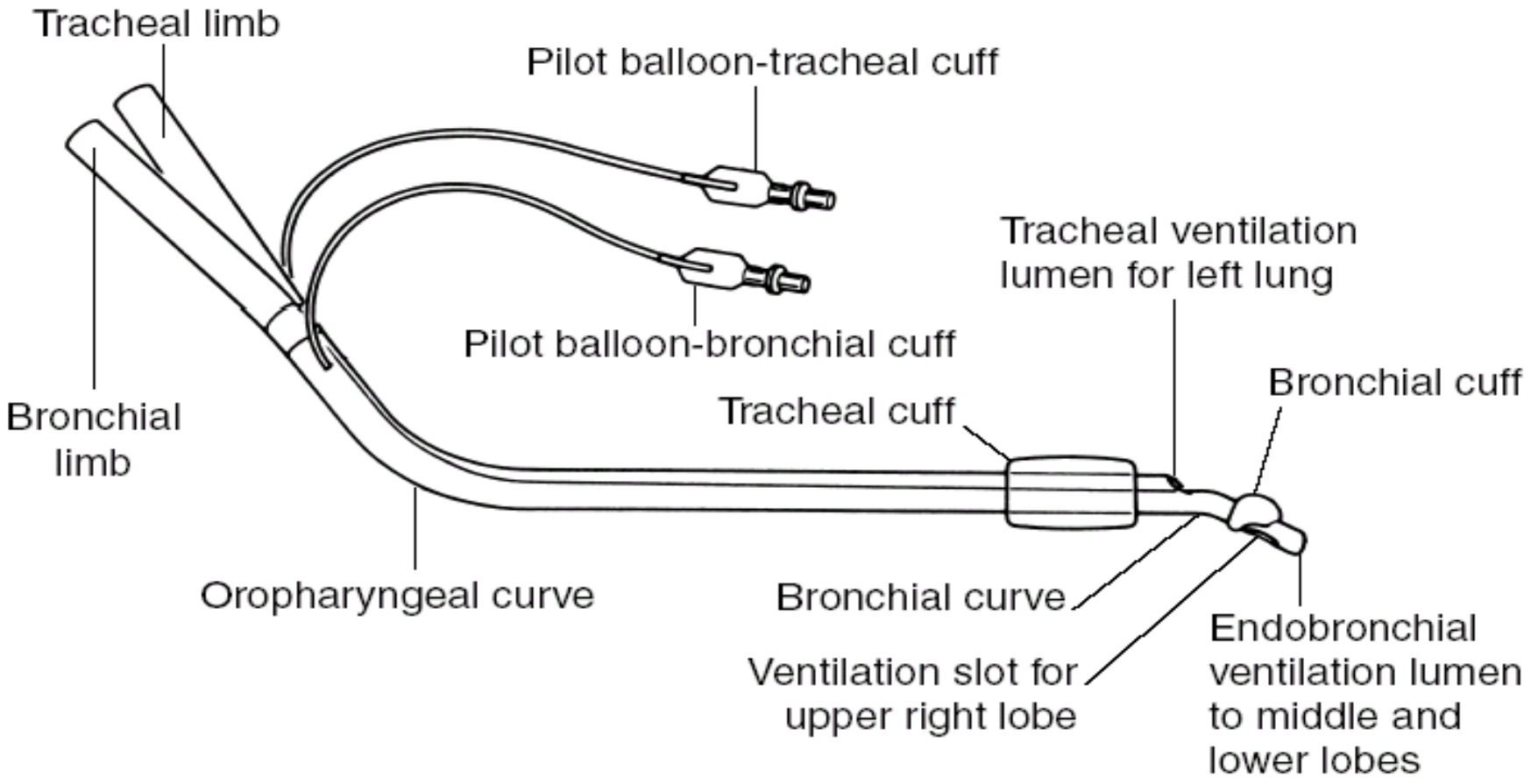
Anatomic Considerations

1) Adult trachea 11-13cm
2) Begins at C6 & bifurcates at T5
3) Rt main bronchus diverges at 25 degree whereas Lt at 55 degree
4) Rt -> Upper, middle, lower lobe bronchus
5) Lt -> Upper & lower lobe bronchus
6) Orifice of Rt upper lobe bronchus is 2.5 cm from carina.



- Lt is about 5 cm from carina
- Rt sided bronchial tube has slit in bronchial cuff for Rt UL ventilation


Trachea
Right main bronchus
2.5 cm
Bronchus intermedius
2.5 cm
Left main bronchus
5 cm
Right upper lobe bronchus
Apical lower bronchus
Middle lobe bronchus
Lower lobe bronchus
Left upper lobe bronchus
Lingula (lower division) bronchus
Left lower lobe bronchus


Tracheal limb
Pilot balloon-tracheal cuff
Tracheal ventilation lumen for left lung
Pilot balloon-bronchial cuff
Bronchial cuff
Bronchial limb
Tracheal cuff
Oropharyngeal curve
Bronchial curve
Endobronchial ventilation lumen to middle and lower lobes
Ventilation slot for upper right lobe

Properties of DLT

1. Separate channel for each lung for ventilation or suction
2. Two tubes of unequal lengths
3. Shorter ends in trachea
4. Longer into bronchus
5. Tracheal cuff
6. Bronchial cuff (2-3 ml of air) blue coloured
7. Right slot for right UL bronchus
8. Inflated Br.cuff isolate & protect each lung
9. Each lumen fitted to special connector

10. Suction tube & FOB pass down either lumen
11. White & Carlen DLT -> Carinal hook -> difficult to pass & injure the airway
12. Robertshaw tube – no hook – large lumen
13. Now PVC DLT – 26,28,33,(35,37,39 & 41 F ->ID of 5,5.5,6,6.5mm) 39F for men 37F for women. Large lumen for suction catheter & FOB
14. Transparent moisture during ventilation, view blood & secretion
15. High volume & low pressure cuff

DLT are commonly used

1) Easily placed
2) Rapid conversion to one & two lung ventilation
3) Suction to both lungs
4) CPAP to NDL

<u>Disadvantages of DLT</u>

1) Less effective suction thru narrow lumen
2) Increased airway resistance

Disadvantages of Carlen's tube

- Difficult in insertion
- Trauma to airway
- Amputation of hook
- Malposition
- Interference during pneumonectomy

ROBERTSHAW DLT

1) Introduced in 1962
2) Lumens D shaped & large

French Gauge	41	39	37	35	28
ID in mm	6.5	6	5.5	5	4.5

DLT by Bronchocath

- Right cuff to ride away from RUL bronchus
- Large internal & external diameter ratio, decreased resistance & effective suctioning

DLT – Choice Right or Left

- Right for left thoractomy & vice versa
- Left side is preferred -> obstruction of RUL bronchus
- Left main bronchus lesion -> left may be withdrawn at the time of clamping – SLT
- Left easy to insert

Right DLT

1) If there is tumour of left bronchus
2) Sleeve resection of left bronchus & left lung transplant
3) Use rubber Robertshaw DLT right->slot for UL

4) Larger & shorter exter.circumference -> never advanced to right bronchus

Size Selection:

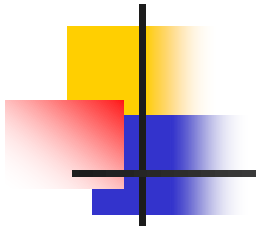
- Largest size DLT is referred
- Too small tubes -> far into bronchus -> obstruct
- Small cuff large air -> airway injury
- Increased resistance
- X-ray chest to measure width of bronchus -> not visible
- Chest CT scan is accurate
- Width of bronchus to size of trachea -> chest x-ray

RELATIVE CONTRA INDICATION OF DLT

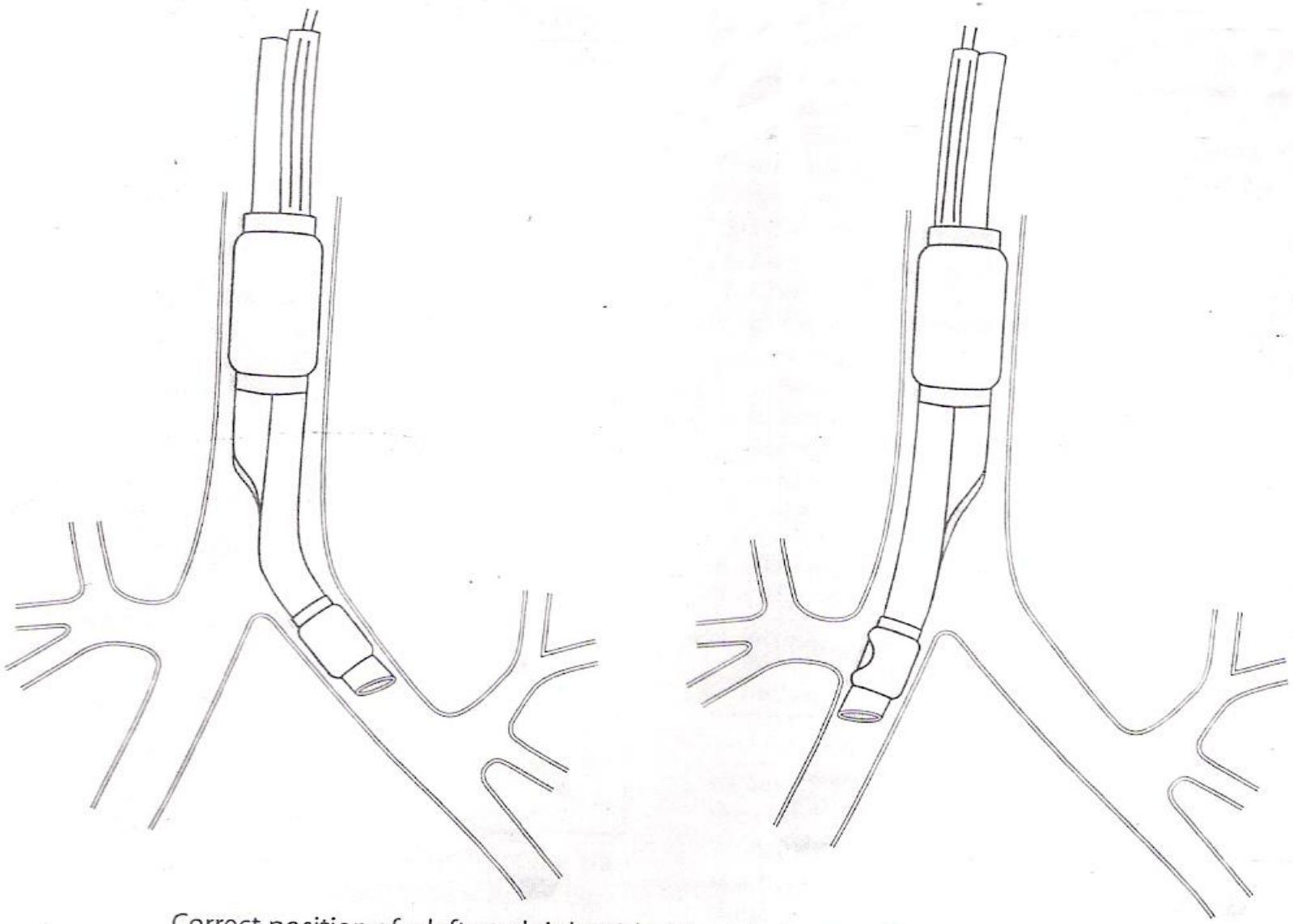
1.Full stomach
2.Airway lesion
3.Pts for whom 35F is too large and 28F is too small
4.Pts with potential airway problem
5.Critically ill ,already intubated
6.Inexperienced anaesthetist
7.Abnormal coagulation profile

INSERTION

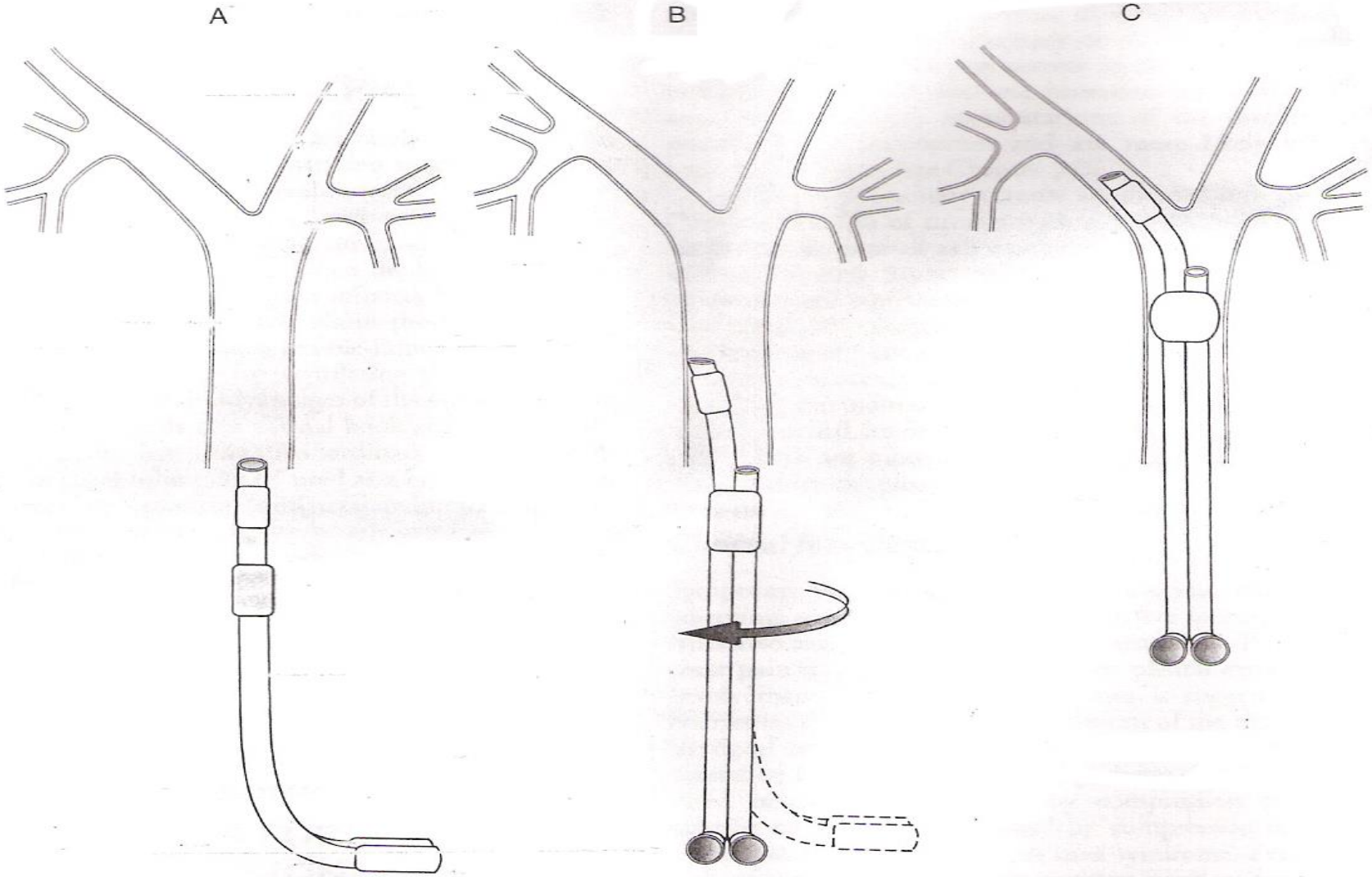
- Laryngoscope with a curved blade.
- DLT with distal curvature concave anteriorly & rotated 90 degree after the tip enters the Lx.
- Advanced until resistance
- Average depth of insertion is 29cm at teeth
- Correct placement using a protocol & confirmed by FOB
- Most DLT accommodate FOB with 3.6 to 4.2mm outer diameter & advanced into trachea – carina visible, bronchial cuff by blue colour.



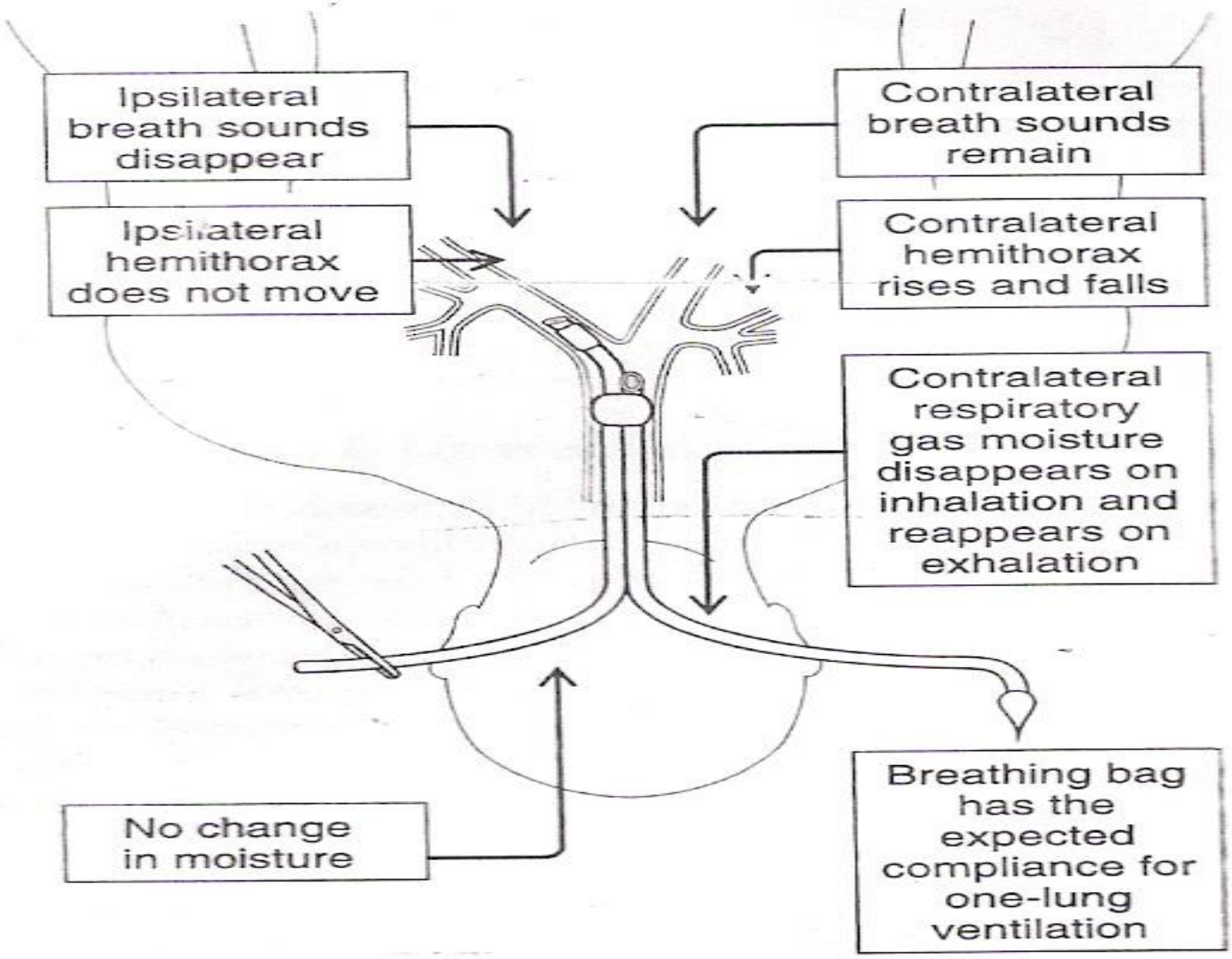
- Bronchial cuff inflated with 2-3ml of air
- Position confirmed after patient is positioned for surgery



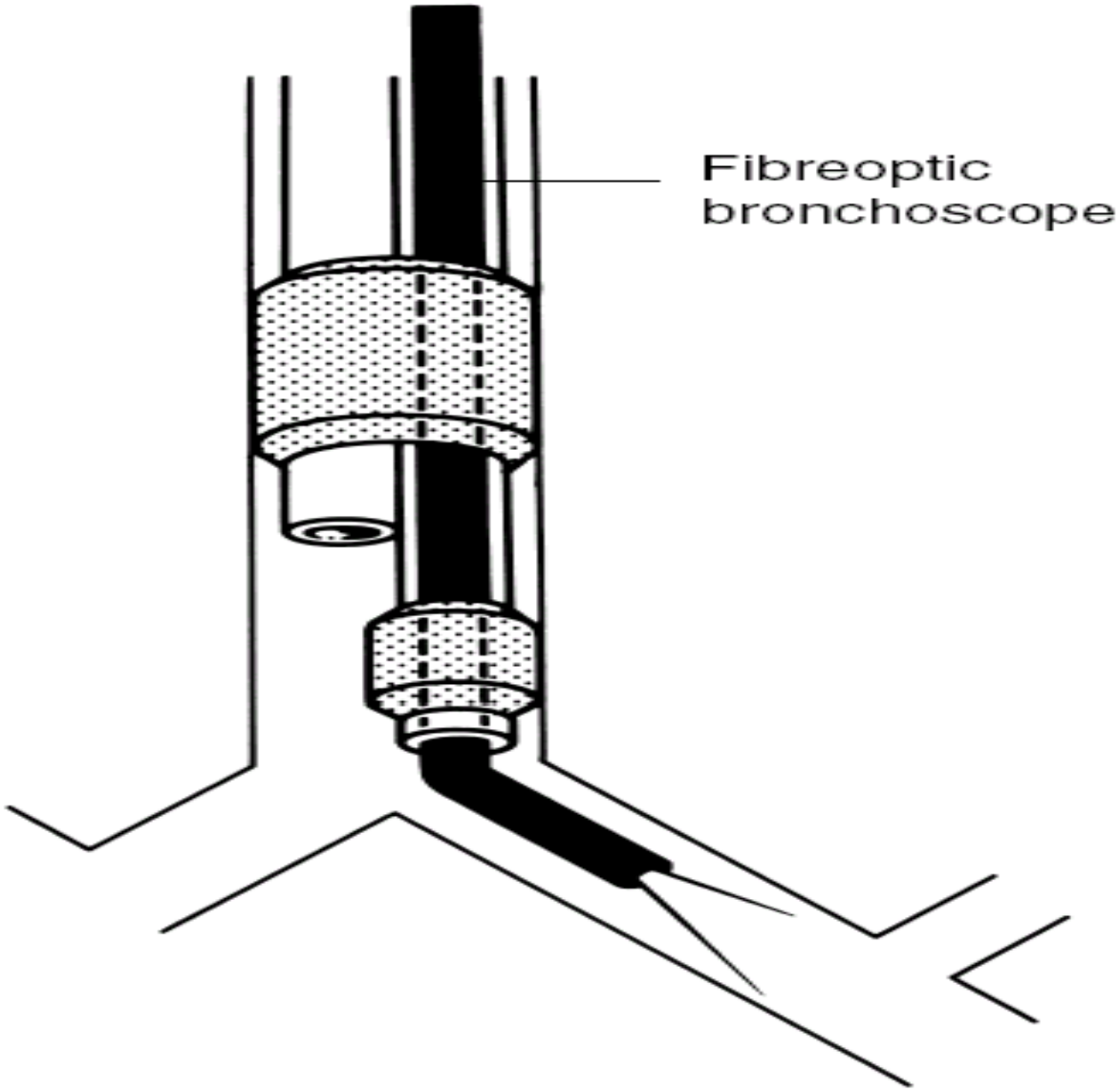
Correct position of a left- and right-sided double-lumen tube.

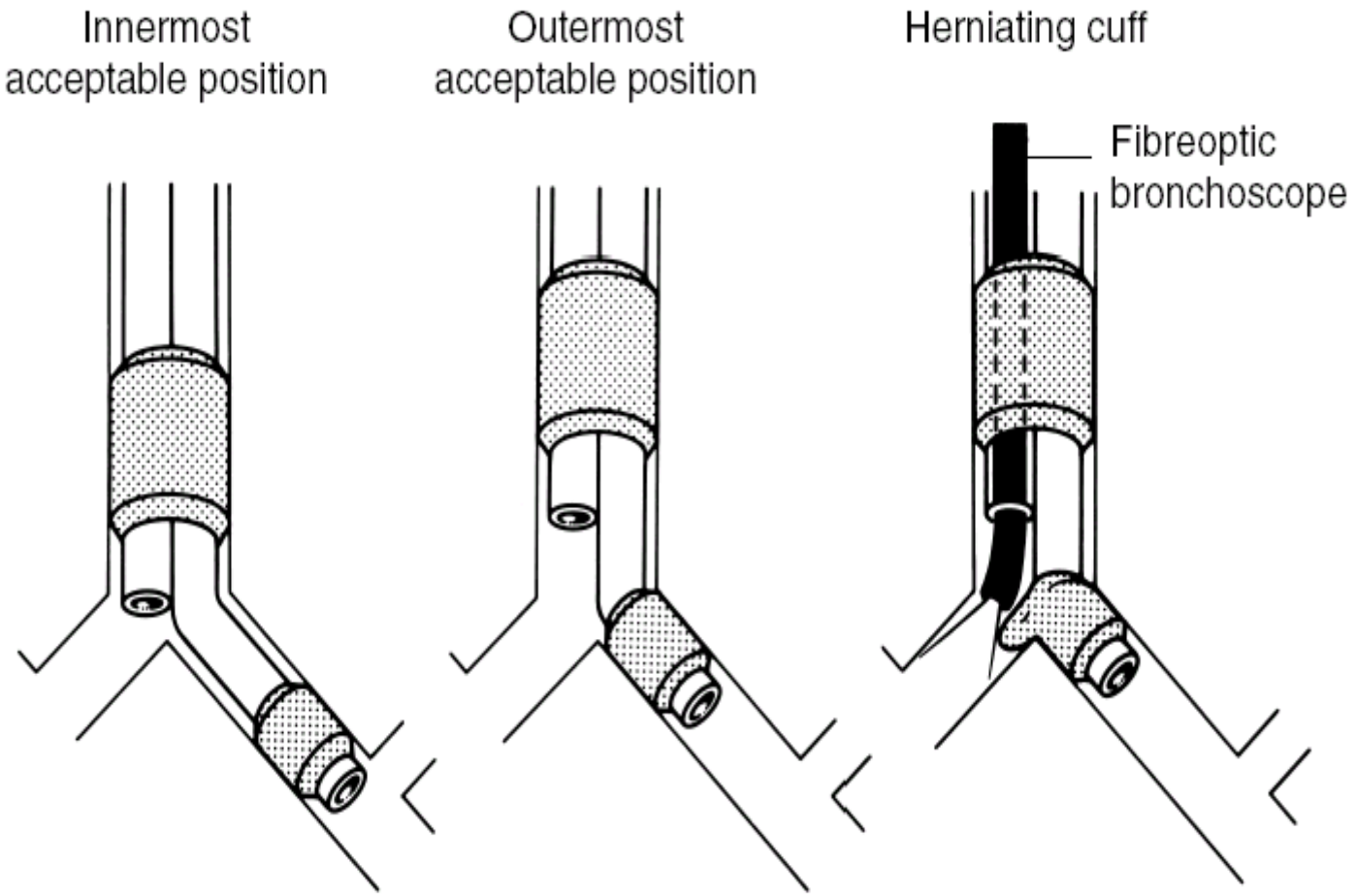


Placement of a left-sided double-lumen tube. Note that the tube is turned 90° as soon as it enters the larynx. ***A:*** Initial position. ***B:*** Rotated 90°. ***C:*** Final position.



Results of unilateral clamping of the tracheal tube when the double-lumen tube is in the correct position.


Fibreoptic
bronchoscope


Innermost
acceptable position
Outermost
acceptable position
Herniating cuff
Fibreoptic
bronchoscope

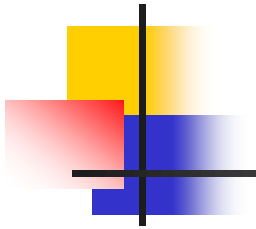
Protocol for checking DLT (Left)

- Inflate the tracheal cuff 5-7 ml of air.
- Check the bilateral breath sounds. Unilateral sound indicate that the tube is too far down.
- Inflate the bronchial cuff(1-2ml)
- Clamp the tracheal lumen
- Check for unilateral left sided breath sounds

a) Persistent right sided breath sounds – bronchial opening is still in trachea.

b) Unilateral right sided breath sounds – incorrect entry of tube into right bronchus.

c) Absence of breath sounds over the entire right lung & left upper lobe indicates that too far down the left bronchus



- Unclamp the tracheal lumen & clamp the bronchial lumen
- Check for unilateral right sided breath sounds.

WHAT IS NEW?

Recent advances

- Newer devices for OLV
- Role of NO
- Pressure Control Ventilation
- Continuous ABG monitoring

FOB

Fibrescope used to prevent complication due to malposition of DLT.So gain familiarity with technique.

If DLT can not be introduced use

1. Fogarty Endobronchial Blocker (FEB)
2. Univent tube
3. Arndt endobronchial blocker

FEB:

It is placed parallel outside or coaxially the SLT.

It has an occlusion balloon 3-6ml, positioned with the aid of FOB.

Drawback:

- Procedural difficulty to direct FEB into desired bronchus.
- Not hollow – unable to pass suction catheter
- Dislodged during surgical manipulation
- HPLV cuff -> mucosal ischaemia

Univent:

Bronchial blocker is housed in antr groove of SLT & advanced beyond the tip under FOB tracheal tube is rotated to the side to be occluded.

ID 6-9 mm

ADVANTAGES:

- Used easily in Supine & lateral position
- Suction can be applied
- Same tube used for POV

Limitation:

- Deflate very slowly
- HPLV cuff- mucosal ischaemia

ARNDT Tube (Wire reinforced with snare guide)

- Introduced in 1999 -> used for difficult intubation.
- Tube blocker introduced into SLT using multiport airway adopter – Ventilation continued during blocker positioning
- LV cuff -> less chance of ischaemia
- Available in sizes Fr 5,7,9 -> 4.5,6,7.5mmSLT.
  Cuff ->0.5 to 12 ml of air
  Length -> 50-78 cm

- Blocker has two lumens:
  1) One loop retains a nylon wire couples the blocker to FOB, once loop is removed after positioning can be used for suctioning & application for CPAP.
  2) Other lumen for cuff inflation
- Tube useful for children
- Used nasally for difficult intubation
- Very expensive

Role of NO:

- Inhaled NO distributes into alveoli -> microvasodilater of capillaries, Improve V/Q mismatch, useful in OLV.
- NO -> Vasodilatation of dependent lung -> HPV in NDL & reduce degree of shunt.

Complications of DLT

I) Intubation – hook unable to pass

II) Unable to advance bronchial limb

   a) Too large

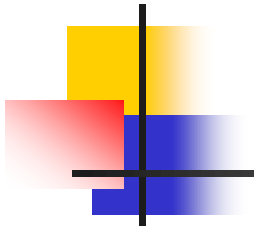
   b) Airway Obstruction

III) Trauma

   1) Dental

   2) Airway trauma

   3) Ruptured thoracic aneursysm



IV) Position
   a) Not far enough onto bronchus
   b) Down wrong bronchus
   c) Too deep in correct bronchus
   d) Changes during surgery
      1) Surgical manipulation
      2) Movement of pt to LDP
      3) Head movement
      4) Tube not secured

V) Hypoxaemia

VI) Malpositioned DLT

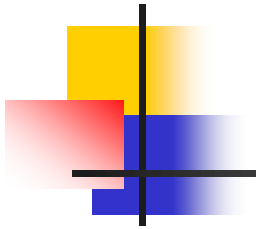
VII) Miscellaneous

OPTIMISATION OF OXYGENATION DURING OLV

- Major reasons of arterial desaturation:
- P(A-a)O2
- Low FIO2
- Gross hypoventilation of of DL
- Malposition of DLT
- Malfunction of DLT(blockage by secretion,bronchial cuff herniation)

STRATEGIES TO OPTIMISE OXYGENATION

- Confirm proper positioning of DLT in supine and then in lateral position ,confirmed with FOB
- Maintain two lung ventilation as much and as long as possible
- High FIO2.Initial setting of OLV-FIO2-1,assuming an intact HPV.PaO2 during OLV should be 150-200mmof Hg.TV-10ml/kg and adjusted according to airway pressure.RR-to target PaCO2 of 40mm of Hg.
- Consider PCV in cases with high airway pressure
- If hypoxaemia develops,



- Confirm DLT position and patency with FOB
- Institute CPAP of 5-10cm of H2O to NDL
- Institute PEEP of 5-10 cm to DL
- If all these fail intermittent ventilation to NDL to be started with surgeons collaboration
- Consider high frequency ventilation of NDL
- Consider NO if hypoxaemia coexists with pulmonary hypertension
- Consider early clamping of PA of operative lung as soon as possible
- O2-via small suction catheter attached to O2flowmeter to collapsed lung-2L/mt

ANCILLARY MEASURES

- Close monitoring and vigilance is mandatory besides ECG,ABP,CVP,EtCO2&SaO2. Following initiation of OLV,PaO2 continues to decrease for upto 45mts
- Hypothermia and hypocapnia to be avoided as HPV is suppressed .
- Hypovolemia and hypotension are undesirable because of ill effects on oxygenation by decrease in CO
- Do not accept suspected malpositions of DLT&proceed with surgery.
- Prevent and treat bronchospasm
- Use the largest possible DLT to prevent hypoventilation,malposition,and to facilitate suctioning
- If soiling of good lung &desaturation-Postpone the surgery

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THANK YOU