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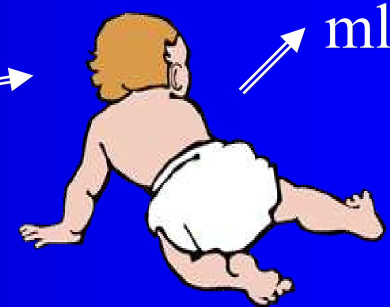
生存所需的氧气与CO_2的产生



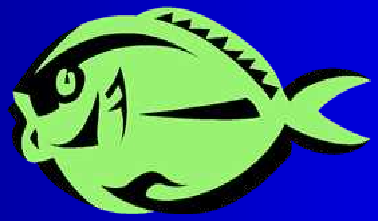
- 耗氧及产生CO_2的量不同，但其比率相同

呼吸商（R）

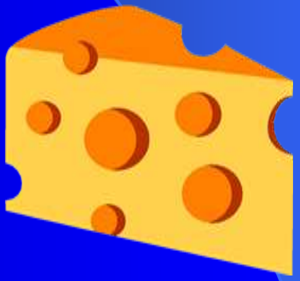
- CO_2产生量与O_2消耗量的比

碳水化合物

蛋白质

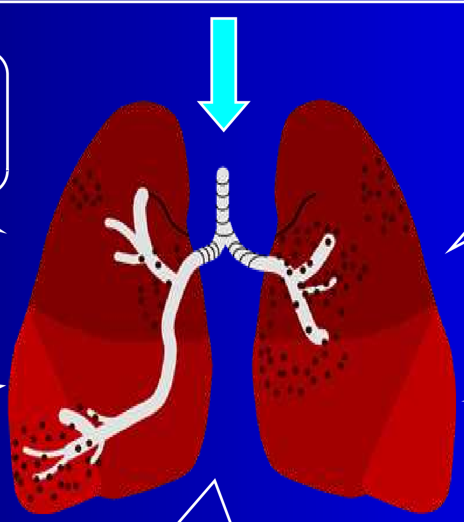


脂肪



R= 0.75~0.9 通常以0.8计

摄取O_2排出CO_2—肺的气体交换作用

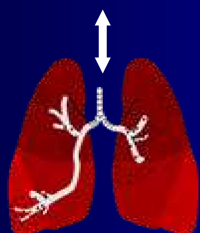


气体交换的条件

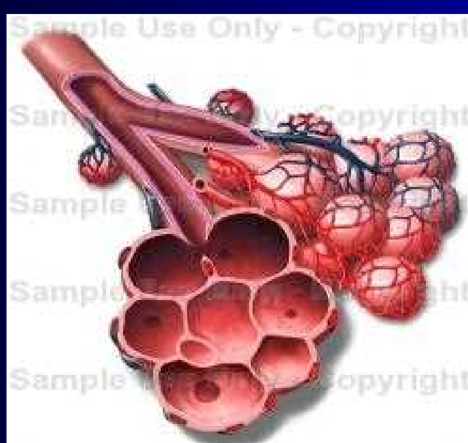
- 充分的通气
- 通气与血流平衡
- 弥散顺利

影响气体交换的3要因

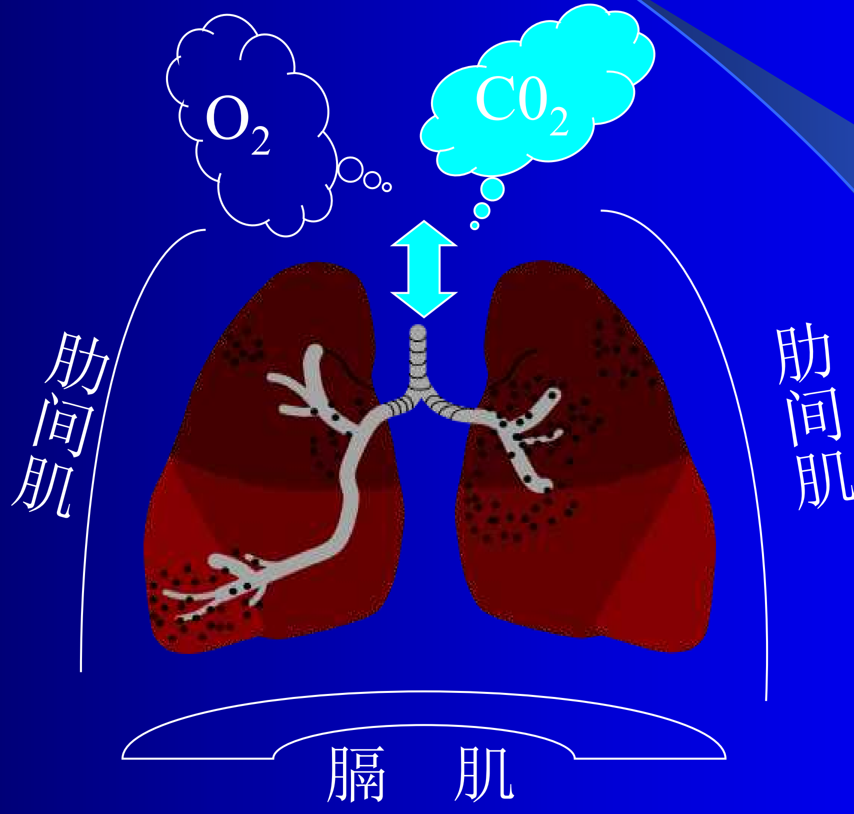
- 环境：大气压 氧浓度
- 通气（肺泡通气）
  潮气量 呼吸频率 死腔量



- 肺泡水平的气体交换
  通气/血流比 弥散能力
  静脉性分流



$PaCO_2$与肺泡通气



动态肺容量

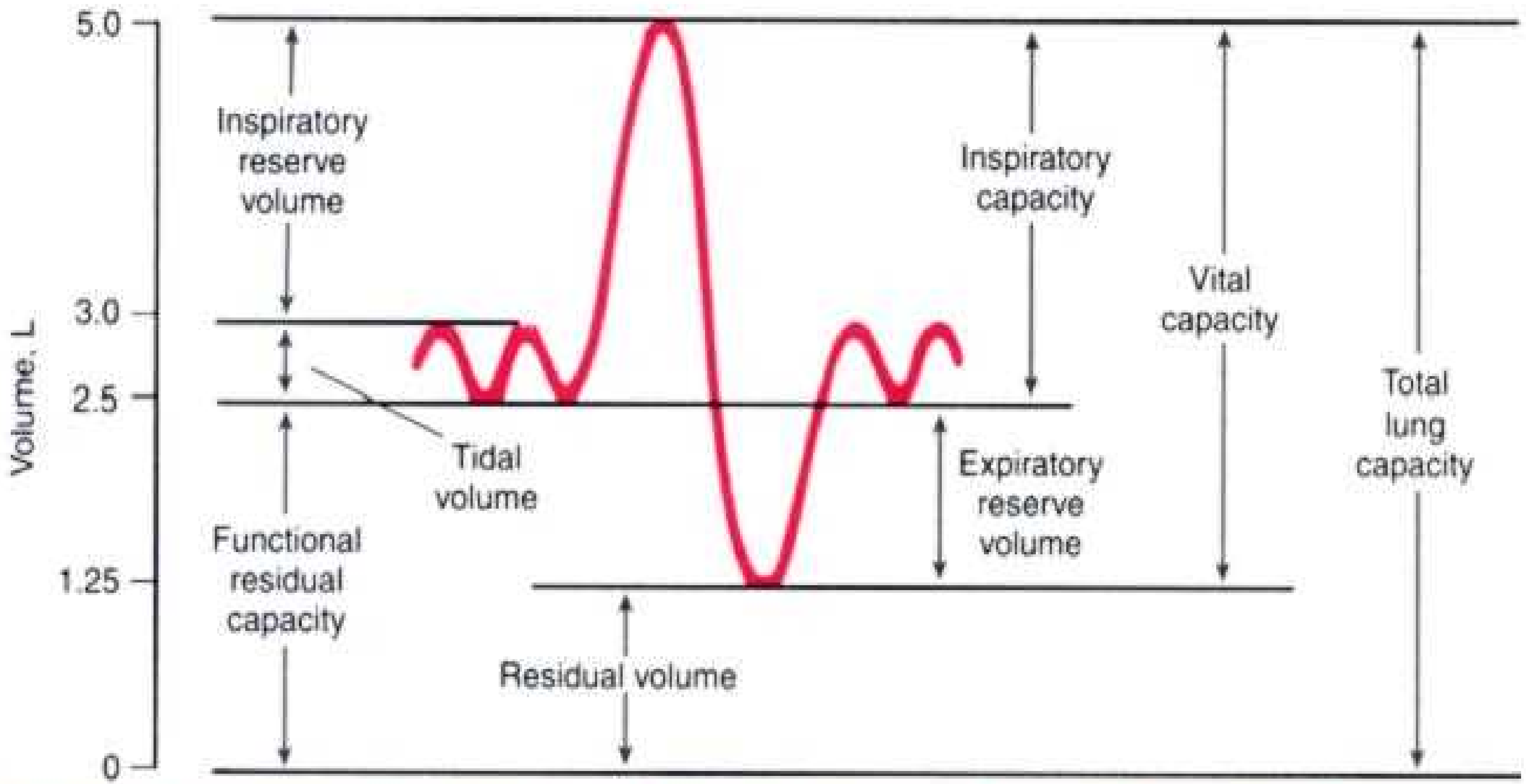


Figure 17-16 The dynamic lung volumes that can be measured by simple spirometry are tidal volume, inspiratory reserve volume, expiratory reserve volume, inspiratory capacity, and vital capacity. The static lung volumes are residual volume, functional residual capacity, and total lung capacity. Static lung volumes cannot be measured by simple spirometry and require separate methods of measurement (e.g., inert gas dilution, nitrogen washout, or whole-body plethysmography).

功能残气量

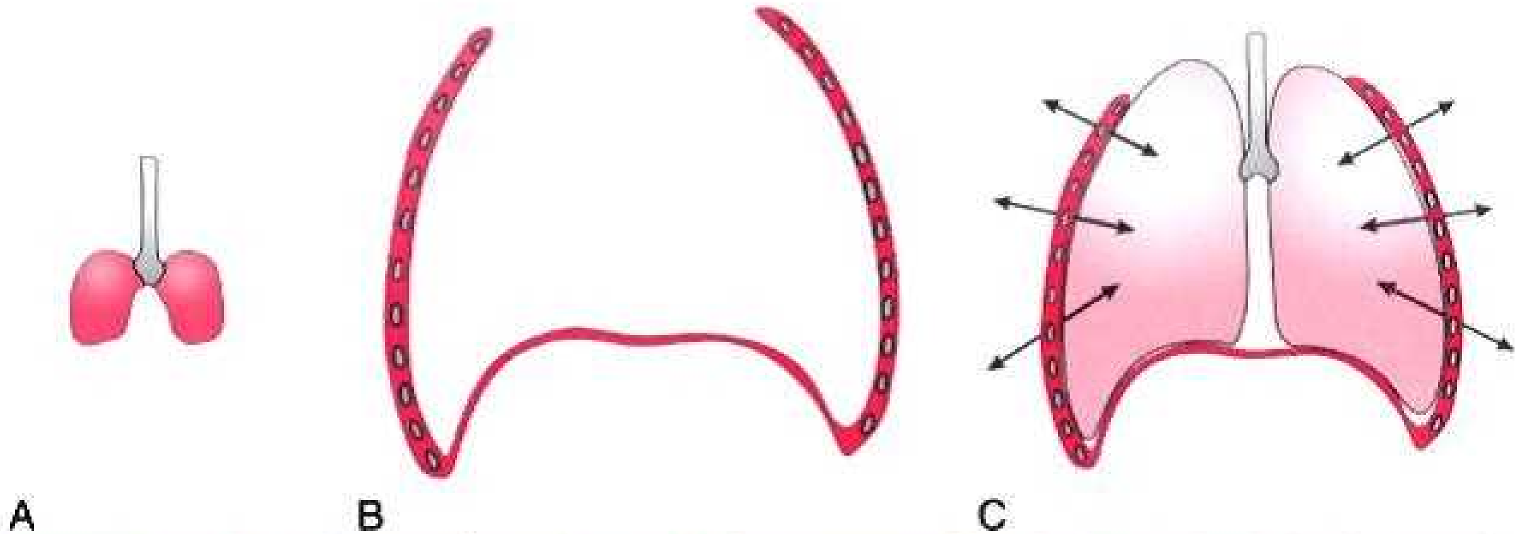
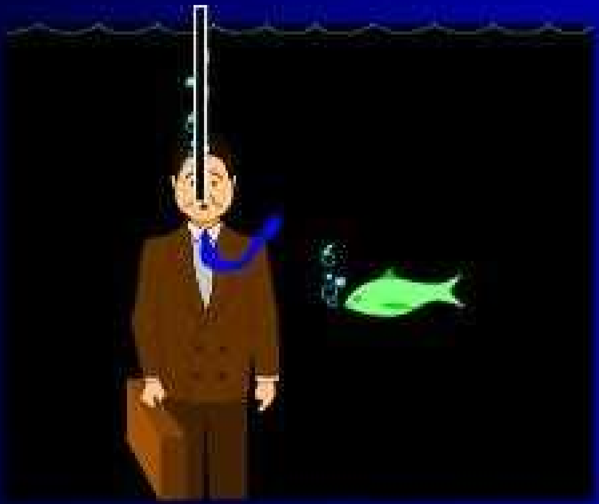


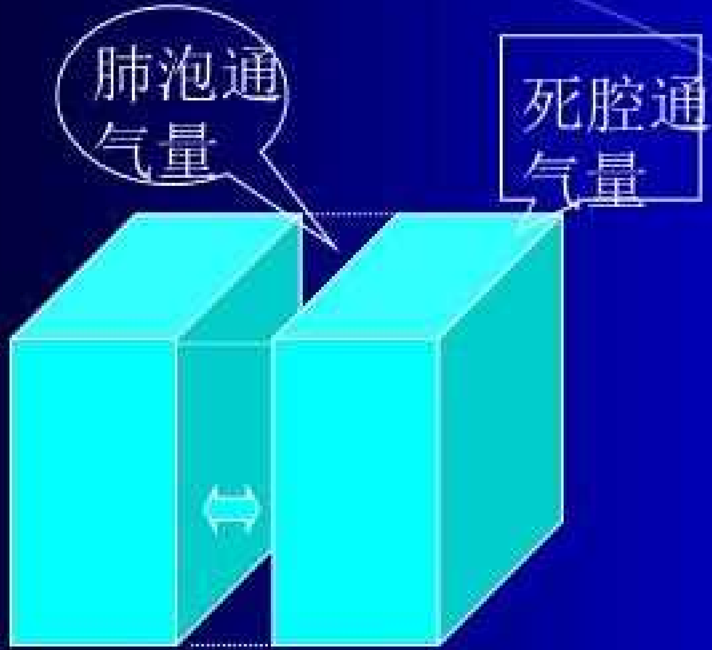
Figure 17-15 A, The resting state of normal lungs when they are removed from the chest cavity; that is, elastic recoil causes total collapse. **B,** The resting state of a normal chest wall and diaphragm when the thoracic apex is open to the atmosphere and the thoracic contents are removed. **C,** The lung volume that exists at the end of expiration is the functional residual capacity (FRC). At FRC, the elastic forces of the lung and chest walls are equal and in opposite directions. The pleural surfaces link these two opposing forces. *(Redrawn with modification from Shapiro BA, Harrison RA, Trout CA: The mechanics of ventilation. In Clinical Application of Respiratory Care, 3rd ed. Chicago, Year Book, 1985, p 57.)*

有效的通气—肺泡通气

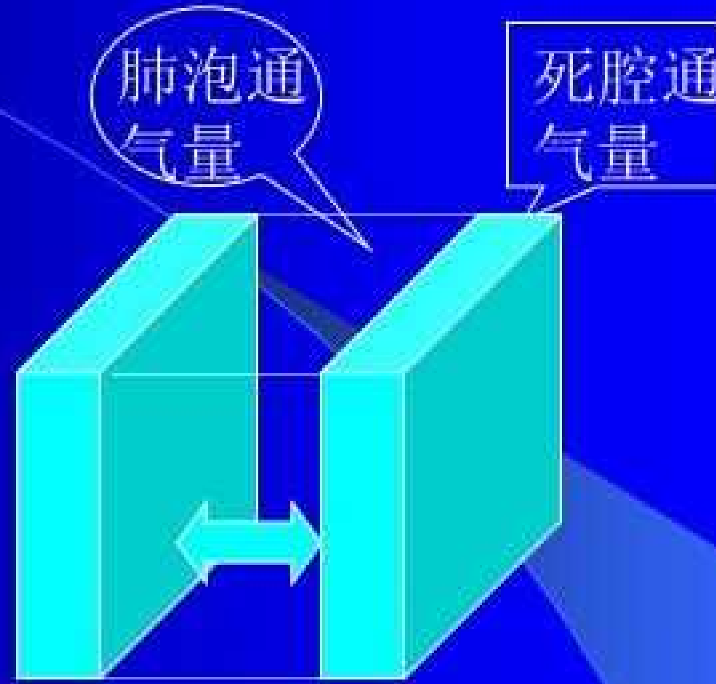


- 从鼻到肺泡以上的气道对气体交换来说是无用的空间，称为死腔。

- 肺泡通气量
  ＝分钟通气量－死腔通气量
  ＝（潮气量V_T－死腔量V_D）×Rf



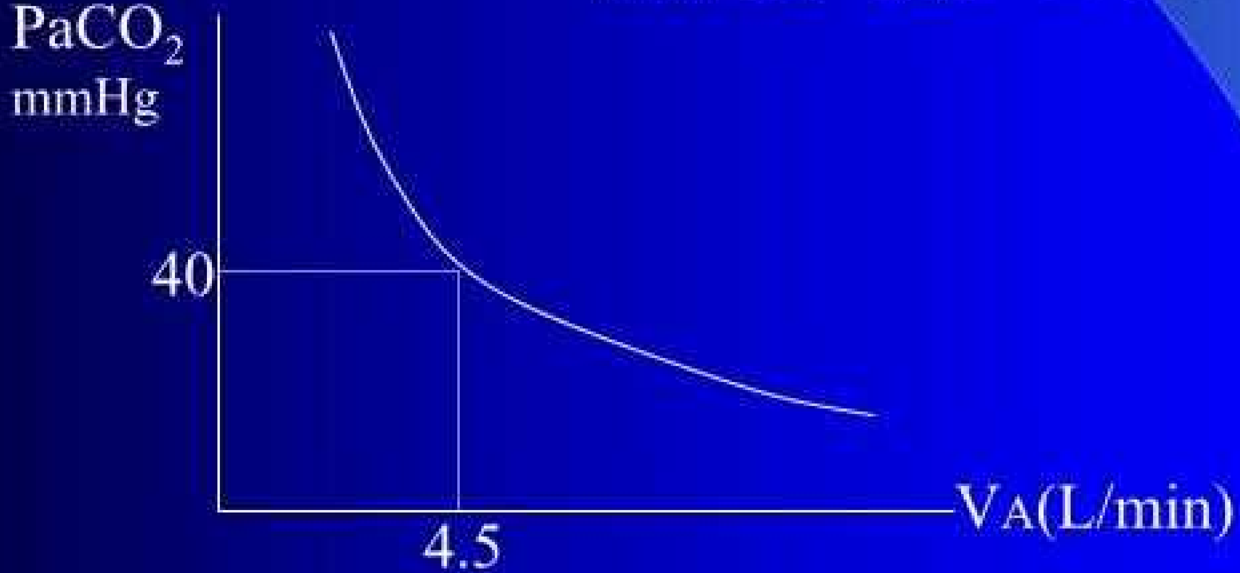
- 浅快呼吸
  Vt＝300ml，Rf=20bpm
  V_A＝(300-150)×20
  =3000ml/min



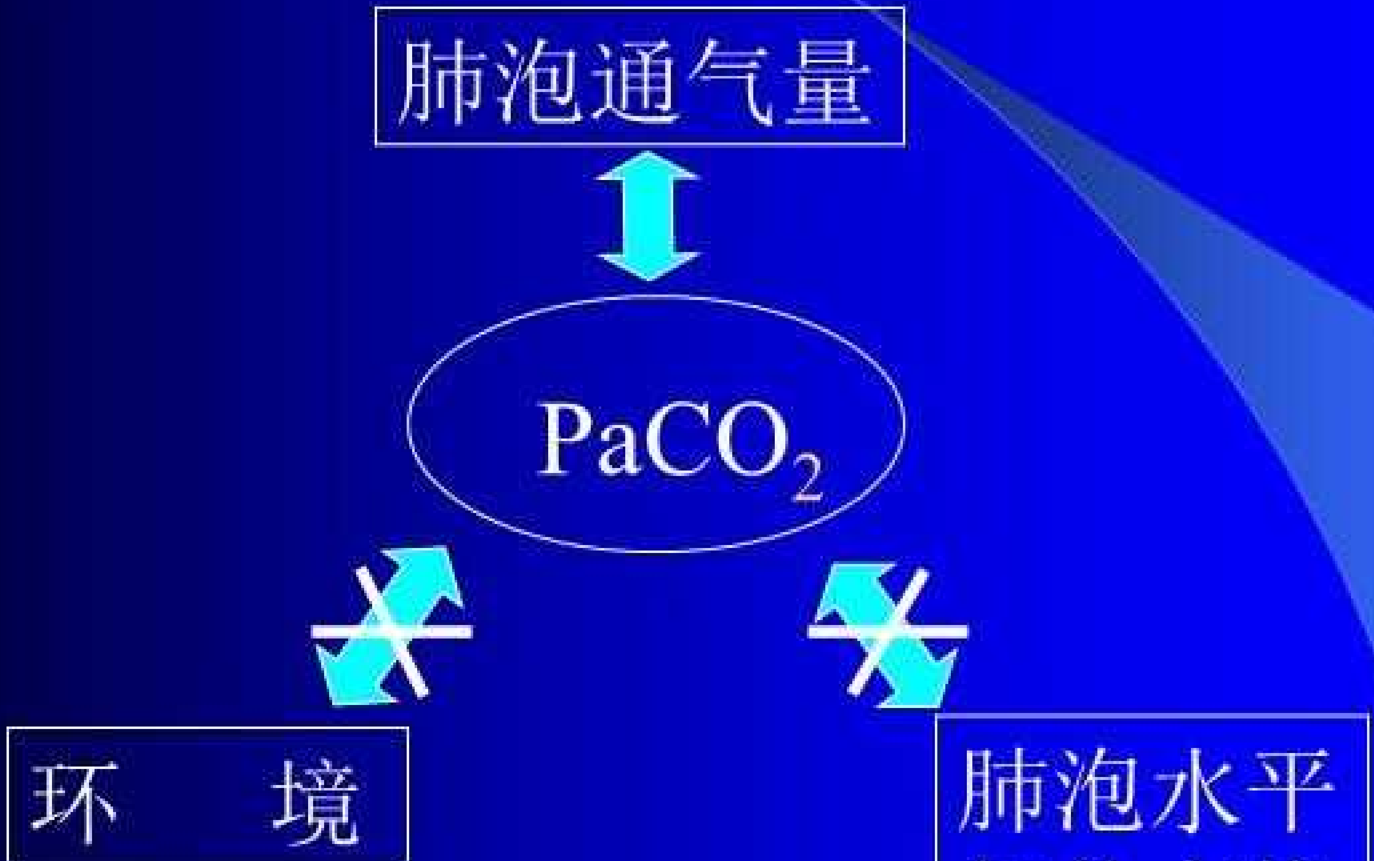
- 深大呼吸
  Vt＝600ml，Rf=10bpm
  V_A＝(600-150)×10
  ＝4500ml/min

$PaCO_2$与肺泡通气量的关系

$$PaCO_2 = K \cdot \frac{\text{二氧化碳产生量（ml/分）}}{\text{肺泡通气量（L/分）}}$$



$PaCO_2$为肺泡通气量的指标



各级氧分压的变化

- $PO_2 = P_B \times FiO_2$
- $P_IO_2 = (P_B - 47) \times FiO_2$
- $P_AO_2 = (P_B - 47) \times FiO_2 - PaCO_2/R$
- $PaO_2 = (P_B - 47) \times FiO_2 - PaCO_2/R - AaDO_2$

环境因素
大气压
氧浓度

由肺泡通
气量决定

反映肺泡
水平气体
交换障碍

肺泡气中PO_2和PCO_2的变化

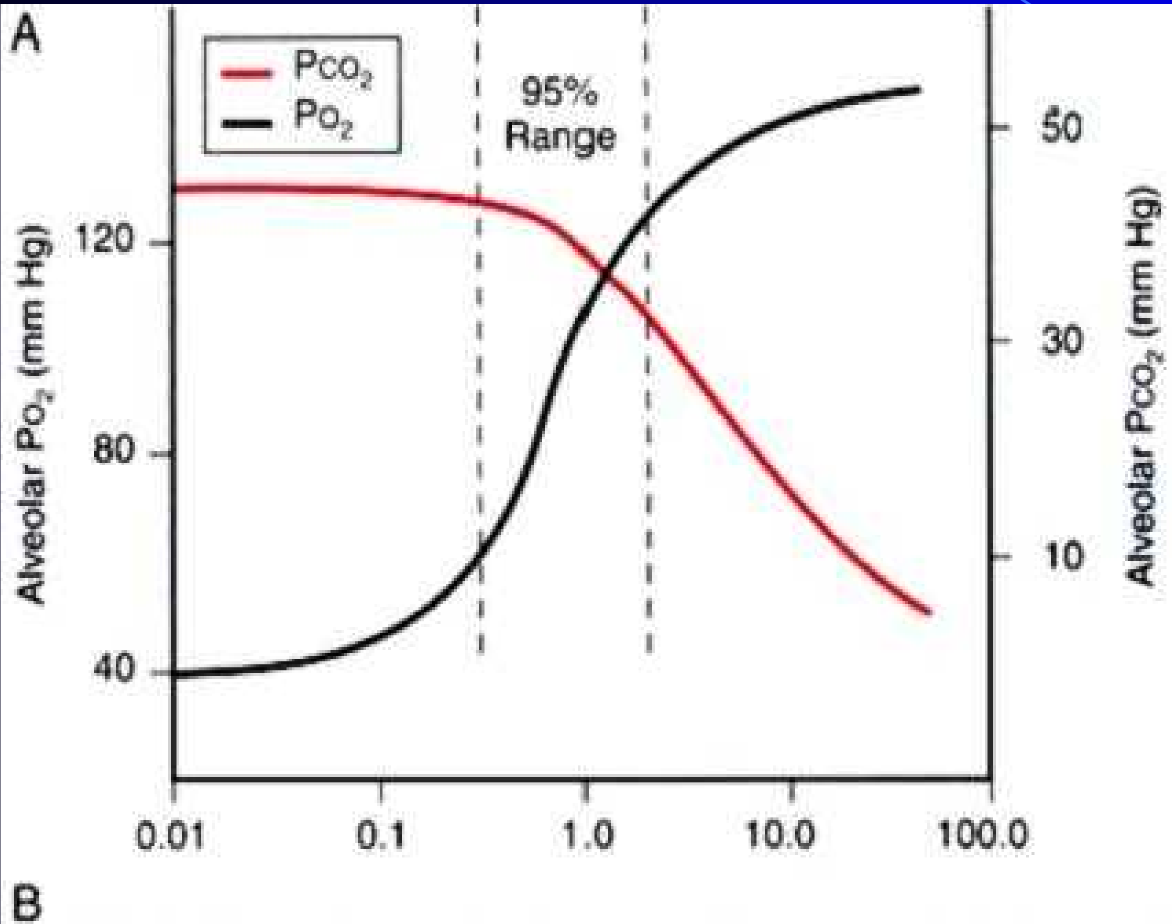


Figure 17-6 **A,** Average distribution of ventilation-perfusion ratios ($\dot{V}_A/\dot{Q}$) in normal young semirecumbent subjects. The 95% range covers from 0.3 to 2.1 (between *dashed lines*). **B,** Corresponding variations in Po_2 and Pco_2 in alveolar gas. *(Redrawn from West JB: Blood flow to the lung and gas exchange. Anesthesiology 41:124, 1974.)*

PaO_2与$PaCO_2$

- 氧浓度增加1%， PaO_2上升7mmHg。
- $PaCO_2$如变化8mmHg， PaO_2反方向变化10mmHg。

高碳酸血症

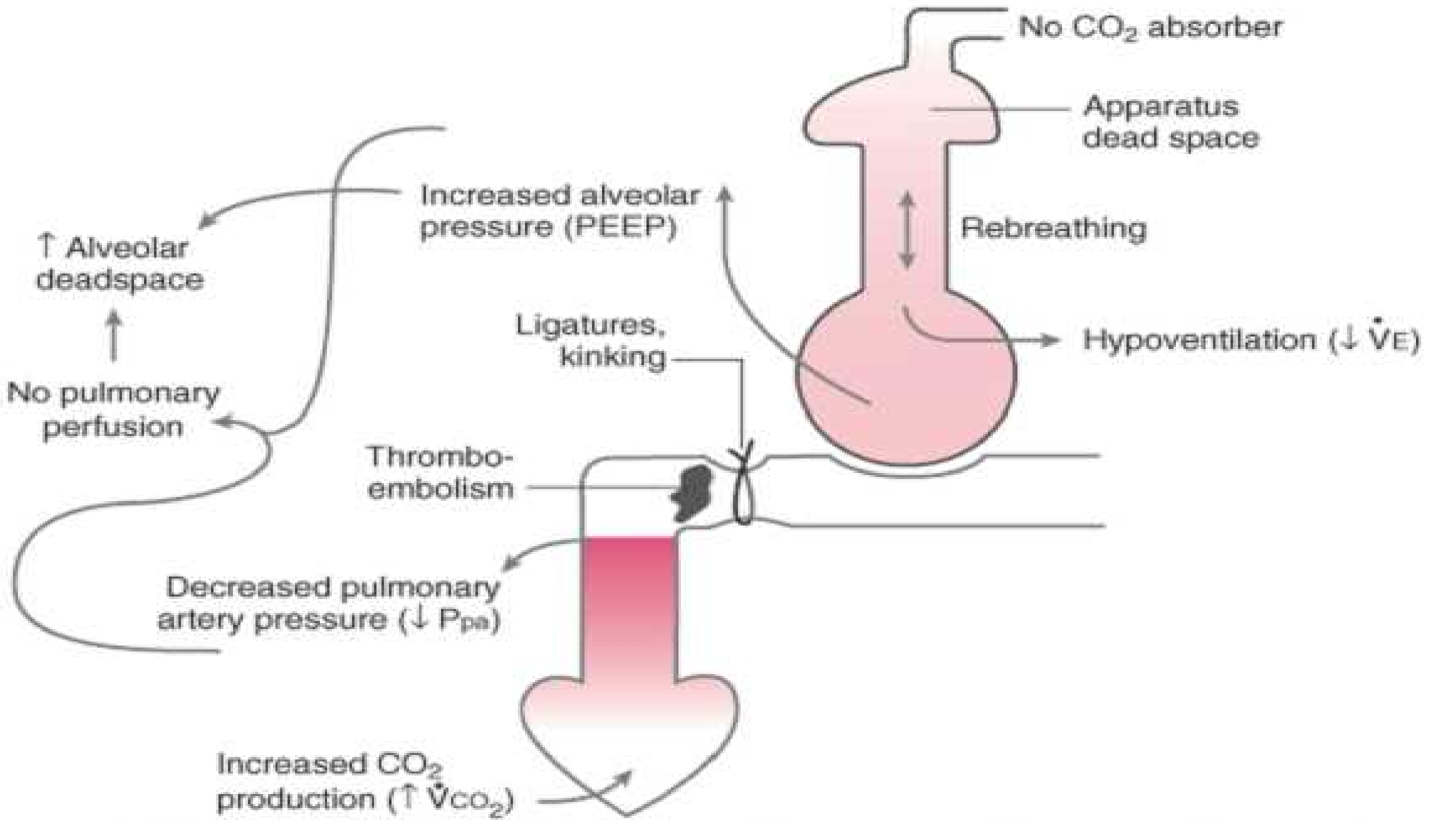


Figure 17-40 Schematic diagram of the causes of hypercapnia during anesthesia. An increase in carbon dioxide (CO_2) production (V□CO_2) will increase $PaCO_2$ with a constant minute ventilation (V□E). Several events can increase alveolar dead space: a decrease in pulmonary artery pressure (Ppa), the application of positive end-expiratory pressure (PEEP), thromboembolism, and mechanical interference with pulmonary arterial flow (ligatures and kinking of vessels). A decrease in V□E causes an increase in $PaCO_2$ with a constant V□CO_2. It is possible for some anesthesia systems to cause rebreathing of CO_2. Finally, the anesthesia apparatus may increase the anatomic dead space, and inadvertent switching

CO_2气腹对通气的影响

气腹将使横隔抬高而减少功能残气量，也可使气道压增加而导致通气血流比改变。对一般患者、肥胖以及ASAIII-IV的患者，气腹可使其肺顺应性降低30%-50%。

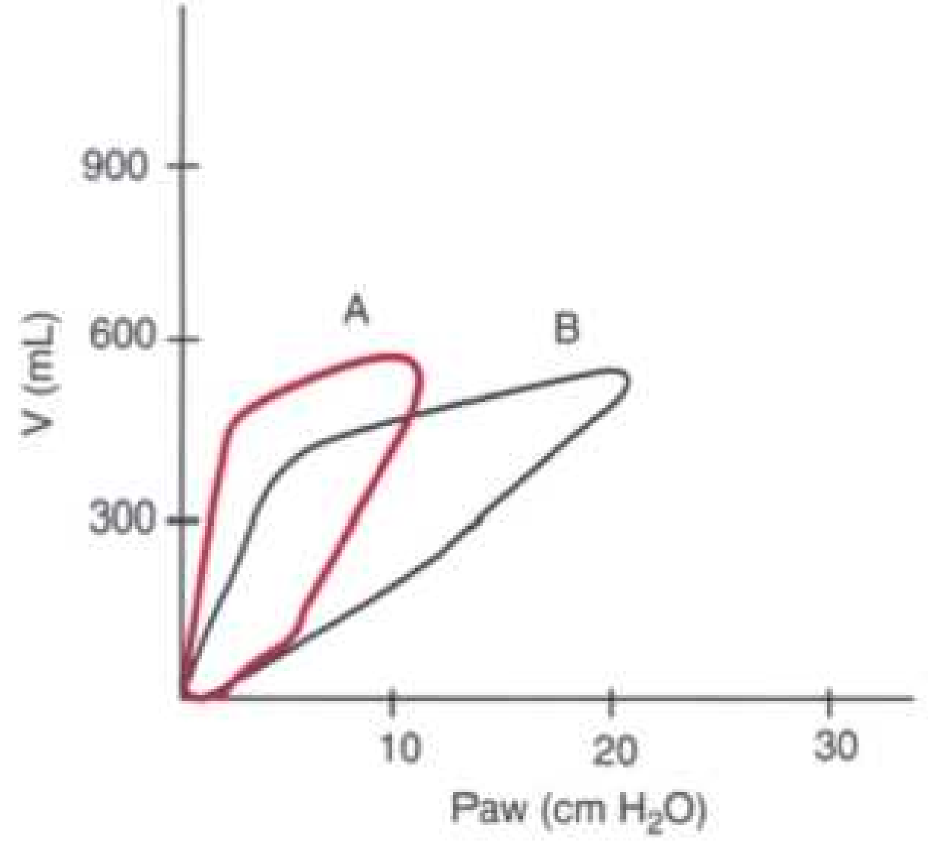
胆囊切除术中肺总顺应性改变

腹内压力14mmHg；

头抬高10°；

A：充气前；

B：充气后30min。



	TV	Ppeak	Pplat	C	$P_{ET}CO_2$
A	522	12	9	56	31
B	525	21	19	27	39

CO_2气腹对通气的影响

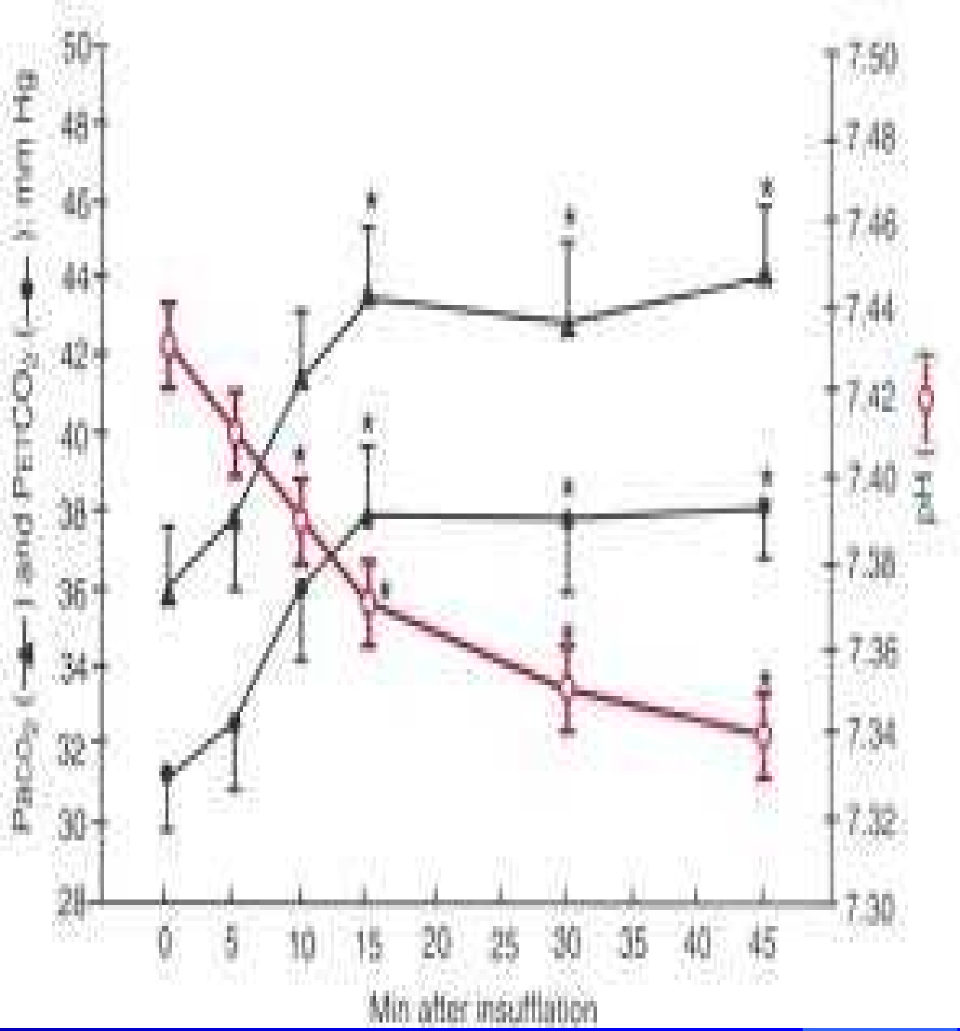
对于无心血管疾病的患者，腹内压力14mmHg；头抬高10-20度的头高位或头低位将不会引起生理死腔量增加。

动脉血CO_2分压升高

一般情况下，无论妇科手术时的侧卧位还是胆囊切除术时的头高位，CO_2气腹都可使$PaCO_2$进行性升高。$PaCO_2$在建立气腹后15-30min达到高峰并维持下去，其升高的程度取决于腹内压。此期间后若出现$PaCO_2$再次明显上升，则应仔细寻找原因，如是否存在皮下CO_2气肿等。

胆囊切除术呼吸参数的变化

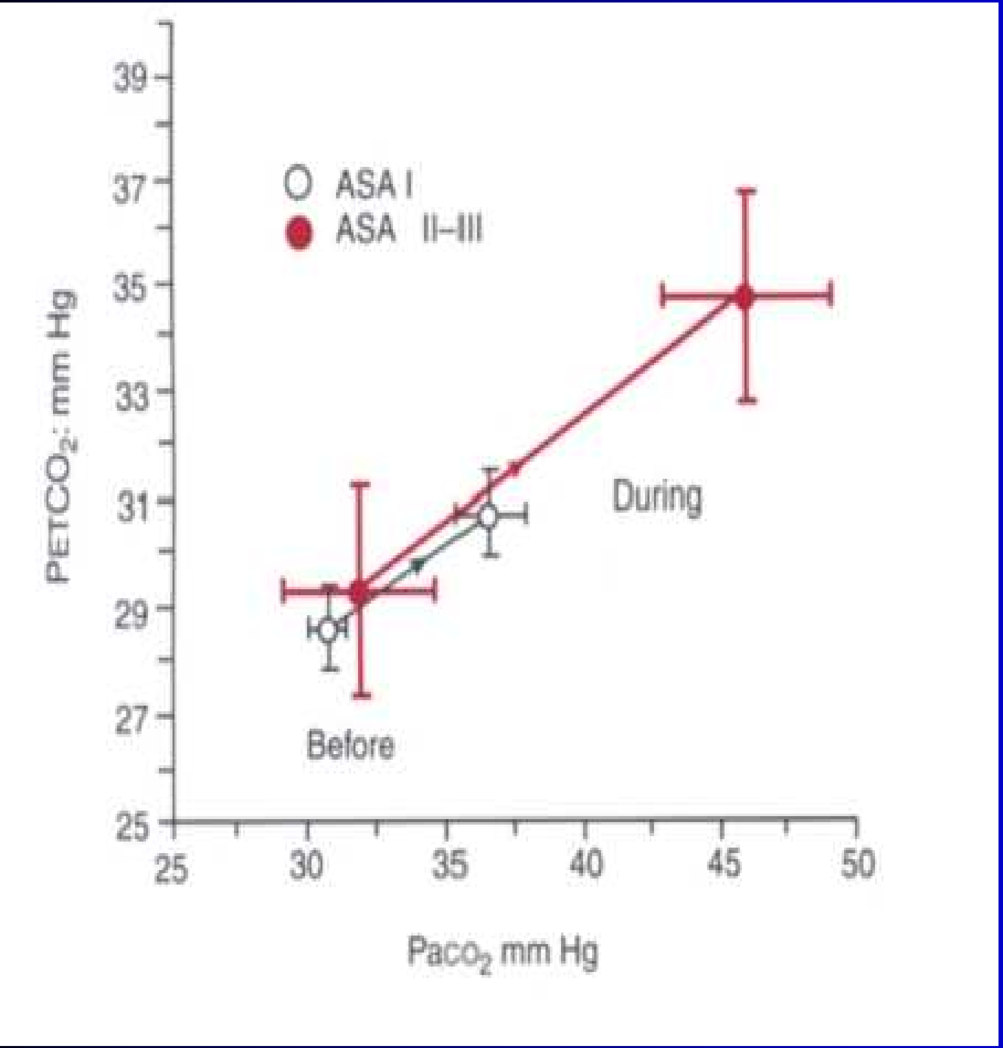
- 13例ASA I－II级的患者；
- 分钟通气量 100ml/kg/min；
- RR12次/min；
- IAP:14mmHg。



$PaCO_2$和$P_{ET}CO_2$之间的关系

在ASAⅡ～Ⅲ级的患者，$PaCO_2$与$P_{ET}CO_2$增加幅度大于ASA Ⅰ级者。这已经在慢性阻塞性肺病(COPD)患者和发绀型先心病患儿中得到证实。

$PaCO_2$和$P_{ET}CO_2$的关系



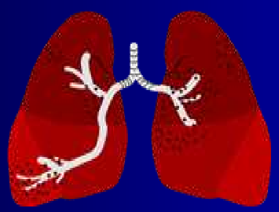
- 测定时间：气腹前与气腹后；
- ASA患者：
- 1组：ASA1级20例；
- 2组：ASA II -III级10例。

$PaCO_2$和$P_{ET}CO_2$的关系

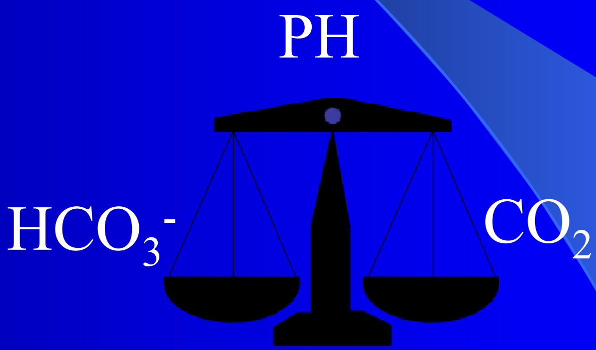
在CO_2排出功能削弱或伴有急性心肺功能紊乱者，$PaCO_2$和$P_{ET}CO_2$之间相关性差。因此，临床怀疑有CO_2潴留时，即使$P_{ET}CO_2$正常，也应当进行动脉血气分析。

测定血气分析的意义

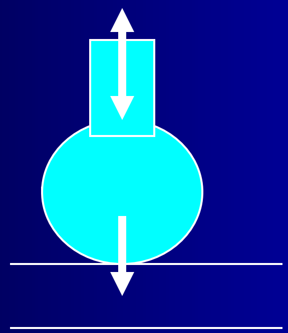
- 掌握气体交换的能力



- 诊断酸碱平衡



- 诊断气体交换障碍的部位



- 维持生命的指南针

腹腔镜期间$PaCO_2$增加的原因

- 腹腔CO_2吸收；
- 通气和血流比例失调；生理无效腔量增大；

  腹内压增高

  病人体位

  机械通气

  心排血量减少

  病情严重者。

腹腔镜期间$PaCO_2$增加的原因

- 代谢增强；
- 麻醉药抑制通气（如自主呼吸时）；
- 意外事件

  CO_2气肿

  CO_2气胸

  CO_2栓塞