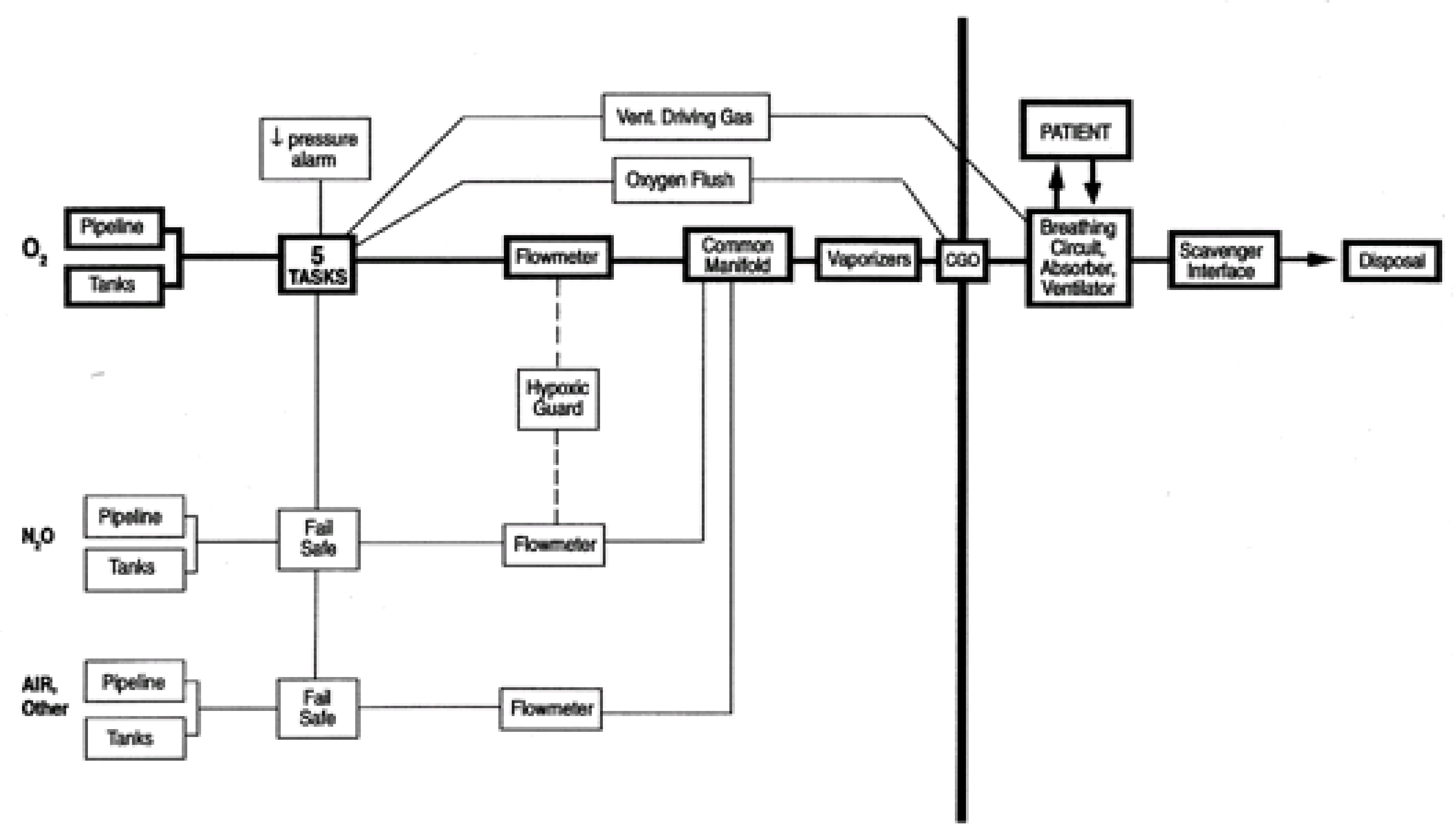
Anaesthesia Machine, Monitoring

L.Dadák
ARK FNUSA & LF MU

Anaesthesia Machine

is able to ventilate the patient by defined mixture of gasses

O2


↓ pressure alarm
Vent. Driving Gas
Oxygen Flush
PATIENT
O_2
Pipeline
Tanks
5 TASKS
Flowmeter
Common Manifold
Vaporizers
CGO
Breathing Circuit, Absorber, Ventilator
Scavenger Interface
Disposal
Hypoxic Guard
N_2O
Pipeline
Tanks
Fail Safe
Flowmeter
AIR, Other
Pipeline
Tanks
Fail Safe
Flowmeter

Gas – ISO norm

O2 - white

- fractionally distill liquefied air into its various components, (N2 distilling as a vapor, oxygen O2 is left as a liquid.

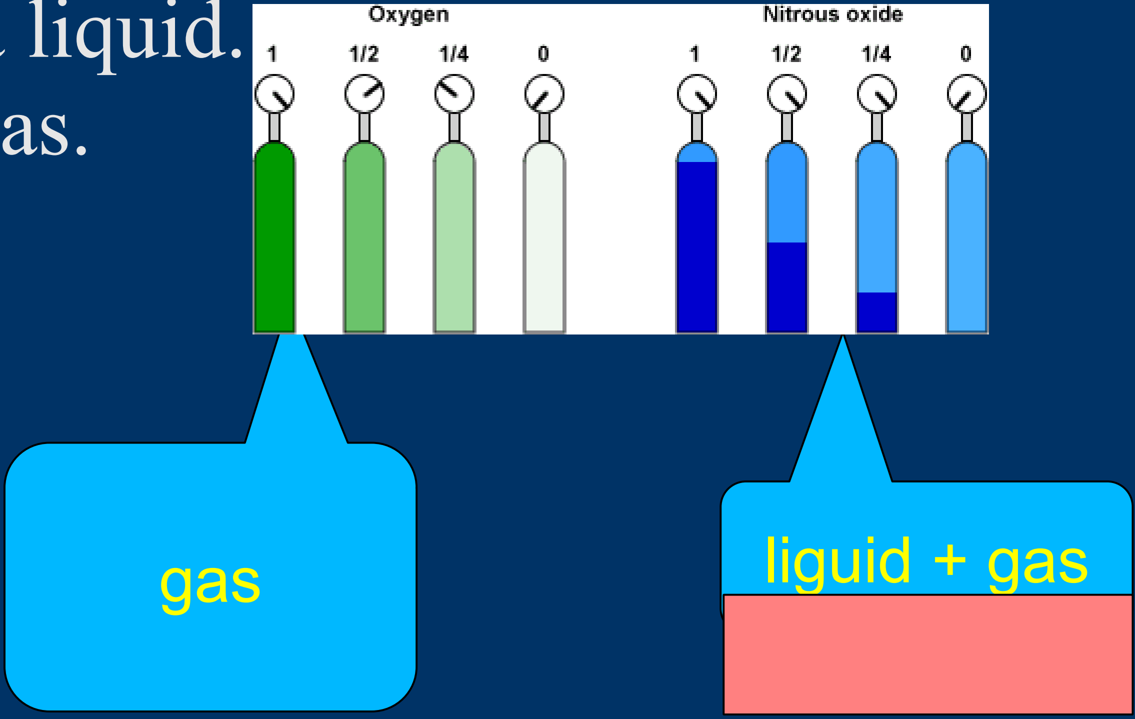
Stored as compressed gas.

N20 - blue

- pressure 5 MPa

Air white/gray

CO2 - gray



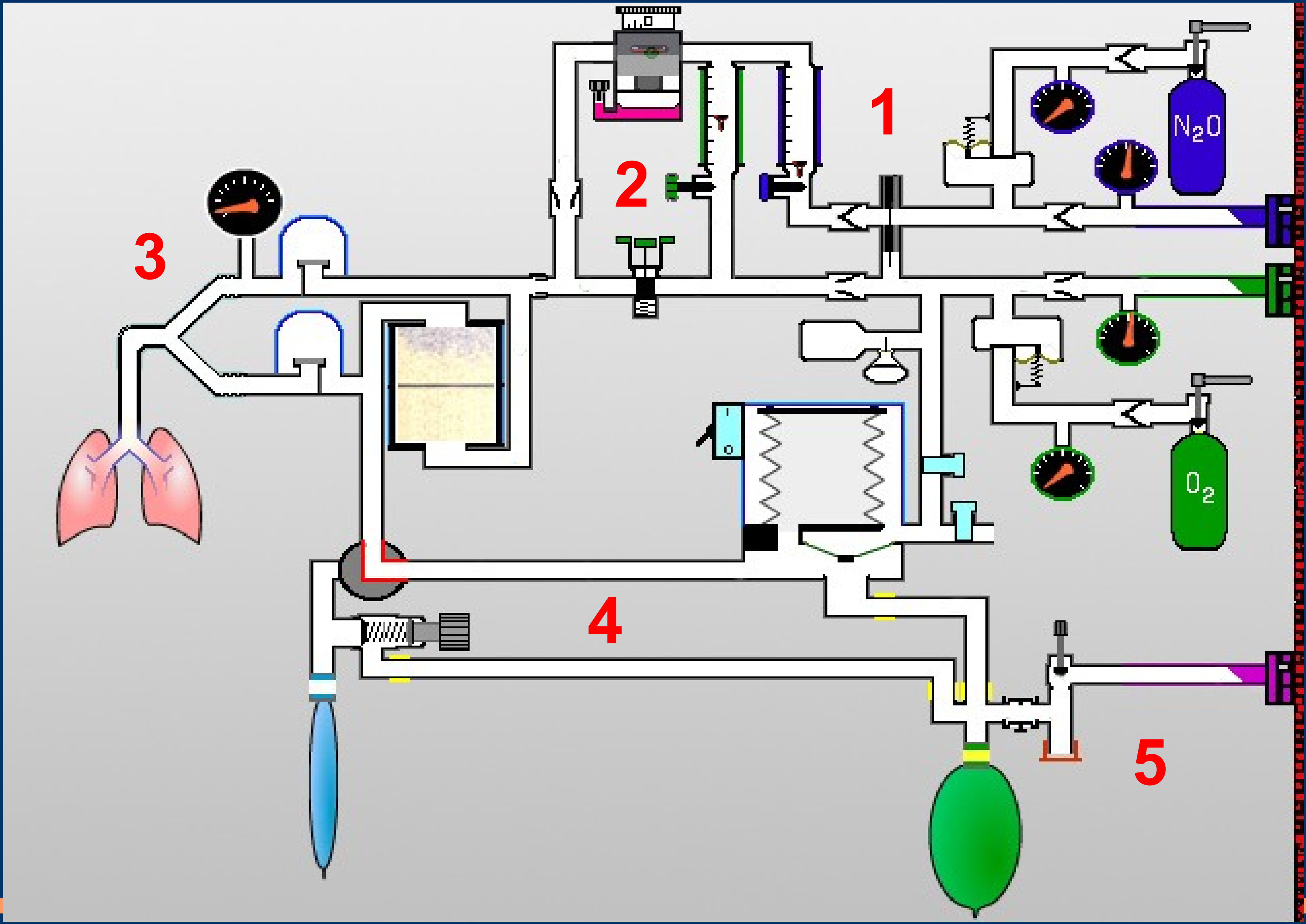
Anesthesia Machine

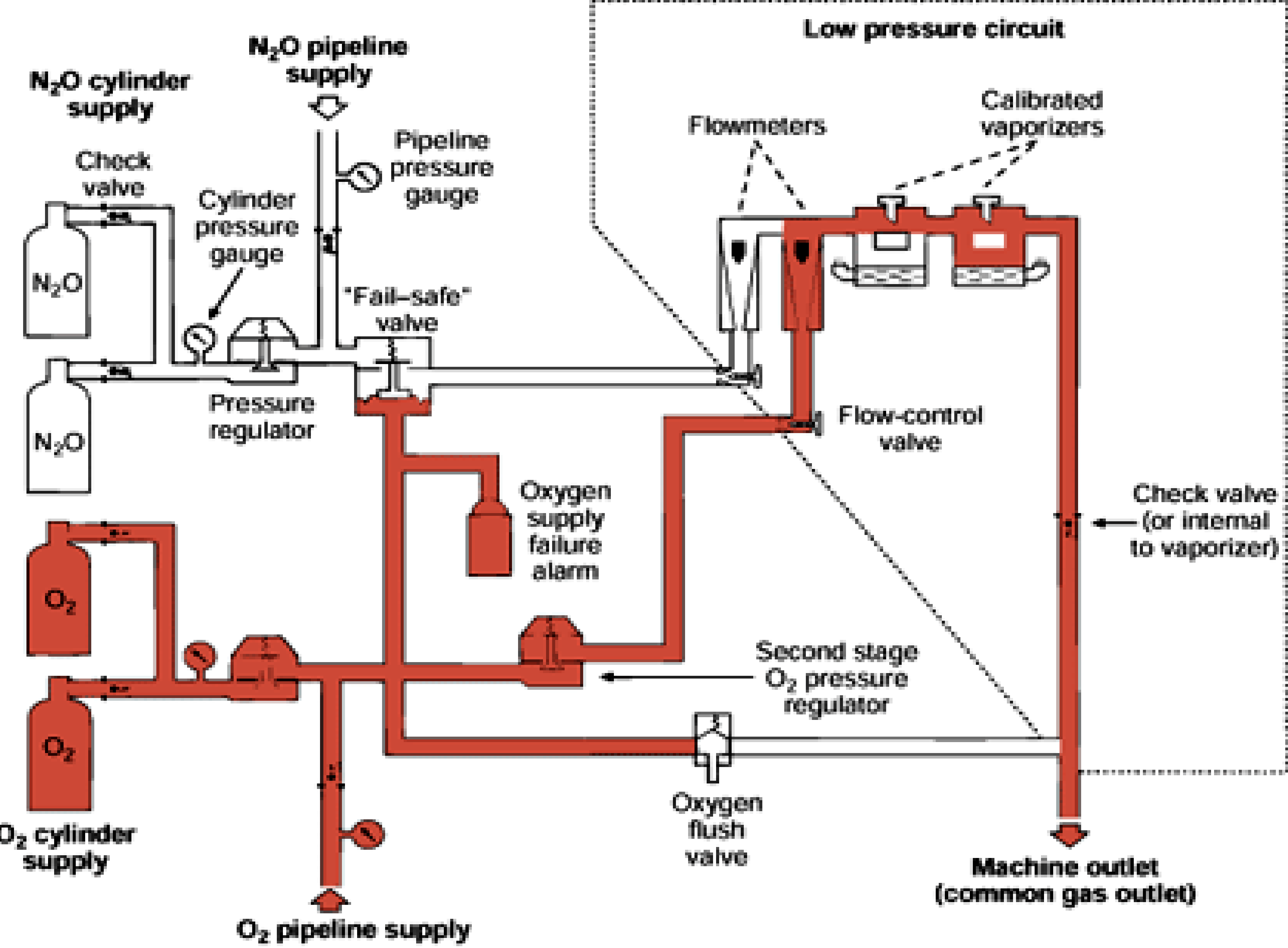
is able to ventilate the patient by defined mixture of gasses

Parts:

1. High pressure system
2. Low pressure system
3. Breathing circuit – in/expiratory part
4. Ventilation systems (manual and mechanical)
5. Scavenging system

Parts of anesth. machine

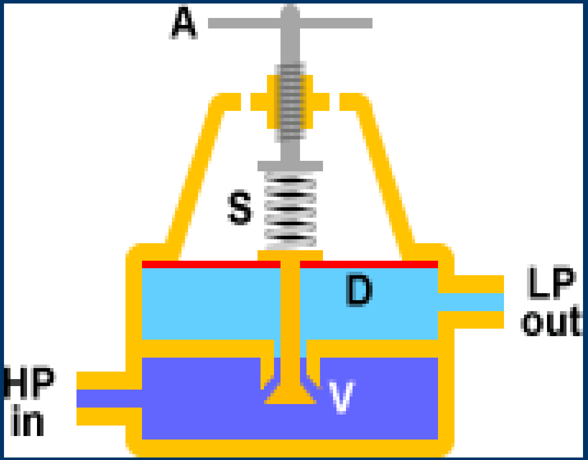



Low pressure circuit
N_2O pipeline supply
N_2O cylinder supply
Pipeline pressure gauge
Check valve
Cylinder pressure gauge
Flowmeters
Calibrated vaporizers
N_2O
"Fail–safe" valve
N_2O
Pressure regulator
Flow-control valve
Oxygen supply failure alarm
Check valve (or internal to vaporizer)
O_2
O_2
Second stage O_2 pressure regulator
Oxygen flush valve
O_2 cylinder supply
Machine outlet (common gas outlet)
O_2 pipeline supply

High pressure system

Compressed gas

- Cylinder Supply
- Pipeline Supply
- Oxygen Supply Pressure Failure Safety
  pO2 > pN2O
- Pressures regulator

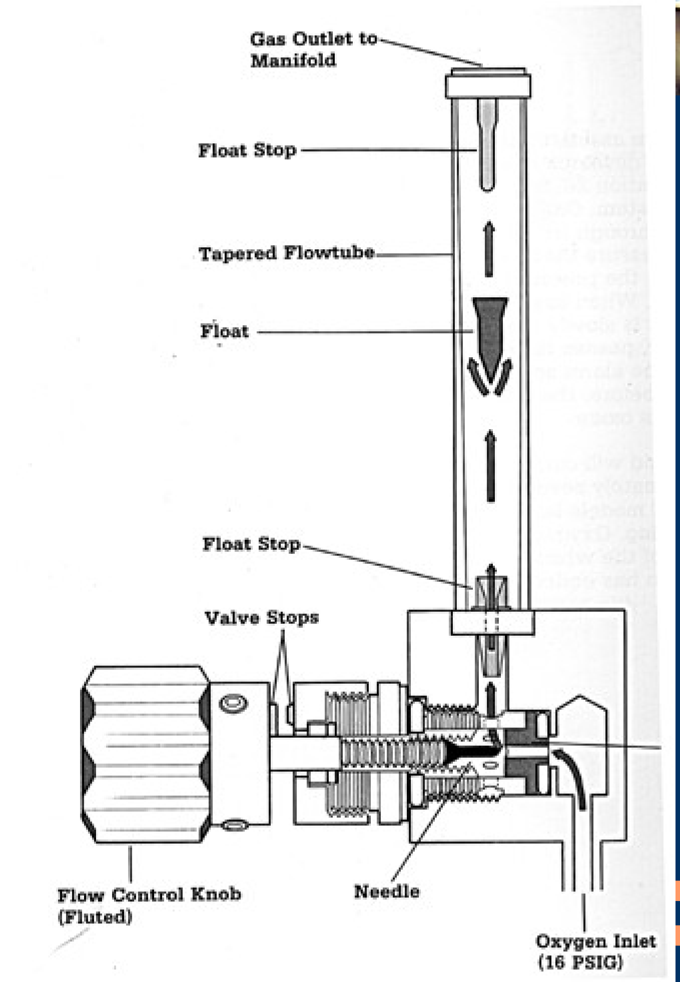


- manometr

Low pressure system

- flowmeter O2, AIR, N2O
- Oxygen flush valve = Bypass,
- Vaporizer
- APL valve

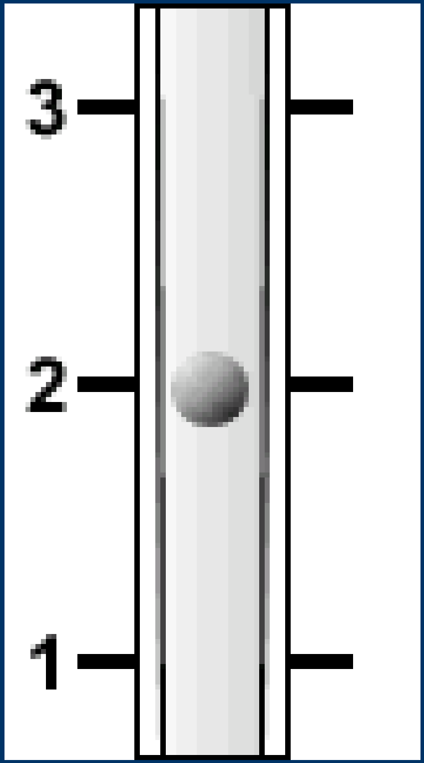
to deliver appropriate concentration, flow



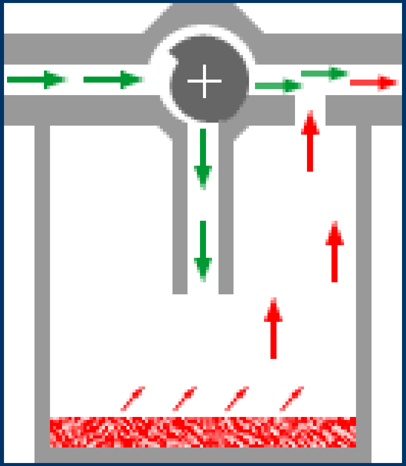
Flow of Anest. gasses

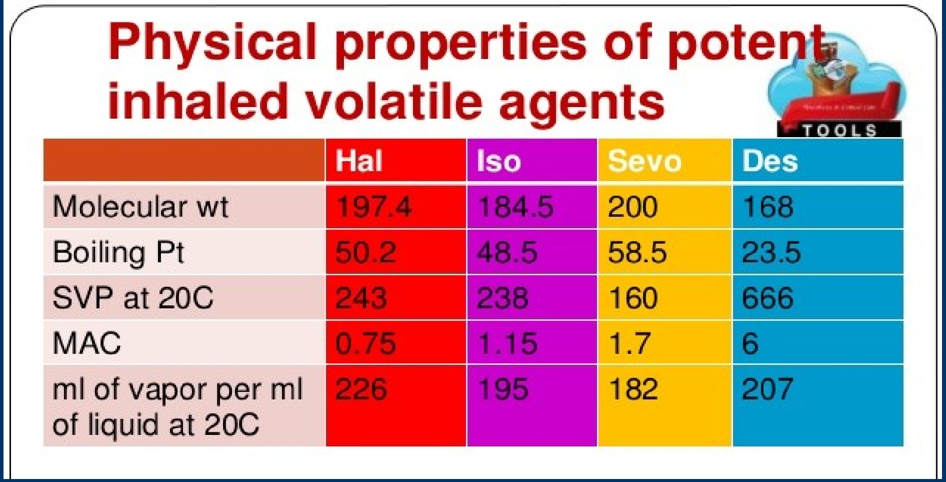
- old machines 2..4 l/min

- low flow > 1 l/min
- minimal flow > 0,5l/min
- closed system .. amount of metabolized O2



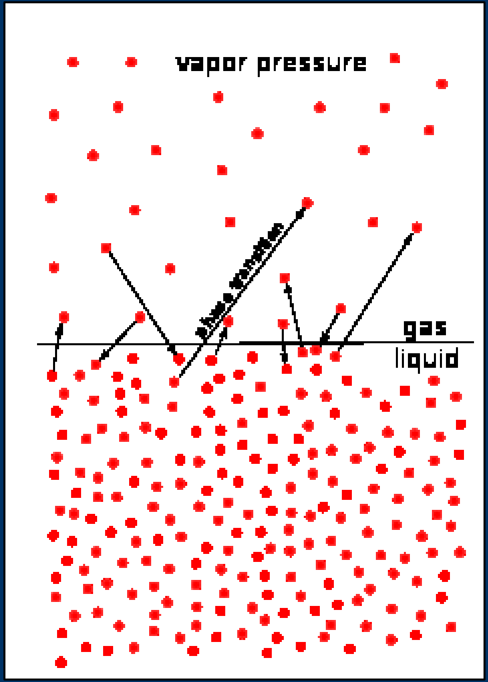
Vaporizer – easy model



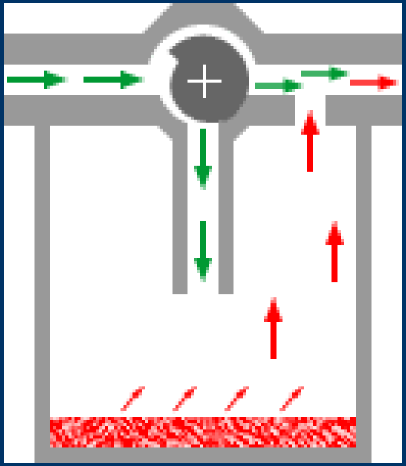


Physical properties of potent inhaled volatile agents

	Hal	Iso	Sevo	Des
Molecular wt	197.4	184.5	200	168
Boiling Pt	50.2	48.5	58.5	23.5
SVP at 20C	243	238	160	666
MAC	0.75	1.15	1.7	6
ml of vapor per ml of liquid at 20C	226	195	182	207



Vaporizers

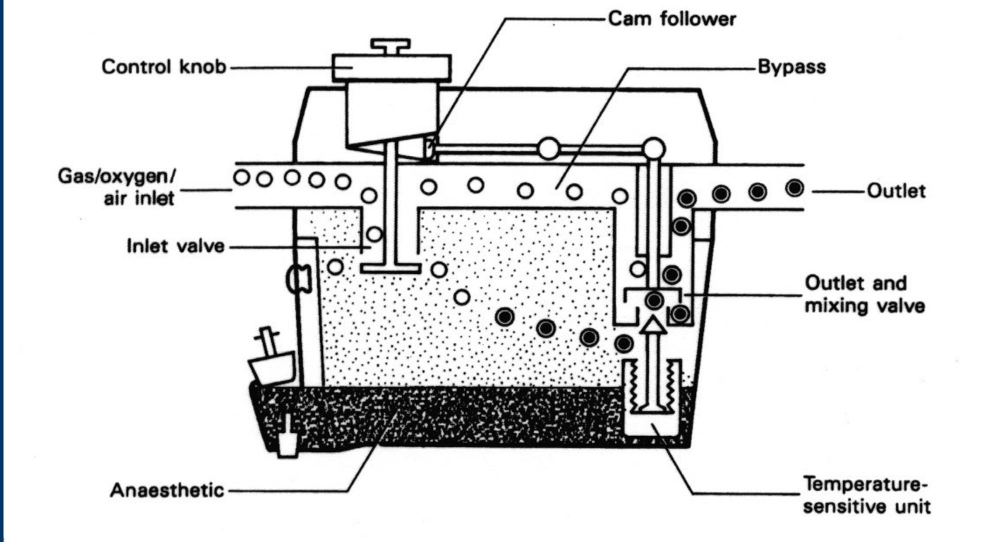


Energy is needed during evaporation.

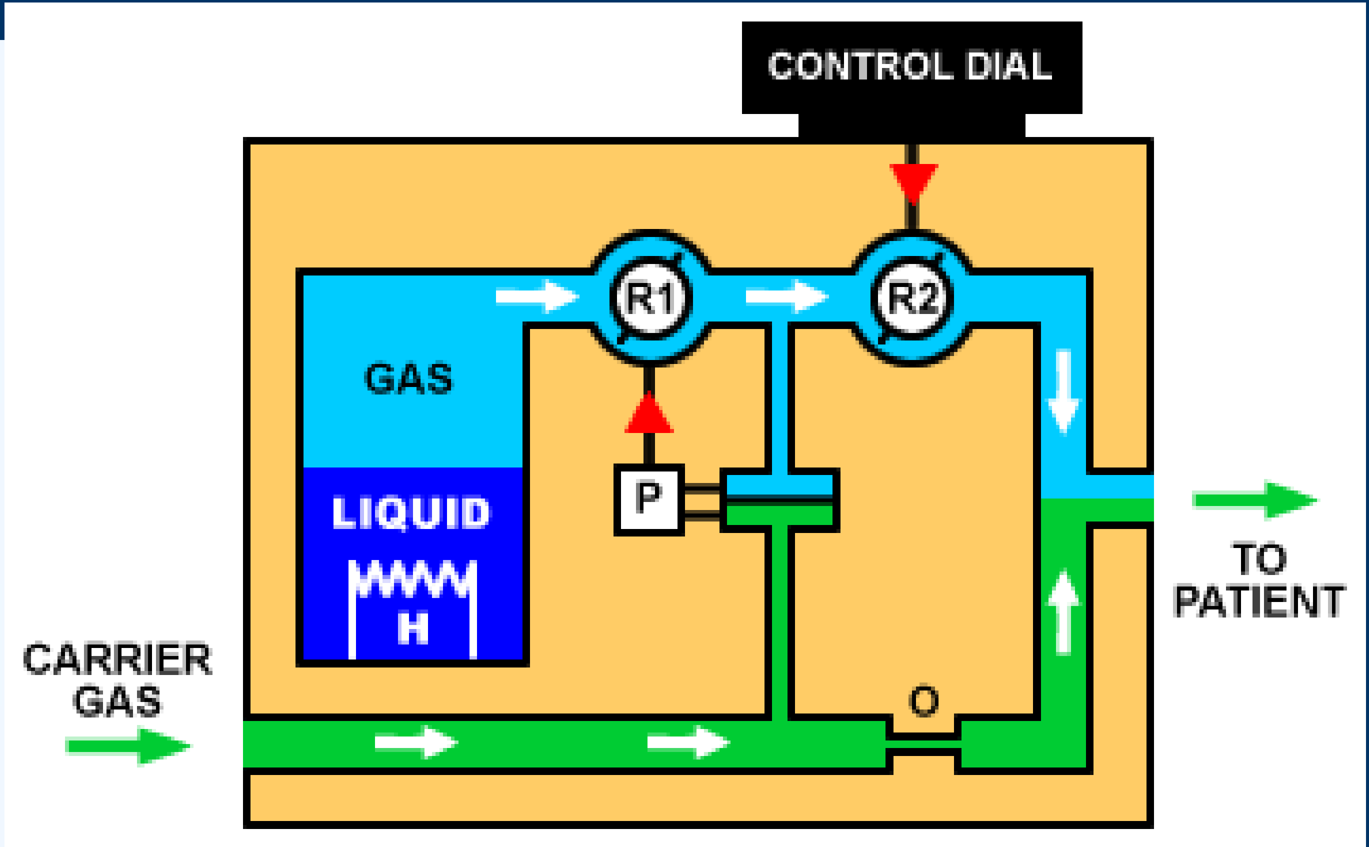
Q (termal energy from outside)

T (the gas temperature is lower at the outlet than at the inlet)

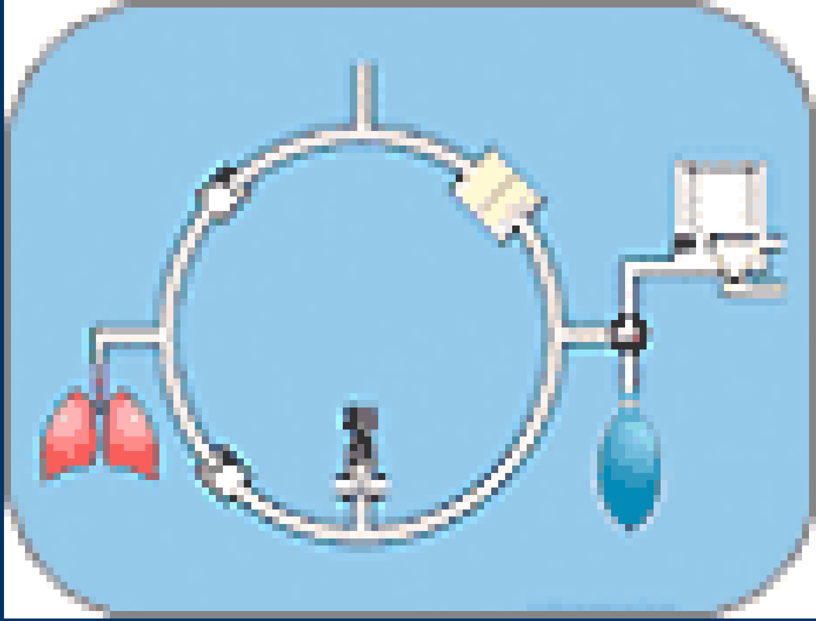
Compensation inside bimetal



Totaly different one … Desfluran

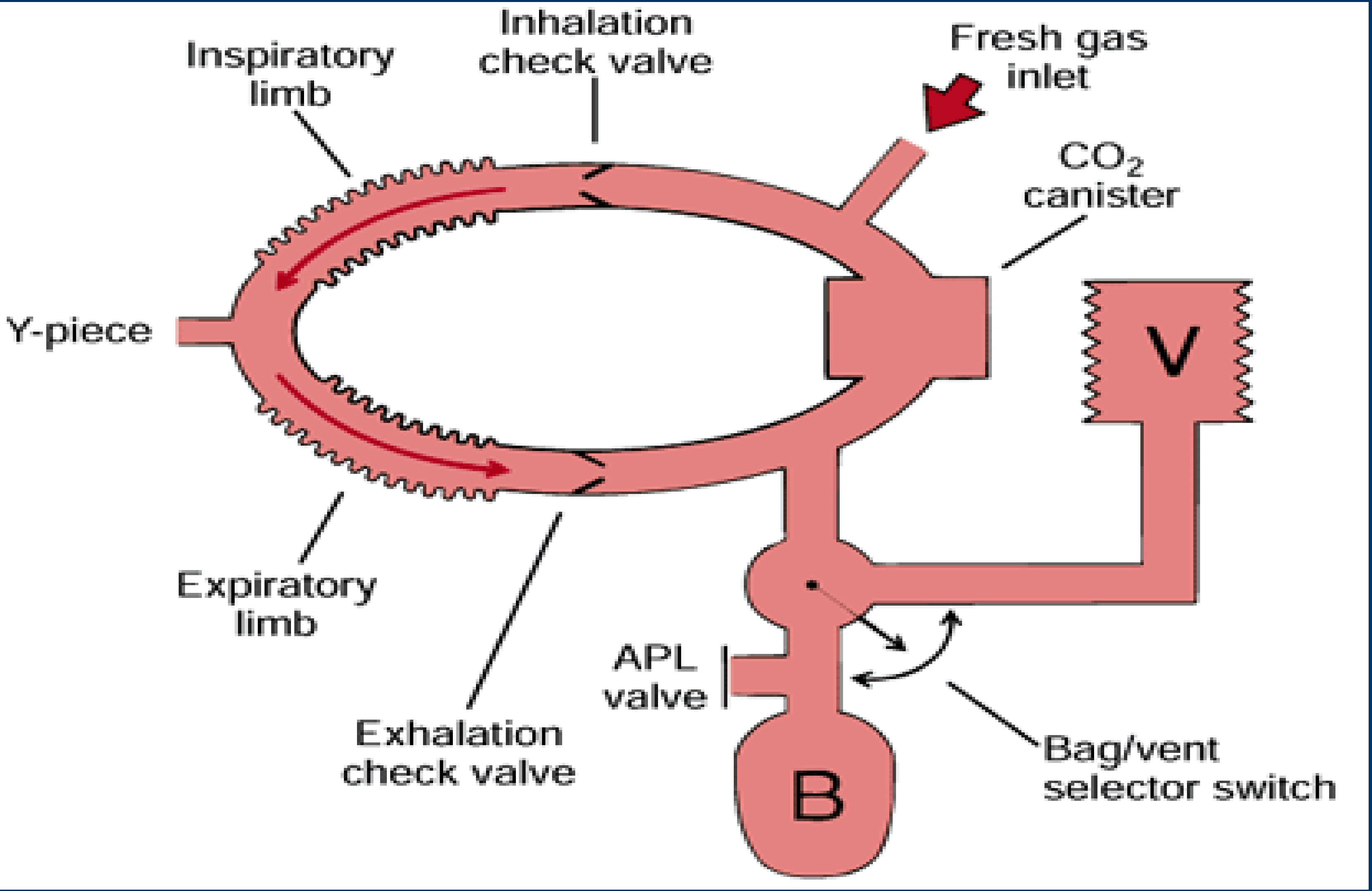


Breathing Circuit



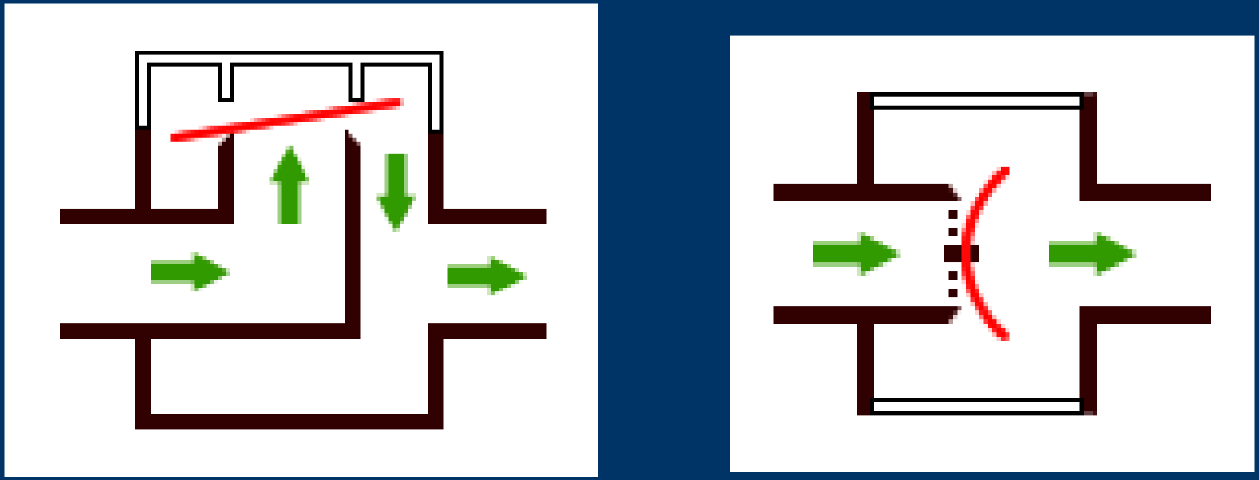
- inspiratory valve
- manometr
- Y connector
- expiratory valve
- volumetr
- CO2 absorber
- tubes
- APL valve

to rebreath expired gas without CO2 – low flow


Inhalation check valve
Inspiratory limb
Fresh gas inlet
CO_2 canister
Y-piece
V
Expiratory limb
Exhalation check valve
APL valve
B
Bag/vent selector switch

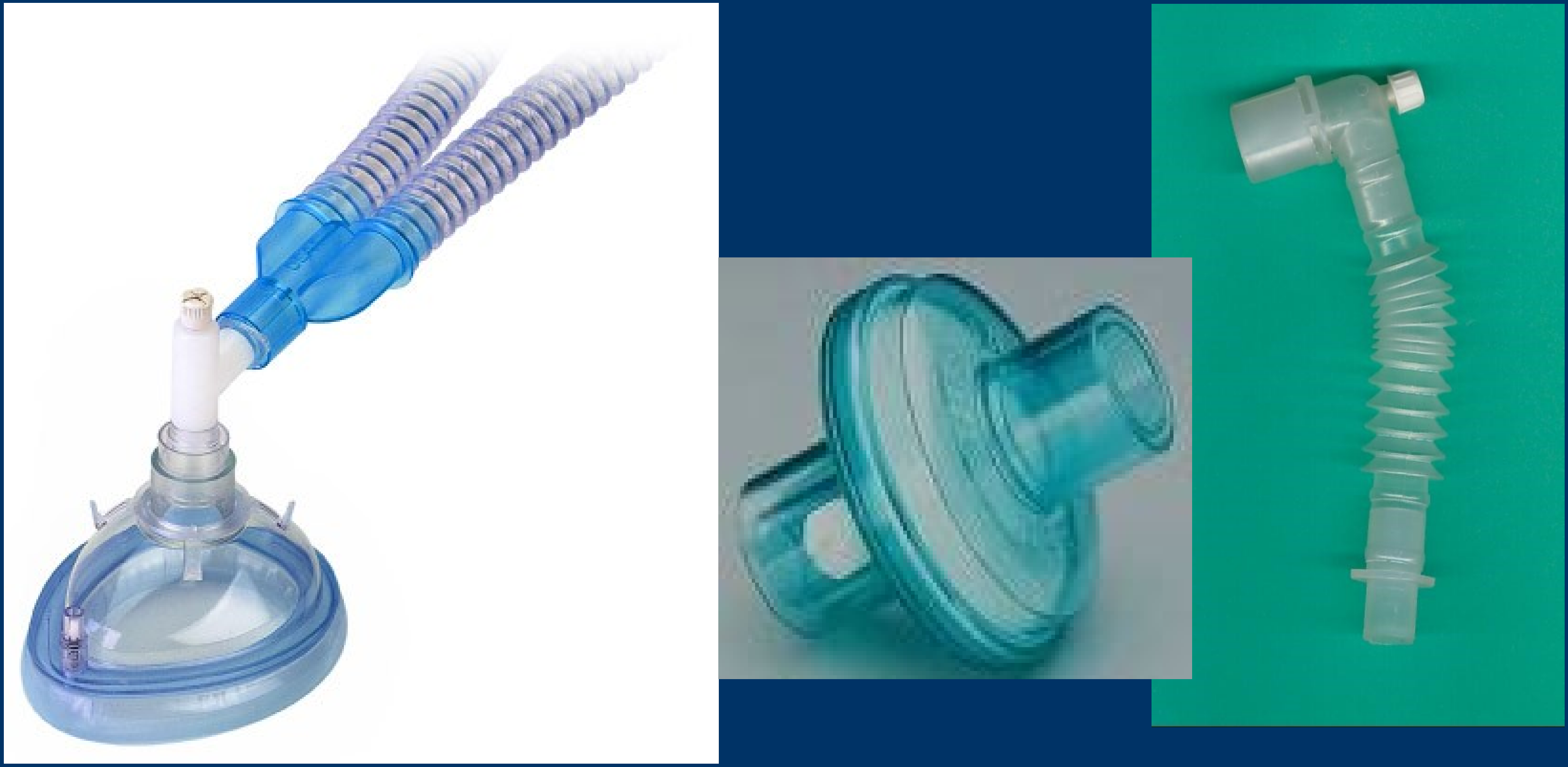
inspiratory + exp. valve

1 dirrection flow

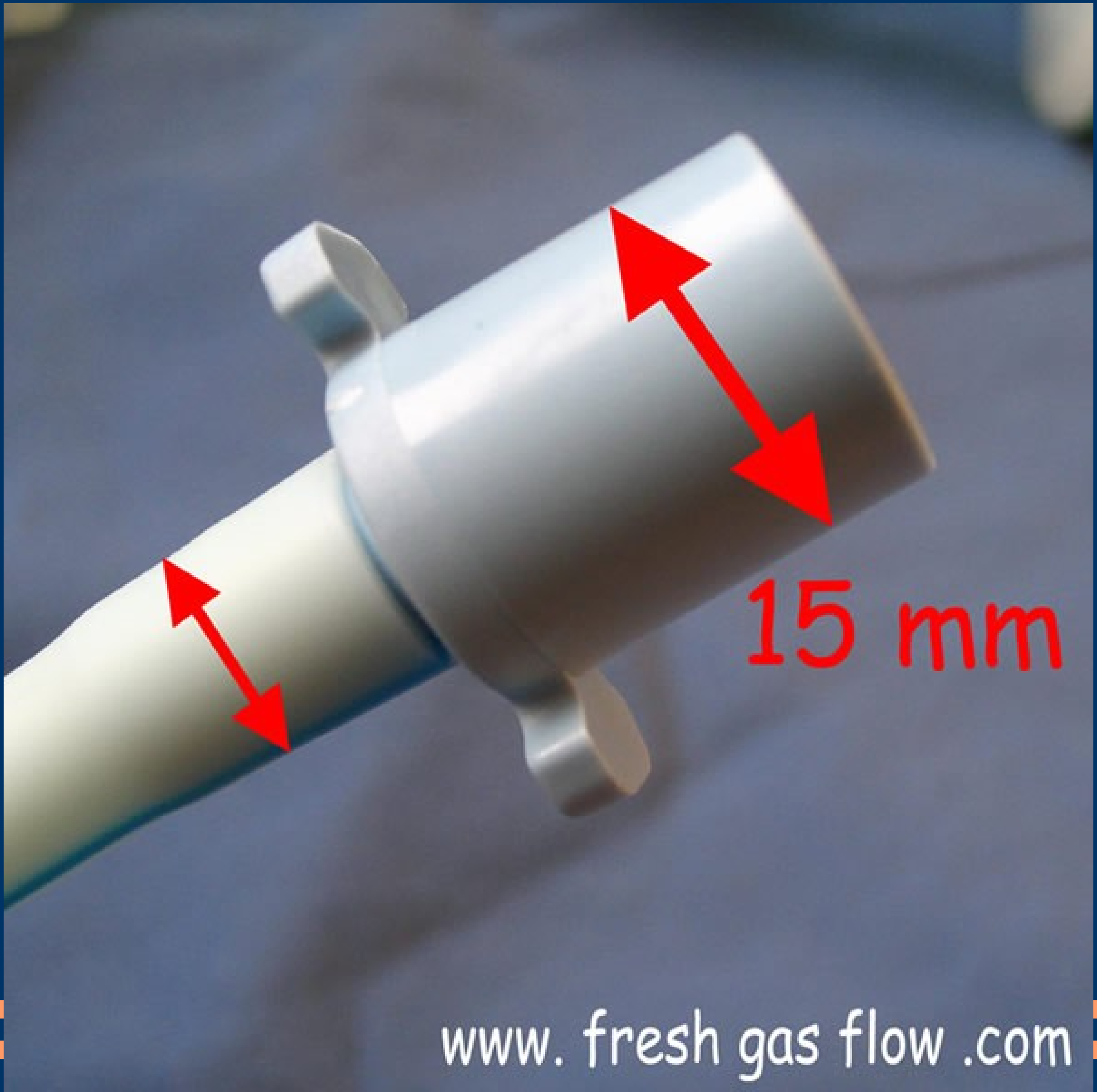


manometr

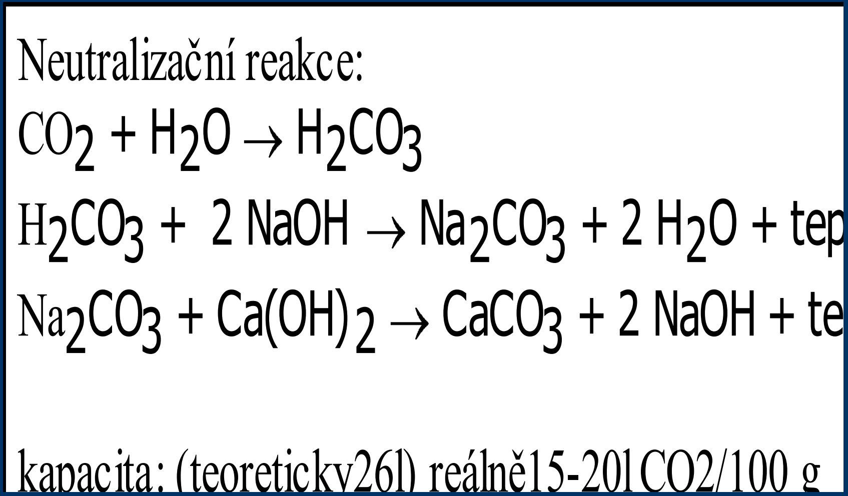
Y connector, filter, tubing



ISO



CO2 absorber



Neutralizační reakce:

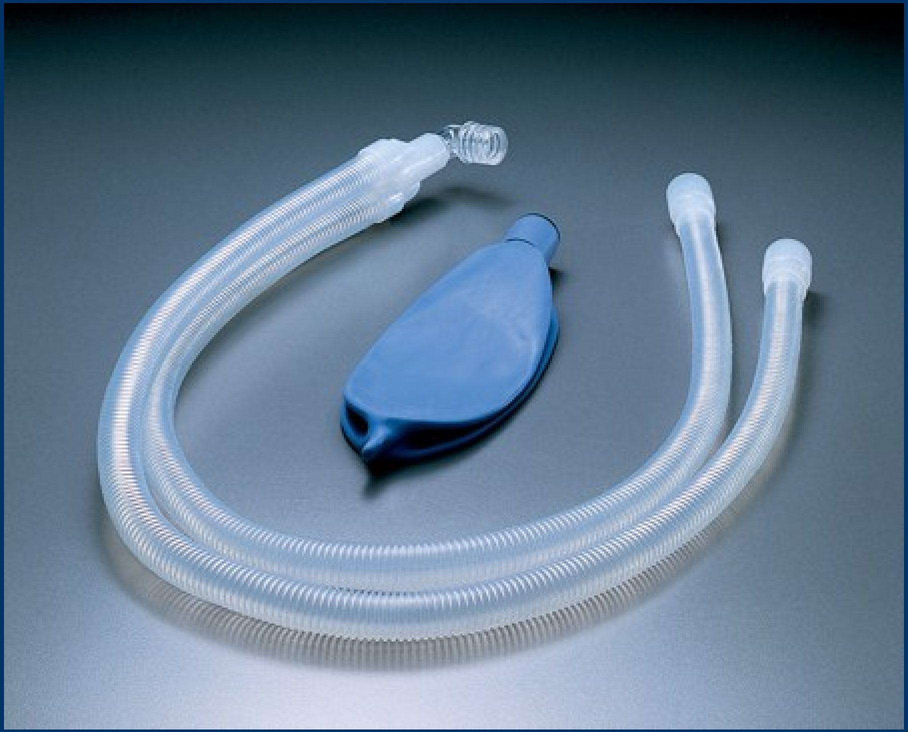
$CO_2 + H_2O \rightarrow H_2CO_3$

$H_2CO_3 + 2\ NaOH \rightarrow Na_2CO_3 + 2\ H_2O +$ tep

$Na_2CO_3 + Ca(OH)_2 \rightarrow CaCO_3 + 2\ NaOH +$ te

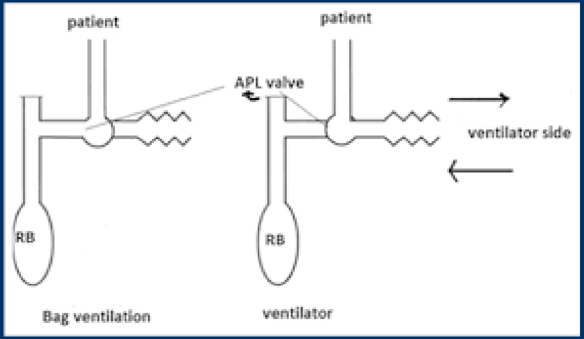
kapacita: (teoreticky26l) reálně15-20l CO2/100 g

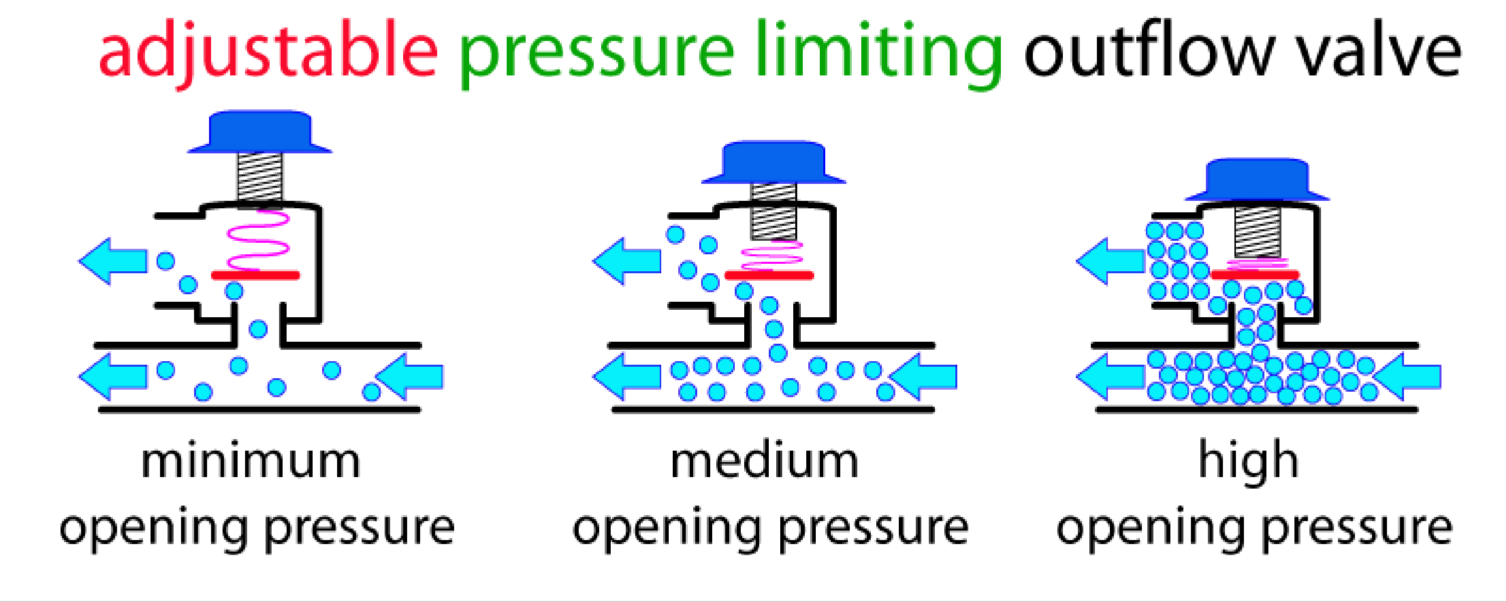
tubing



APL

Works during manual ventilation only



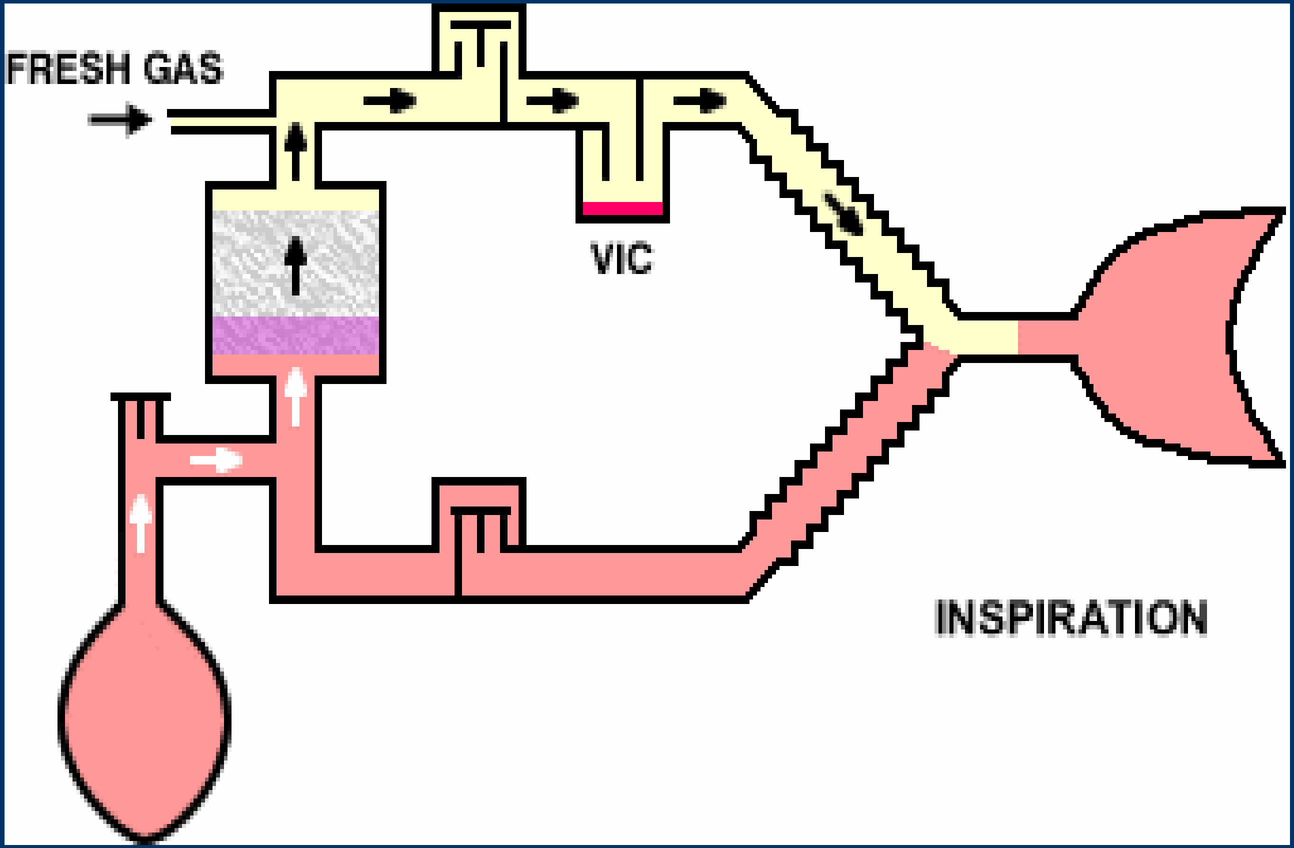


howequipmentworks.com

Adjustable Pressure Limiting valve

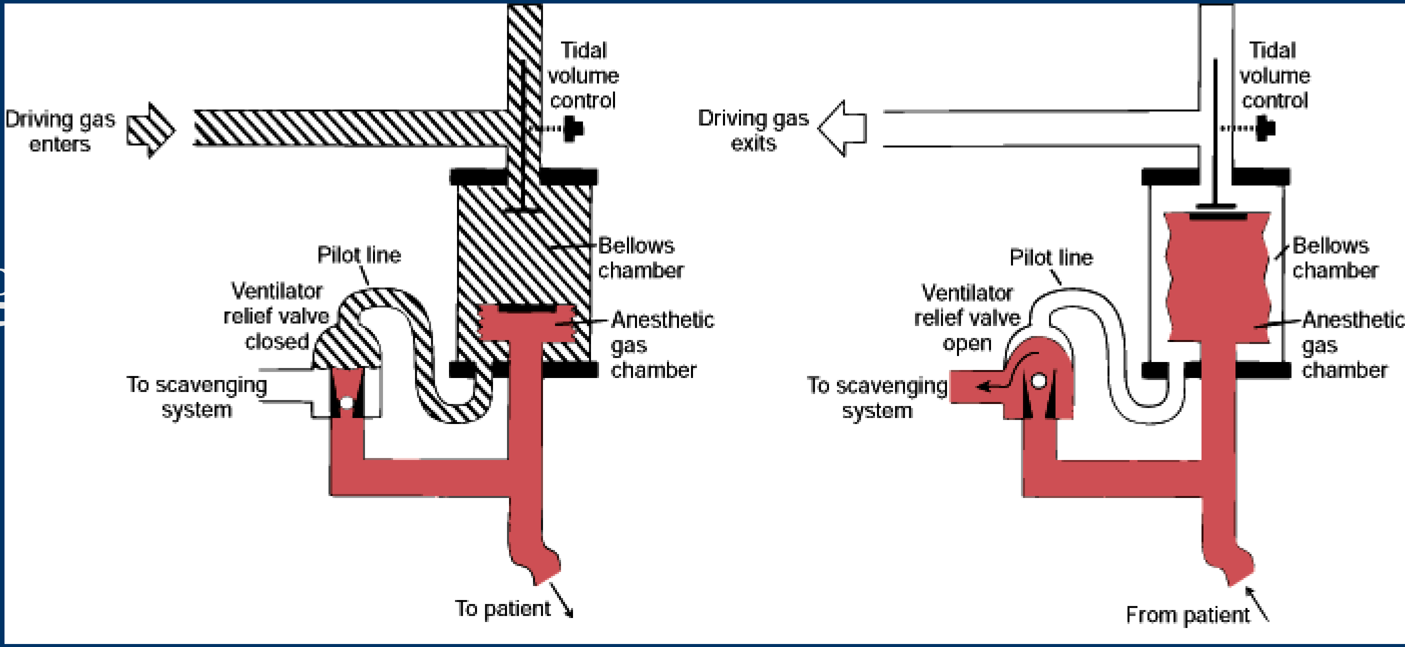
- (APL, "pop-off" valve)
- is located at a position such that it is in pneumatic conection with the breathing circuit only during manual ventilation
- limits the amount of pressure buildup that can occur during manual ventilation. When the user adjusts the APL valve to trap more gas inside the breathing circuit, a spring inside the APL valve is compressed according to how much the user turns the APL valve. The degree of spring compression exerts a proportional force on a sealing diaphragm in the APL valve. The pressure inside the breathing circuit must generate a force that exceeds the spring compression force for the APL valve to open. As pressure continues to build from the combination of fresh gas flow and manual compression of the breathing bag, the opening pressure of the APL valve will be exceeded and excess gas will be vented to the scavenging system.

Breathing Circuit

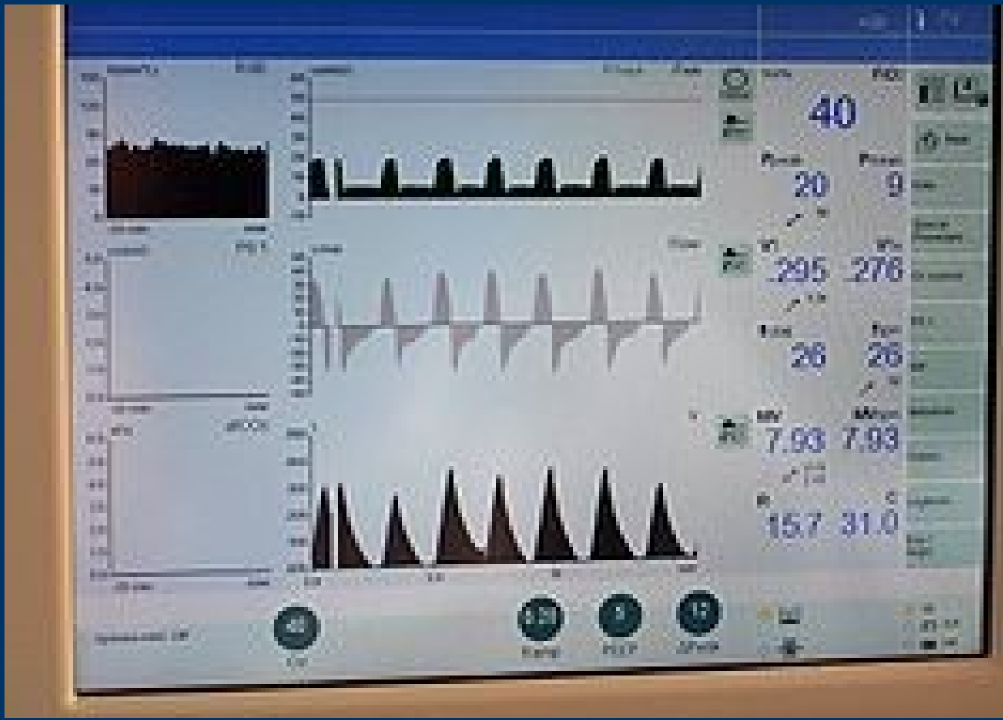


Ventilation system

- ventilator (bellow, chamber)
  (Volum Controled Ventilation, (PCV)
  Vt 6 (..10) ml/kg,
  f according EtCO2,
  PEEP 5
  fiO2 40%
  I:E 1:2
- manualy - bag



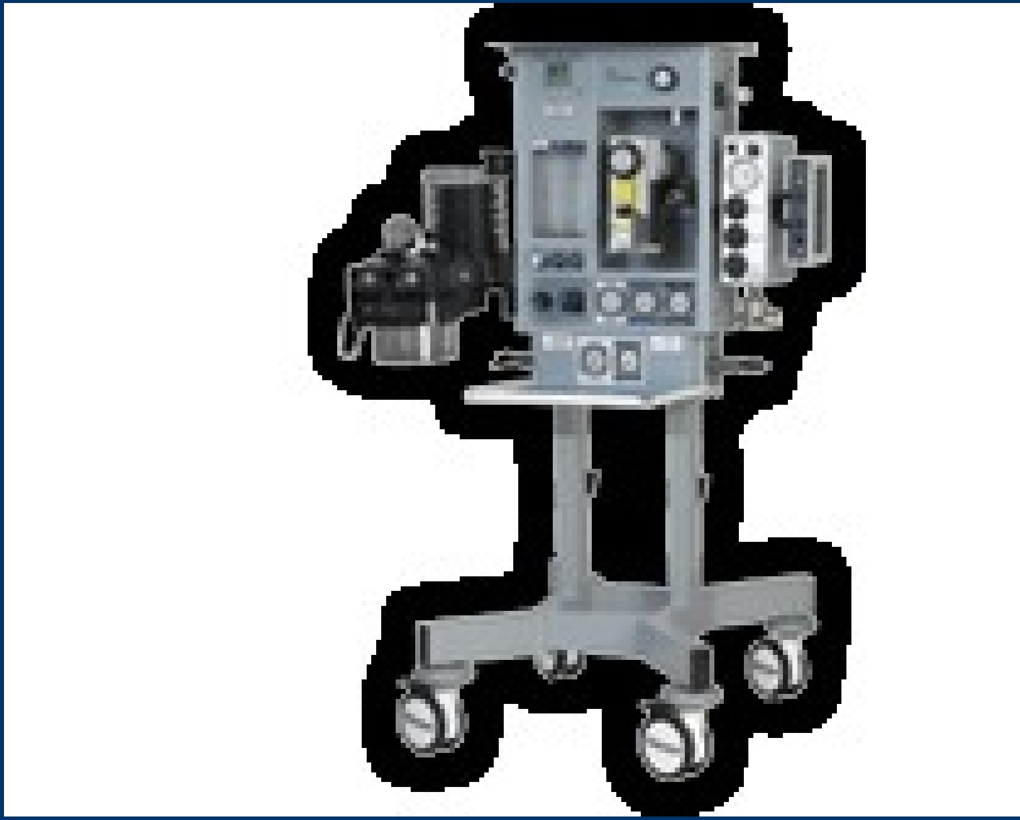
Ventilation system



- power source
  - gas
  - electricity
  - both

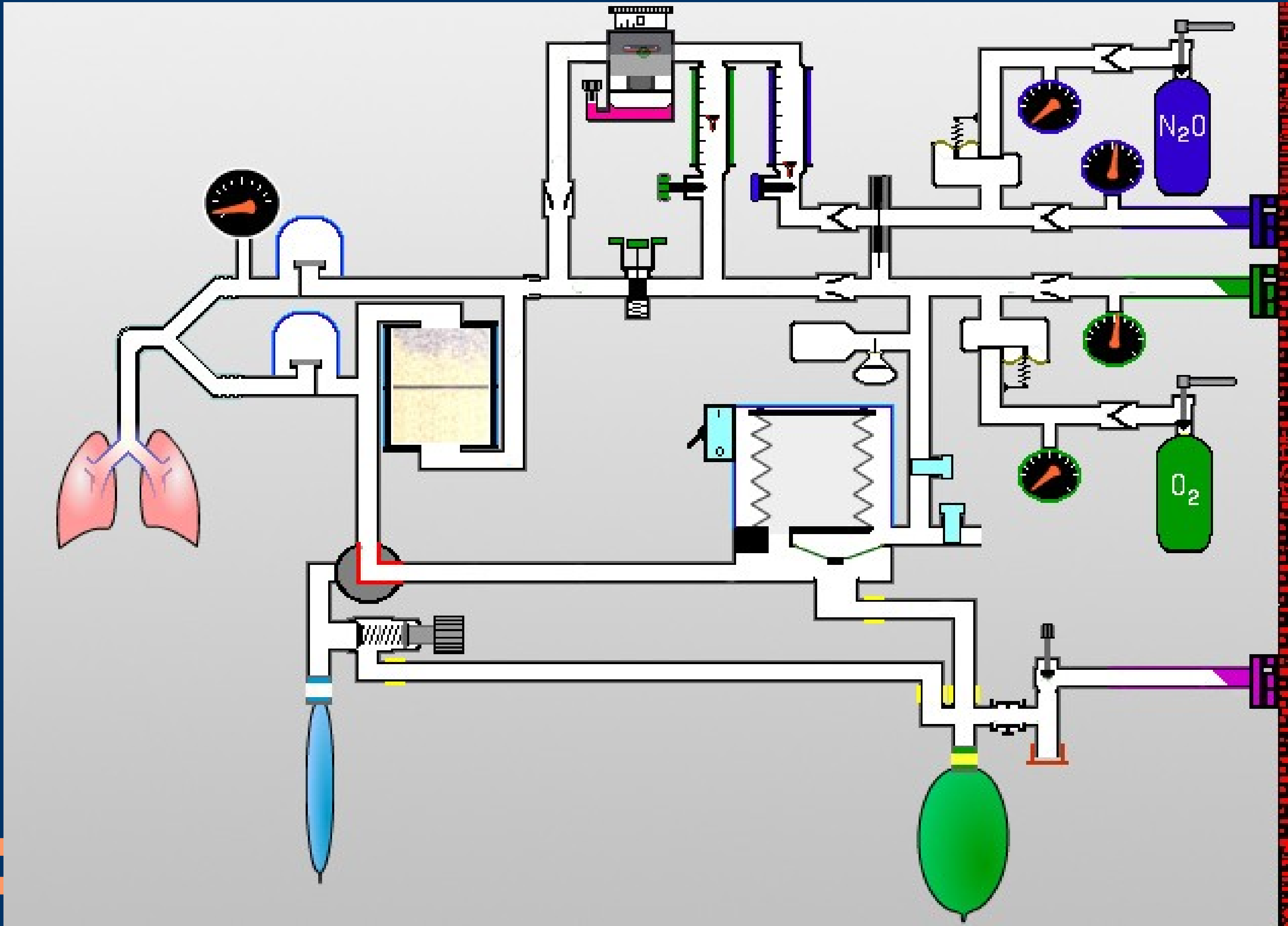
- Drive Mechanism, Circuit degign
  - double-circuit ventilator (patient and drive gas)

Bellow

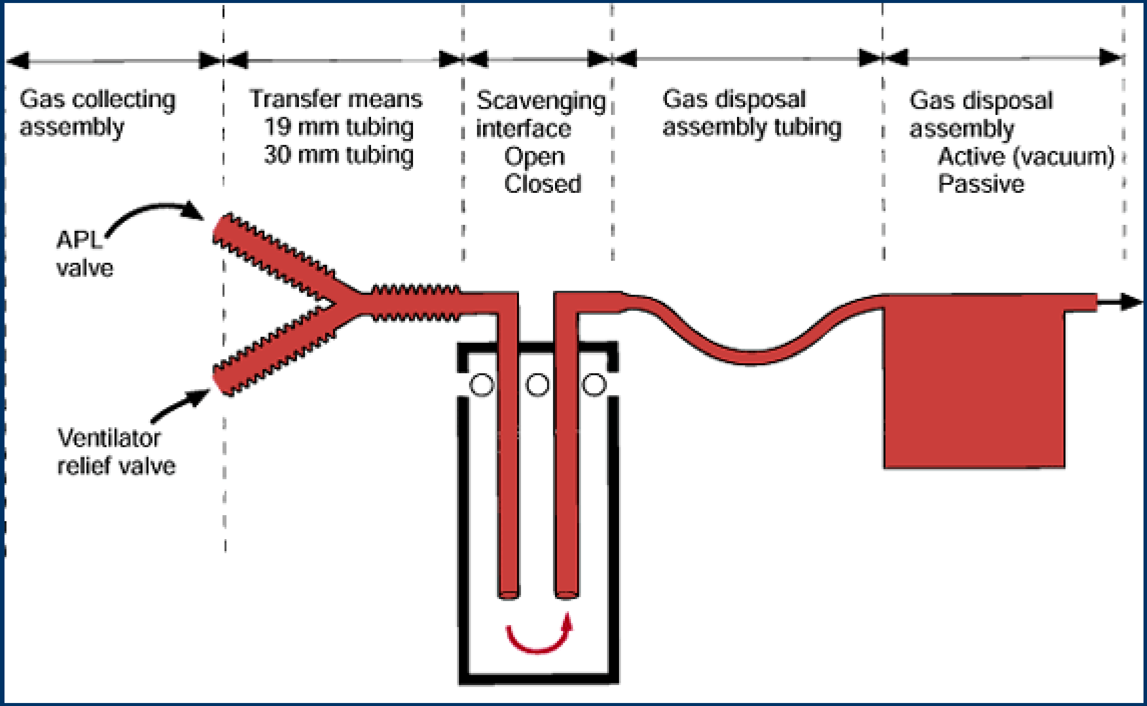


Scavenging system

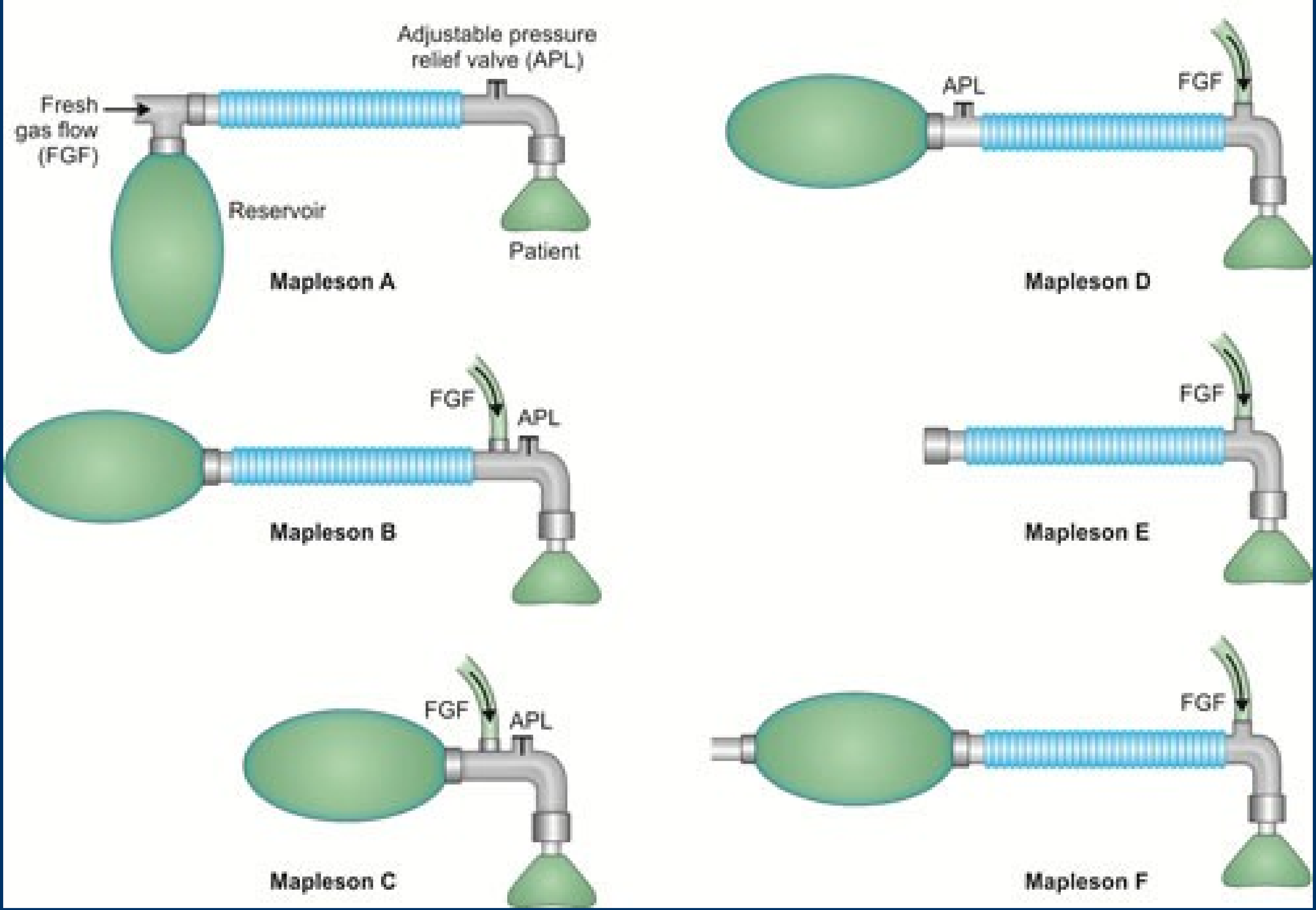
- Keep clean OR atmosphere

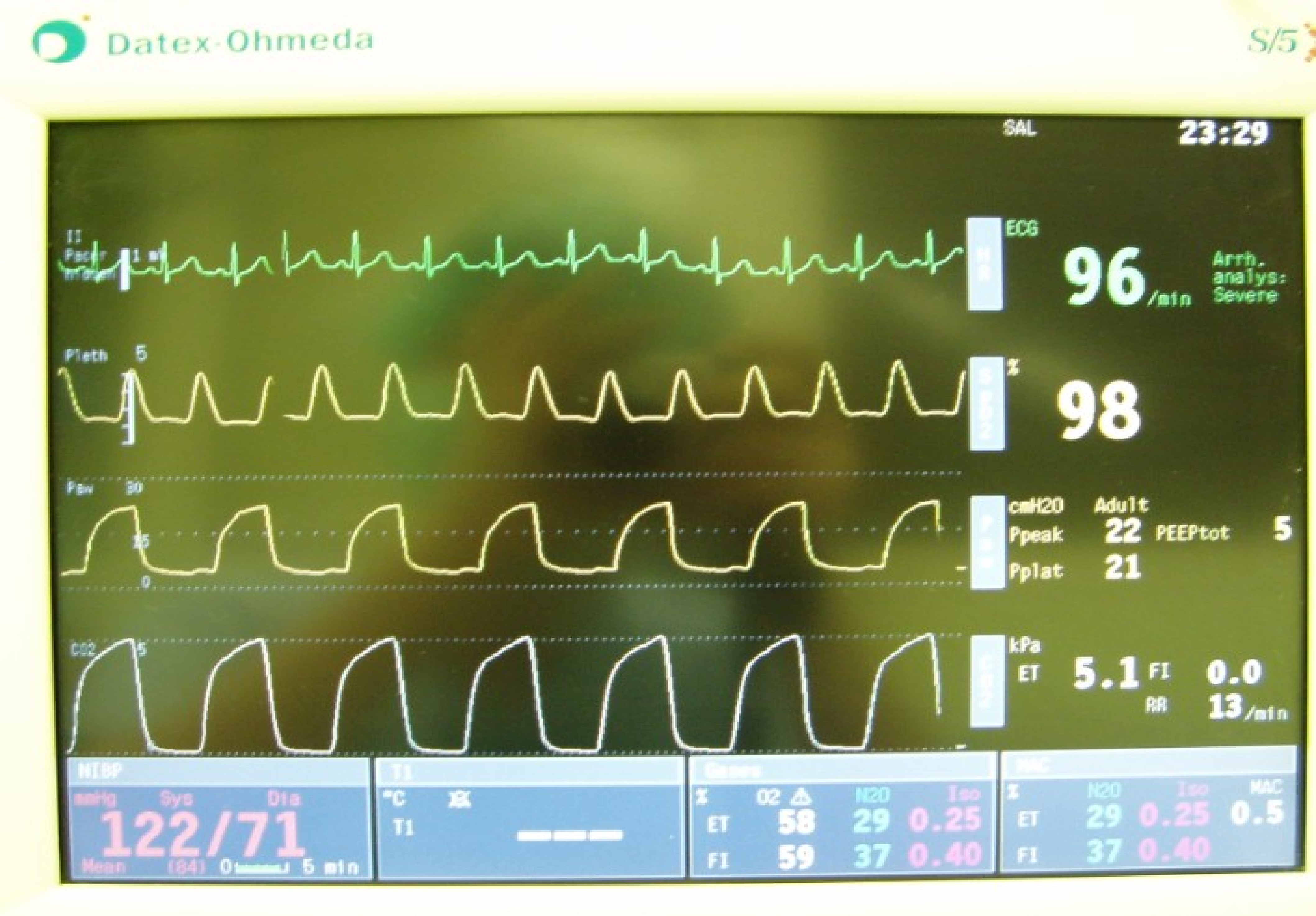


Scavenging system



Non rebreathing systems (do not learn)




Datex-Ohmeda
S/5
SAL
23:29
II
Pacer
1 mV
ECG
HR
96 /min
Arrh. analys: Severe
Pleth 5
SpO2
%
98
Paw 30
15
0
cmH2O Adult
Ppeak 22 PEEPtot 5
Pplat 21
CO2 5
kPa
ET 5.1 FI 0.0
RR 13 /min
NIBP
mmHg Sys Dia
122/71
Mean (84) 0 5 min
T1
°C
T1 ----
Gases
% O2 N2O Iso
ET 58 29 0.25
FI 59 37 0.40
MAC
% N2O Iso MAC
ET 29 0.25 0.5
FI 37 0.40

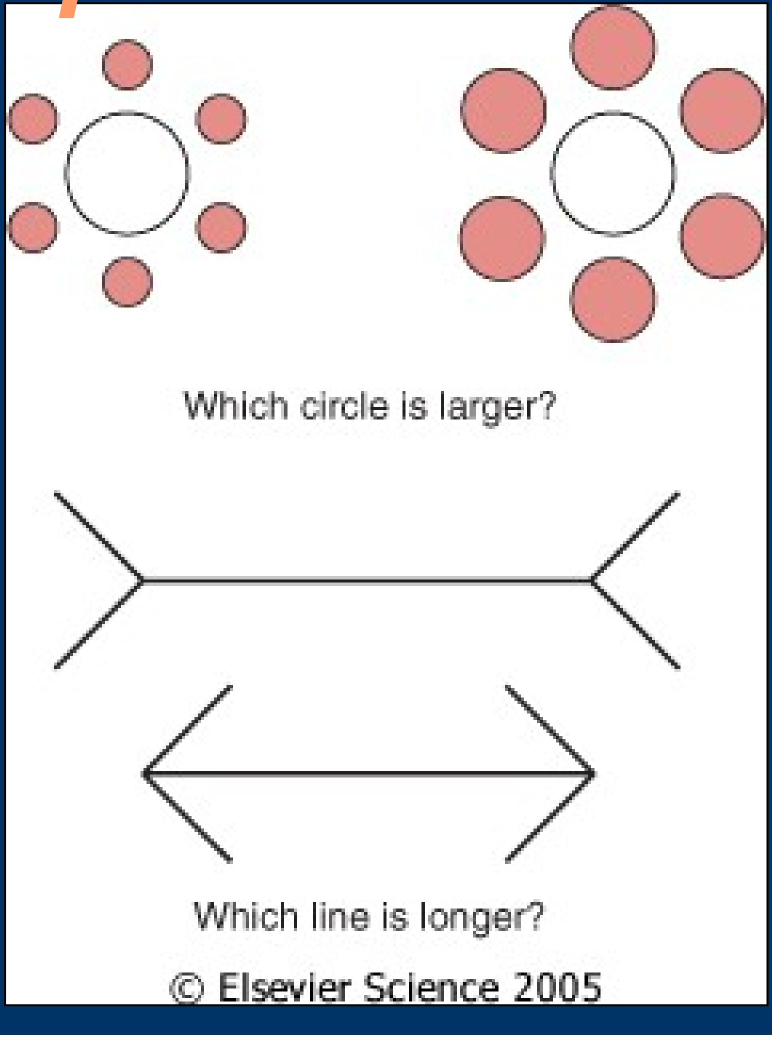
Monitoring system

monere, "to warn"

systematic control

Patient monitoring has been a key aspect of anesthesiology since its beginnings as a medical specialty.

Optical illusions



… it is not possible without eye

Figure 30-1 Optical illusions. We perceive the circles to be different sizes because we infer the size by relative dimensions. The closeness of the smaller circles makes the inner circle appear smaller, and vice versa. The lines appear to be different sizes because we use straight-line perspective to estimate size and distance. This illusion reportedly does not work in cultures where straight lines are not used. Therefore, our internal perceptions lead us to err in estimating size and length. In the same way, the internal programming of our monitors can lead us to misinterpret results.

Monitoring

1) Presence of anesth. / nurse

- Airway + Breathing
  - patent A.
  - quality of B., auscultation
- Circulation
  - quality, f, CRT, color of skin, BP
- depth of A.
  - pupils, sweating, movement

Goal: prevent problem

>>>> *Alarm* <<<<

< ?? What should I do ??>

- notice
- interpret
- reaction = change something
  - alarm off?
  - change limits of alarm?

Auscultator

+ available

- ventilatory problem (bronchospasm, laryngospasm - LM)

- SpO2, EtCO2, ECG detect problem easier than continual auscultation.

Basic monitoring in case of Fail of Anest. Machine

Manometr

- Pressure in cuff
  (tr. tube / TS kanyla)
  … 20 cm H2O

- Pressure in SGD cuff (LM, LT)
  < 60 cm H2O

ECG

- Heart Frequency
- rhytm
- extrasystols
- ST
  - ischemia

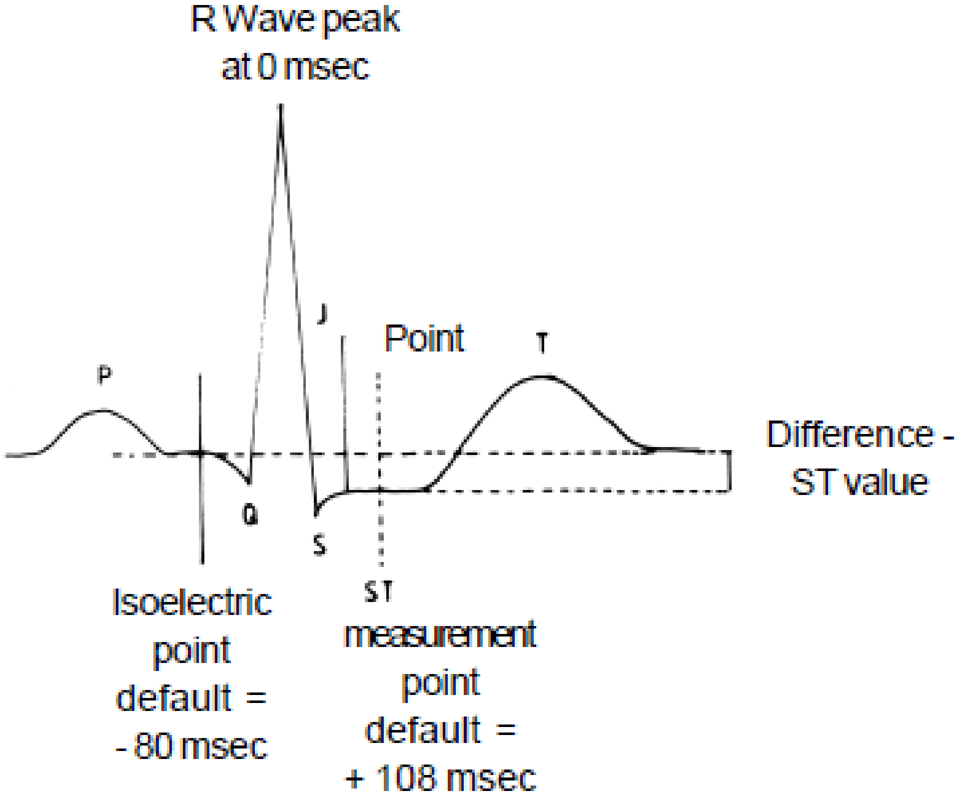


Fig - 4 : Adjustable reference points for automated ST segment analysis

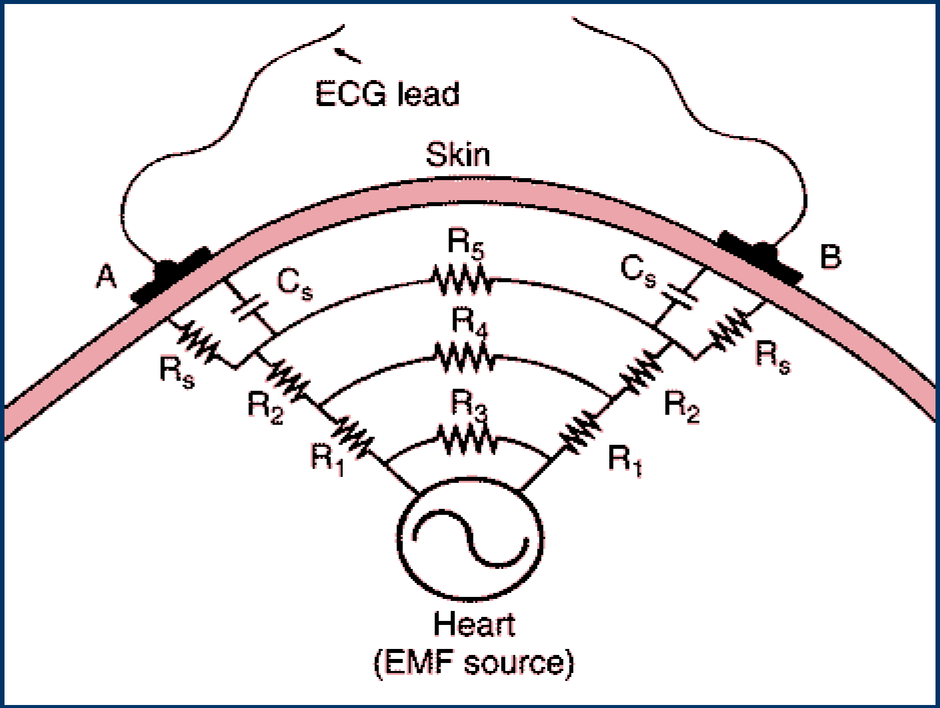
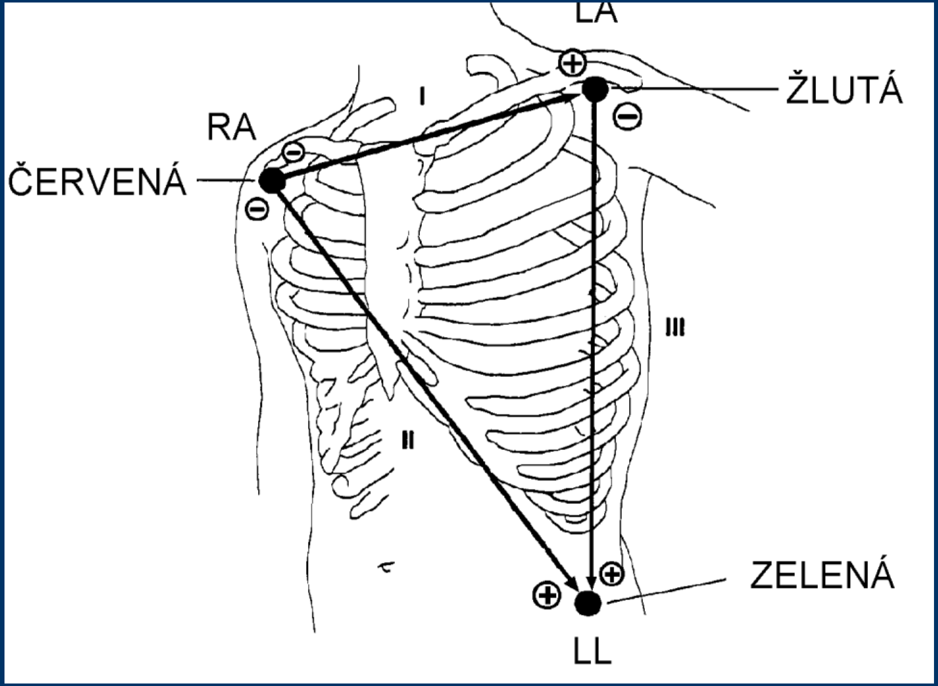
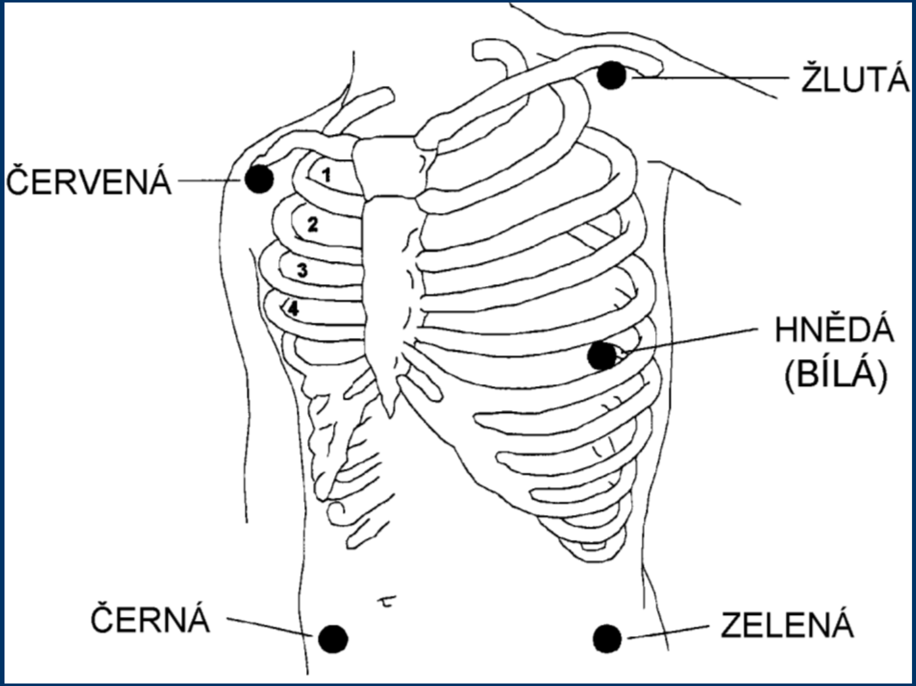


FIGURE 28–30 Why the ECG is so small. Multiple resistances and capacitances in the body decrease the potential and distort the waveform before the EMF reaches the surface.

Positioning of electrodes





sinus rythm

Obr. 2a: *Sinusová tachykardie*

Obr. 2b: *Sinusová bradykardie*

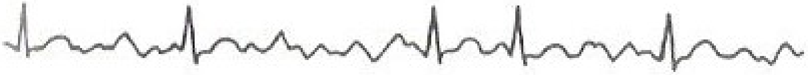
SVT: (no P, QRS narrow, regular)

Obr. 2c: *Supraventrikulární tachykardie*

Fibrilation of Atrii

irregular , QRS narrow

Obr. 2d: *Fibrilace síní – jemnovlnná*

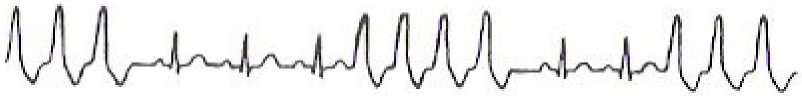


Obr. 2e: *Fibrilace síní – hrubovlnná*

Obr. 2f: *Flutter síní*

Ventricular rythm

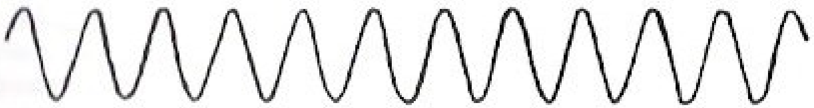
Obr. 2g: *Komorová tachykardie*



Obr. 2h: *Repetitivní komorová tachykardie*

Obr. 2j: *Preterminální stahy*

Obr. 2k: *Terminální stahy*

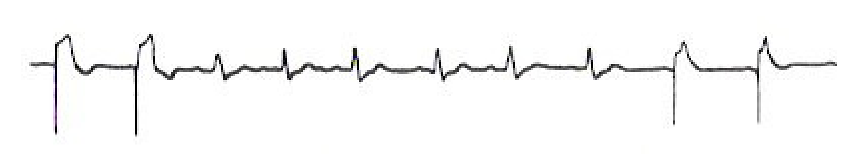


Obr. 2l: *Flutter komor, příp. rychlá komorová paroxyzmální tachykardie*

Stimulation

spike, komplex

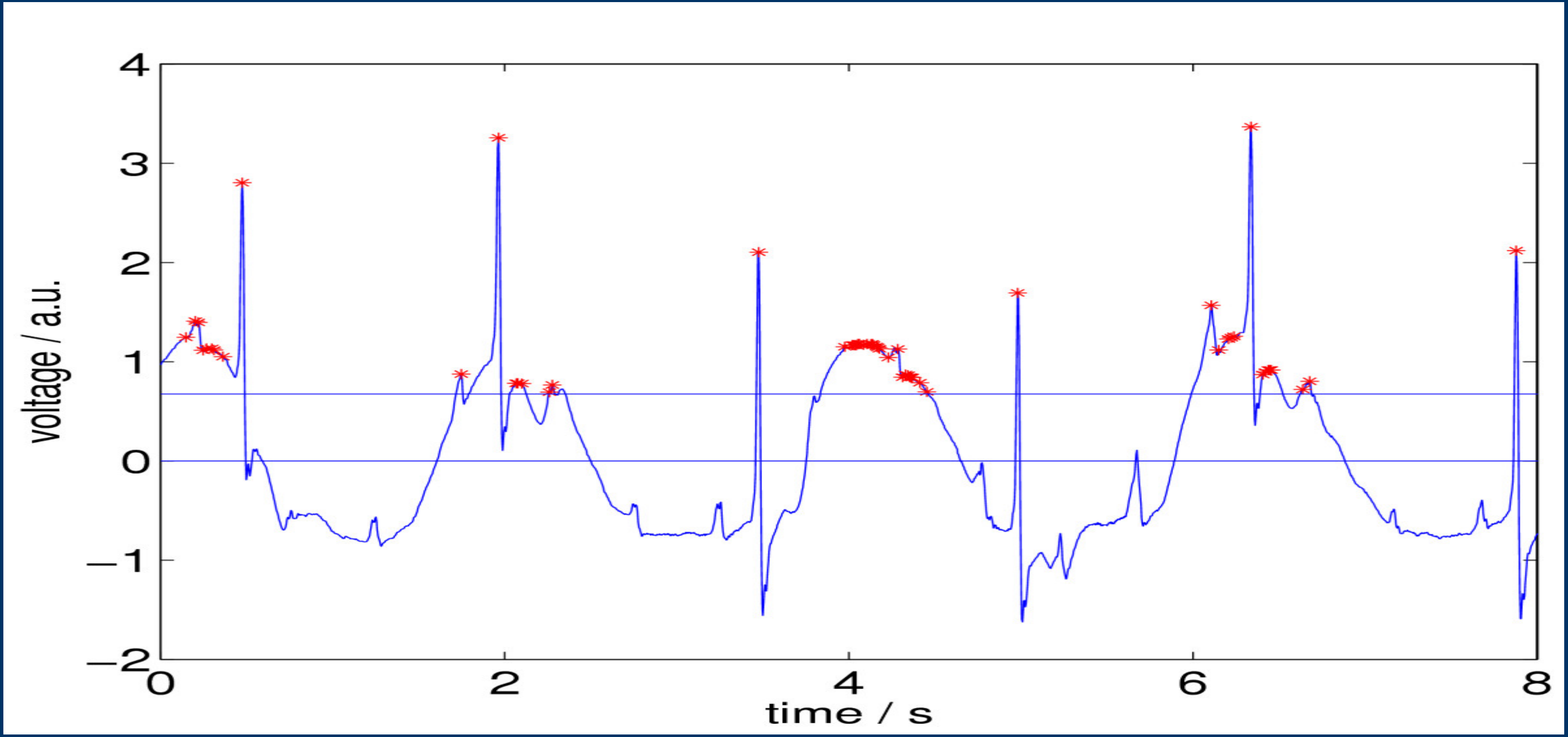
Obr. 2m: Elektrostimulace „fixed rate“



Obr. 2n: Elektrostimulace „on demand“

ECG … Heart frequency

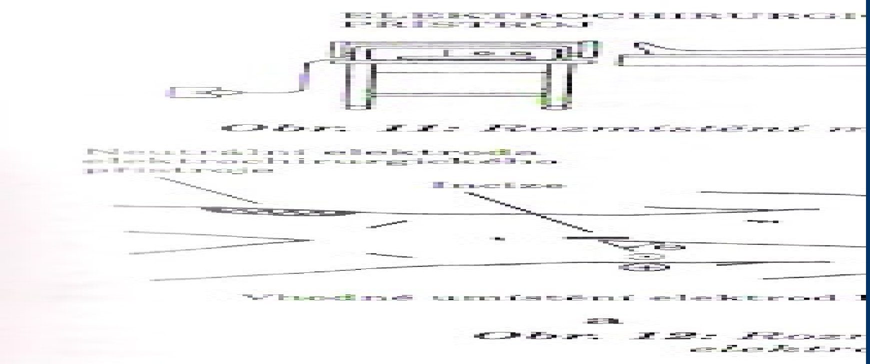
- 45/min or 150/min or ??

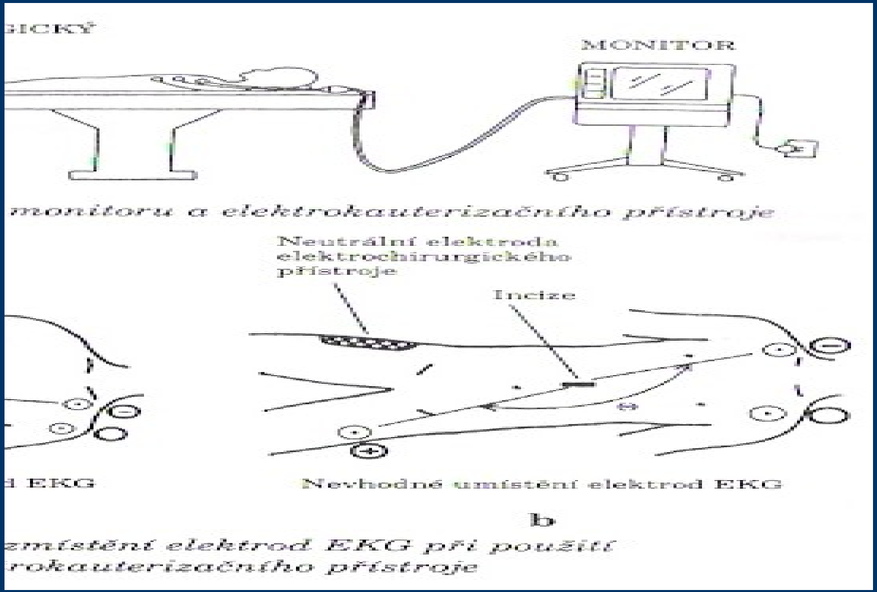


Amann et al. BioMedical Engineering OnLine 2005 4:60 doi:10.1186/1475-925X-4-60

ECG – complication of monitoring

- electric interference ()
- 50Hz coross ECG cabel
- cabel as anntena (loop)
- no signal 10s after defibrilation





NIBP – effect of cuff size

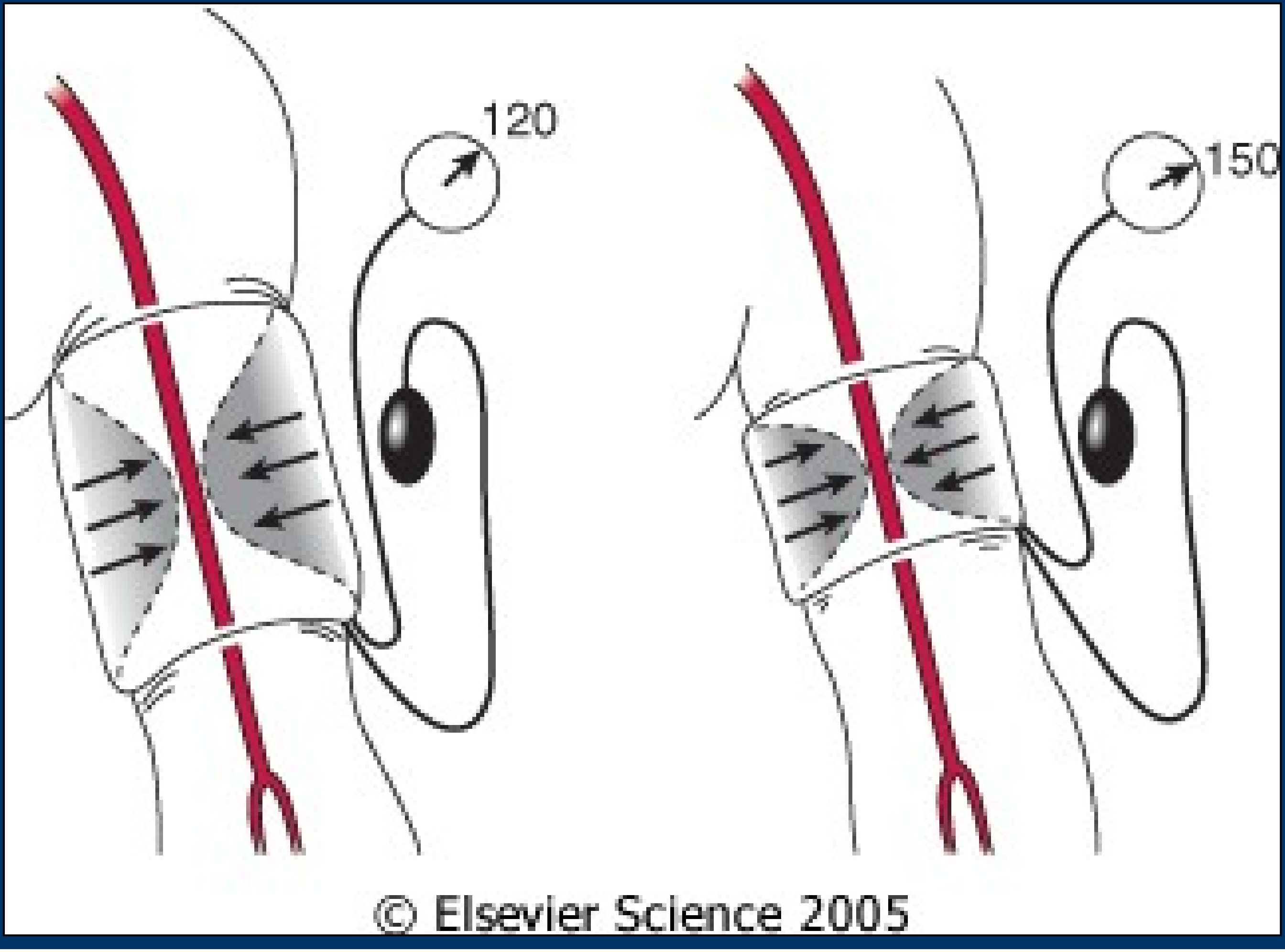


Figure 32-2 Effect of cuff size on manual blood pressure measurement. An inappropriately small blood pressure cuff yields erroneously high values for blood pressure because the pressure within the cuff is incompletely transmitted to the underlying artery.

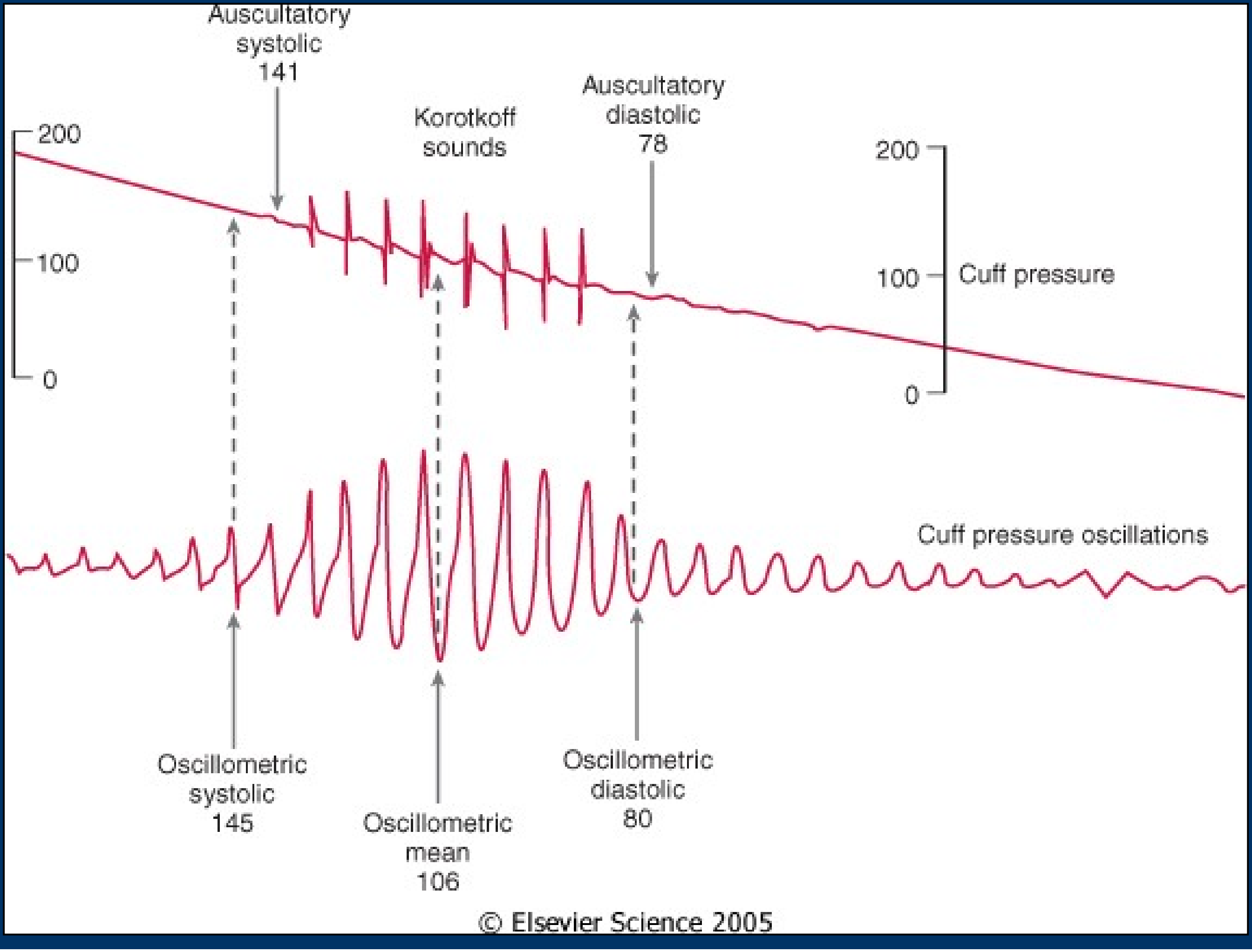


Figure 32-3 Comparison of blood pressure measurements by Korotkoff sounds and oscillometry. Oscillometric systolic blood pressure is recorded at the point where cuff pressure oscillations begin to increase, mean pressure corresponds to the point of maximal oscillations, and diastolic pressure is measured when the oscillations become attenuated. Note the correspondence between these measurements and the Korotkoff sounds that determine auscultatory systolic and diastolic pressure. (Redrawn from Geddes LA: Cardiovascular Devices and Their Applications. New York John Wiley, 1984, Fig 34-2. Reprinted by permission of John Wiley & Sons, Inc.)

NIBP

Complications :

- Pain
- Petechie
- Edema of extremity
- Venous stasis, thrombophlebitis
- Peripheral neuropathy
- Compartment syndrome

- Uneasy measurement
- movements
- transport
- bradycardia < 40/min
- obesity
- shock - vasoconstriction

IBP, Canylation of artery

- real-time, beat to beat
- rapid changes - drugs / mechanic
- repeated bload samples [BGasses]
- failure of NIBP
- additional information from puls curve
  - Pulse Pressure Variation

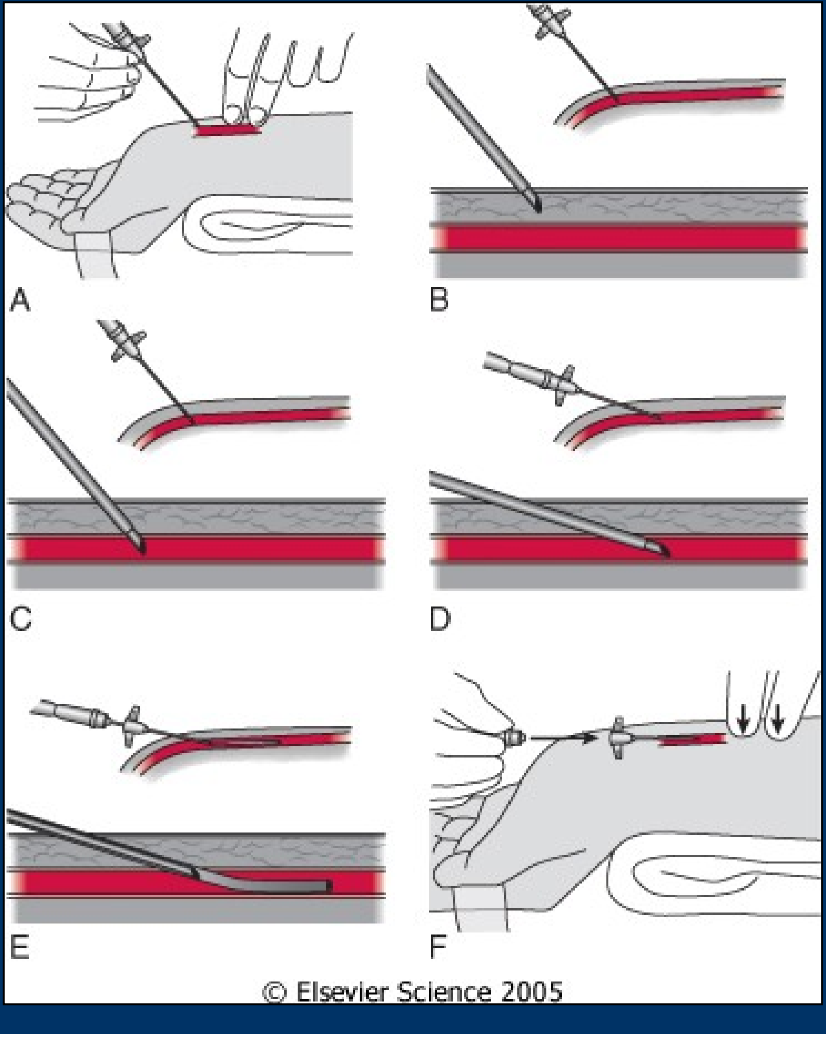
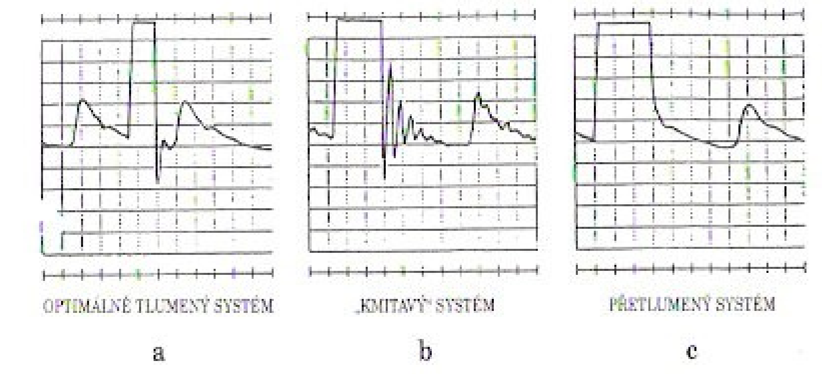


Figure 32-4 Percutaneous radial artery cannulation. A, The wrist is positioned and the artery identified by palpation. B, The catheter-over-needle assembly is introduced through the skin and advanced toward the artery. C, Entry of the needle tip into the artery is identified by the flash of arterial blood in the needle hub reservoir. D, The needle-catheter assembly is advanced at a lower angle to ensure entry of the catheter tip into the vessel. E, If blood flow continues into the needle reservoir, the catheter is advanced gently over the needle into the artery. F, The catheter is attached to pressure monitoring tubing while maintaining proximal occlusive pressure on the artery.

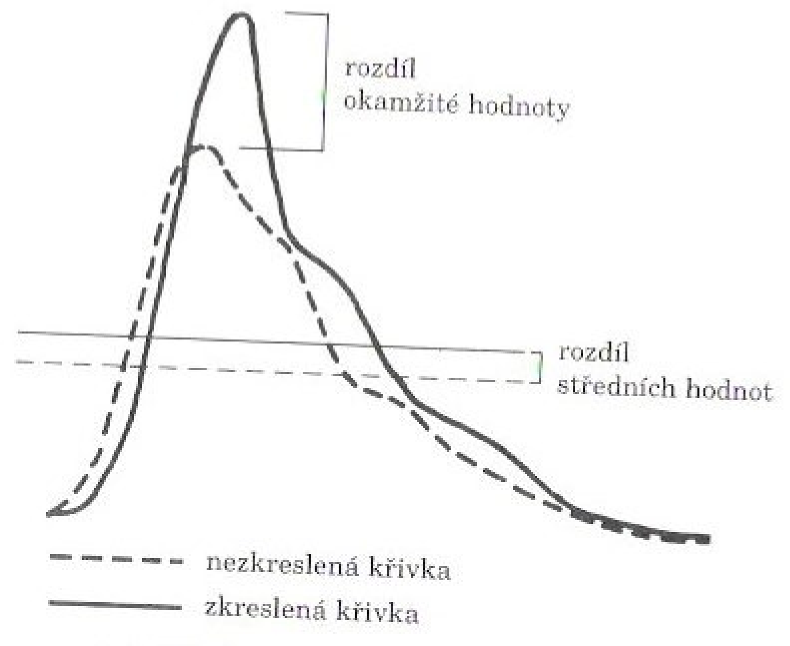
Invasive Pressure

a. radialis / a. femoralis / a. brachialis
arterie – hose – cell – infusion (cont. flush of cannyla ml/h)

- fluid is not compressible X air
- cloat of blood / cranking increase ressistance



Obr. 15: Zkreslení tlakové křivky přenosem



Obr. 17: *Vliv přenosového zkreslení tlakové křivky na střední hodnotu tlaku*

!!Alarm!! Low BP

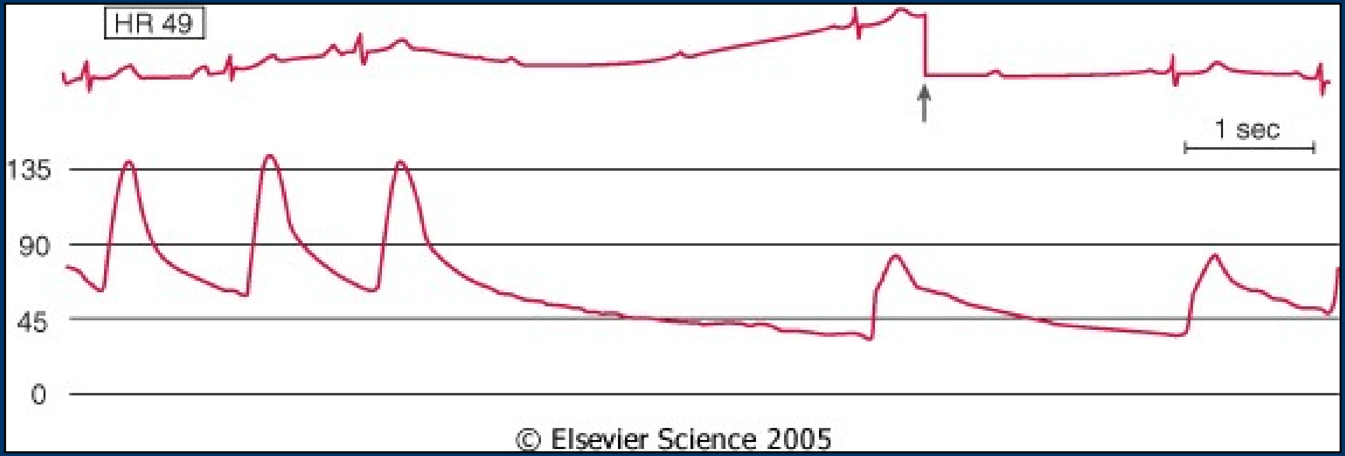


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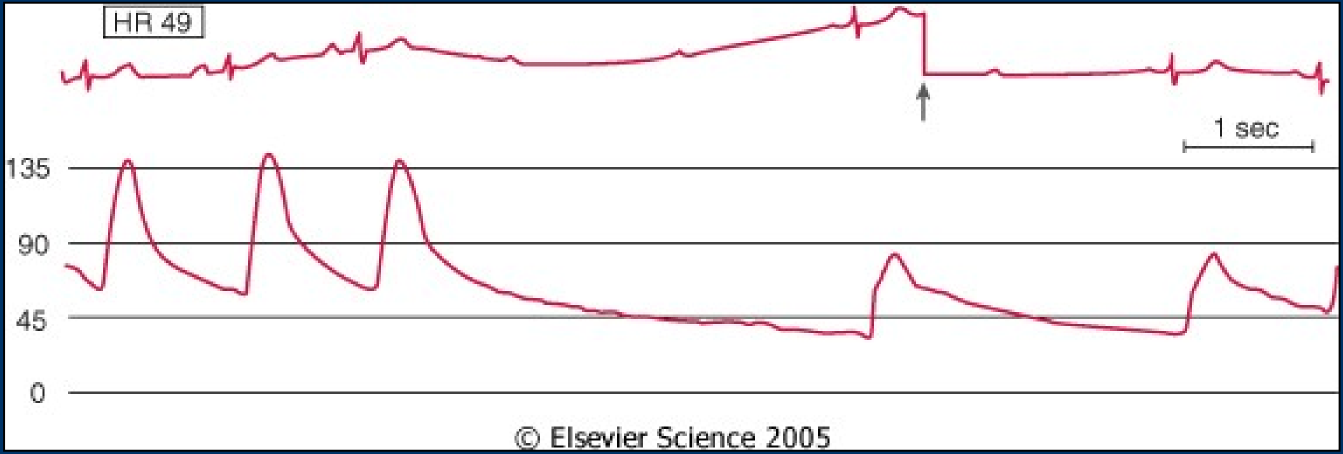
Figure 32-1 Digital heart rate (HR) displays may fail to warn of dangerous bradyarrhythmias. Direct observation of the electrocardiogram (ECG) and the arterial blood pressure traces reveals complete heart block and a 4-second period of asystole, whereas the digital display reports an HR of 49 beats/min. Note that the ECG filter (arrow) corrects the baseline drift so that the trace remains on the recording screen. (From Mark JB: Atlas of Cardiovascular Monitoring. New York, Churchill Livingstone, 1998, Fig. 13-2.)

HR: 49/min,
ECG: AV blok III



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O2 in the body

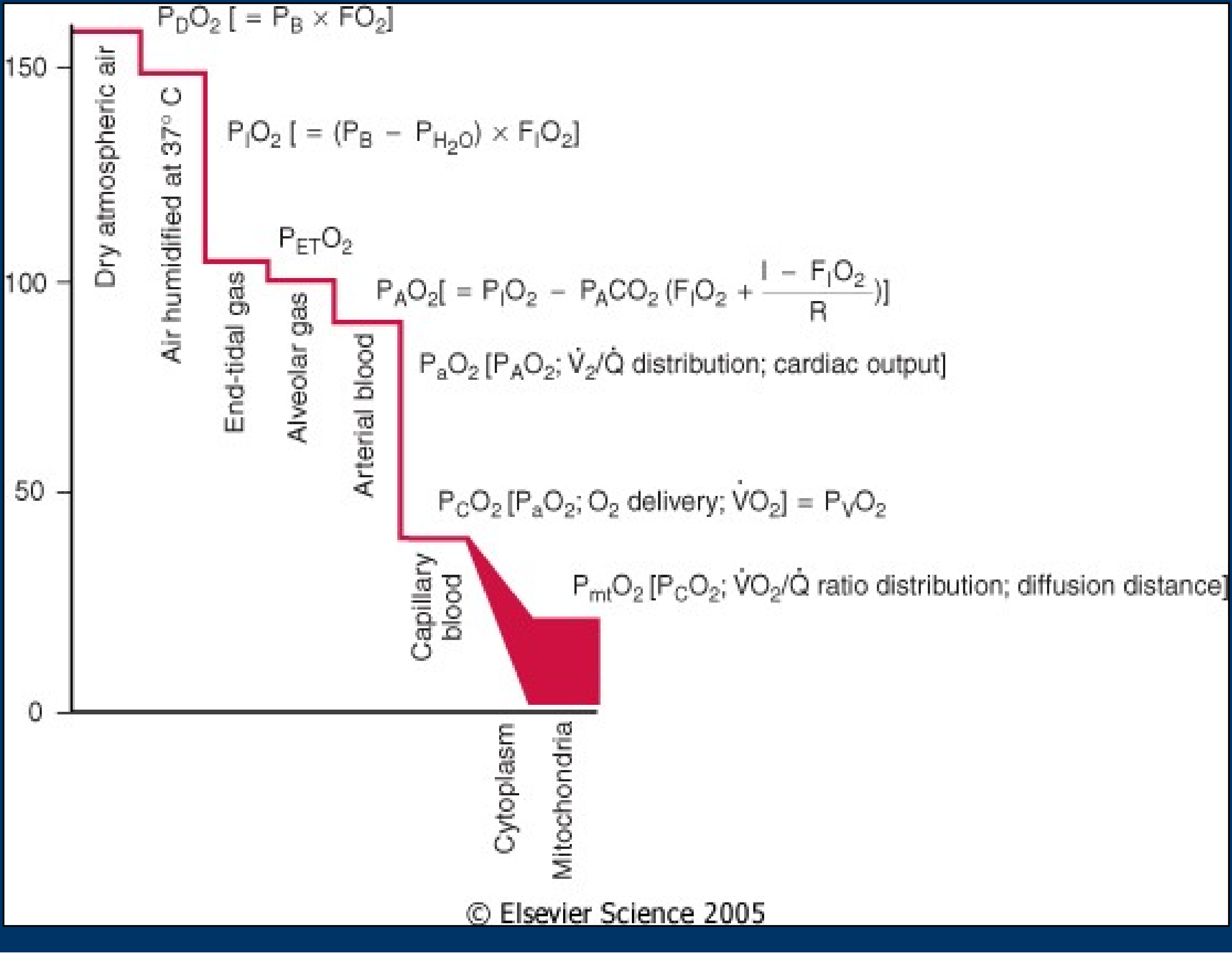

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Figure 36-1 Oxygen transport cascade. A schematic view of the steps in oxygen transport from the atmosphere to the site of utilization in the mitochondrion is shown here. Approximate Po2 values are shown for each step in the cascade, and factors determining those partial pressures are shown within the square brackets. There is a distribution of tissue Po2 values depending on local capillary blood flow, tissue oxygen consumption, and diffusion distances. Mitochondrial Po2 values are depicted as a range because reported levels vary widely. (Adapted from Nunn JF: Nunn's Applied Respiratory Physiology, 4th ed. Boston, Butterworth-Heinemann, 1993.)

Oxygenation of tissues

- monitoring of inspired O2
- SpO2
- Arterial blood gasses
  - low cardiac output and good oxygention function of lung

Saturation, SpO2

A pulse oximeter is a particularly convenient noninvasive measurement instrument. Typically it has a pair of small light-emitting diodes (LEDs) facing a photodiode through a translucent part of the patient's body, usually a fingertip or an earlobe. One LED is red, with wavelength of 660 nm, and the other is infrared, 905, 910, or 940 nm. Absorption at these wavelengths differs significantly between oxyhemoglobin and its deoxygenated form; therefore, the oxy/deoxyhemoglobin ratio can be calculated from the ratio of the absorption of the red and infrared light. The absorbance of oxyhemoglobin and deoxyhemoglobin is the same (isosbestic point) for the wavelengths of 590 and 805 nm; earlier oximeters used these wavelengths for correction for hemoglobin concentration.

Principle of pulse oximetry

- 1000 absorption of light of different wave lenght

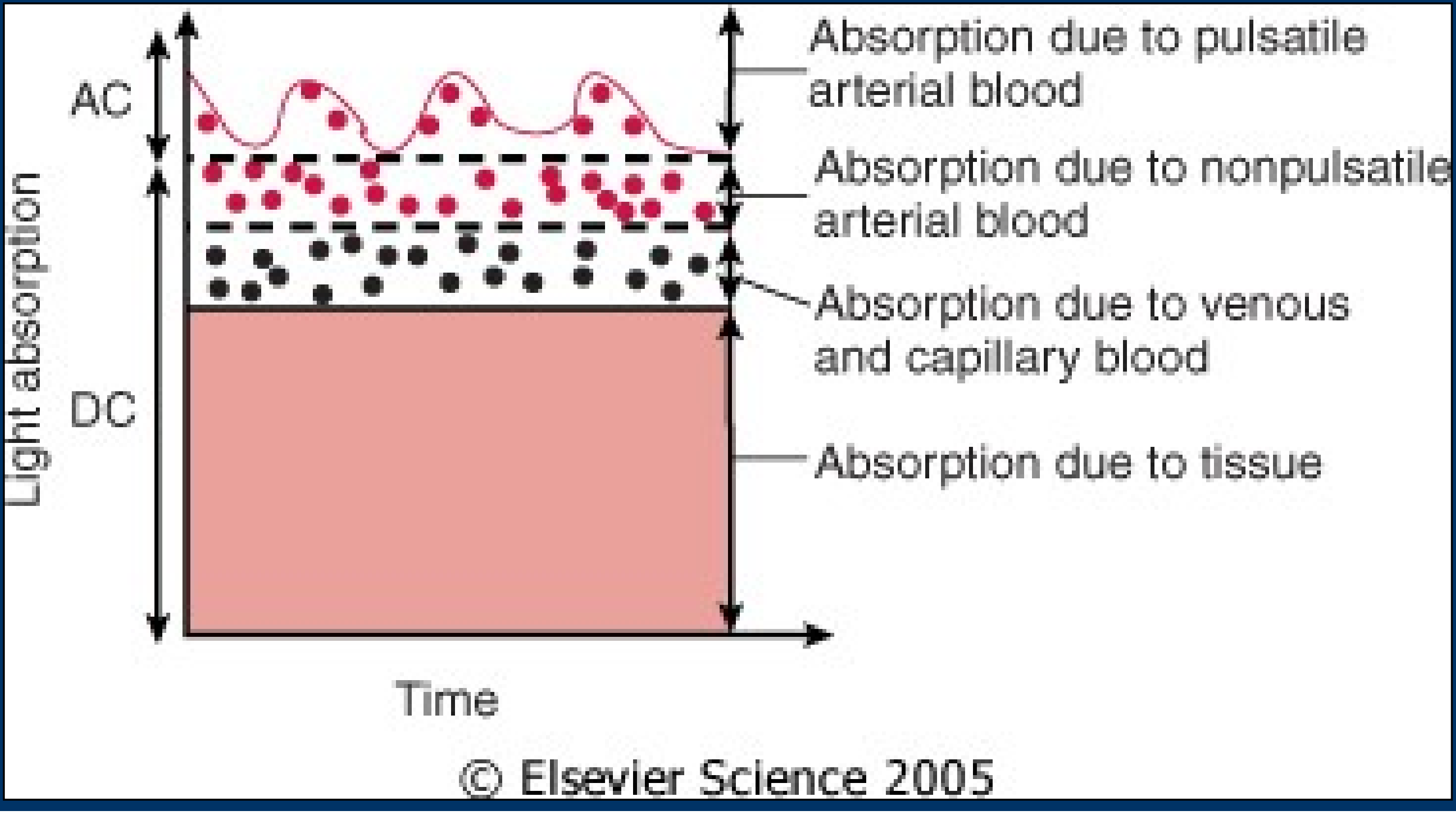

Figure 36-10 Principle of pulse oximetry. Light passing through tissue containing blood is absorbed by tissue and by arterial, capillary, and venous blood. Usually, only the arterial blood is pulsatile. Light absorption may therefore be split into a pulsatile component (AC) and a constant or nonpulsatile component (DC). Hemoglobin O2 saturation may be obtained by application of Equation 19 in the text. (Data from Tremper KK, Barker SJ: Pulse oximetry. Anesthesiology 70:98, 1989.)

2 wavelength , 2 absorptions *for Hb a HbO2*

$$S = \frac{AC_{660} / DC_{660}}{AC_{940} / DC_{940}} \quad \text{aprox.} \quad \% \ HBO/(HB+HBO)$$

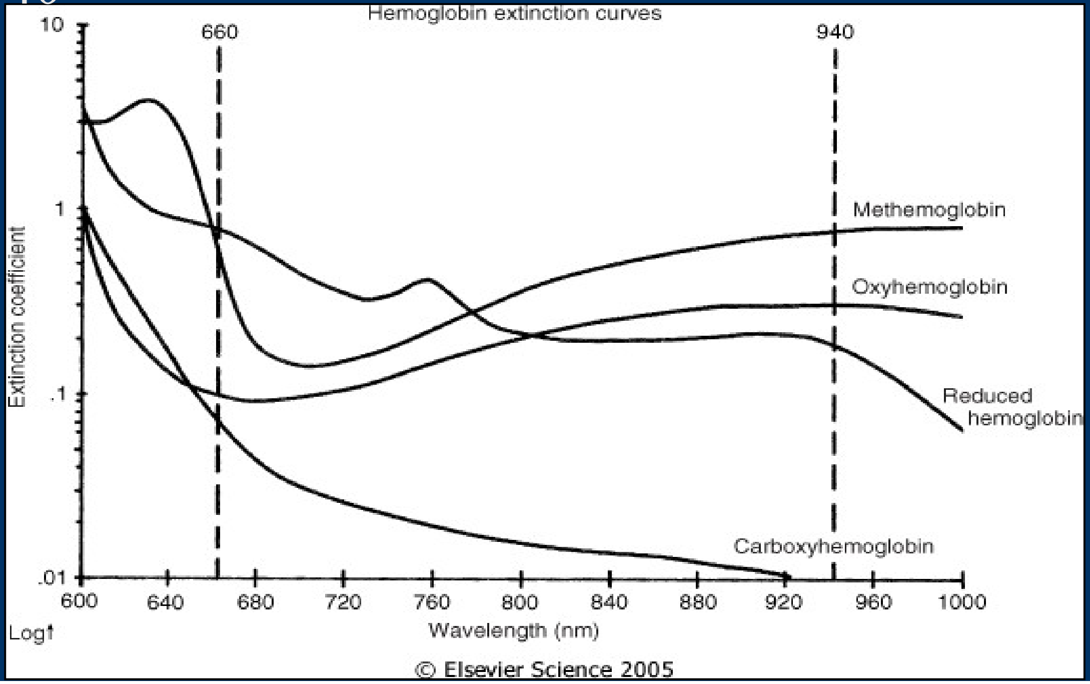

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Figure 30-34 Hemoglobin extinction curves. Pulse oximetry uses the wavelengths of 660 and 940 nm because they are available in solid-state emitters (not all wavelengths are able to be emitted from diodes). Unfortunately, HbCO and HbO2 absorb equally at 660 nm. Therefore, HbCO and HbO2 both read as Sao2 to a conventional pulse oximeter. In addition, Hbmet and reduced Hb share absorption at 660 nm and interfere with correct Sao2 measurement. (Courtesy of Susan Manson, Biox/Ohmeda, Boulder, Colorado, 1986.)

SpO2 = HbO2 = O2 in the tissue

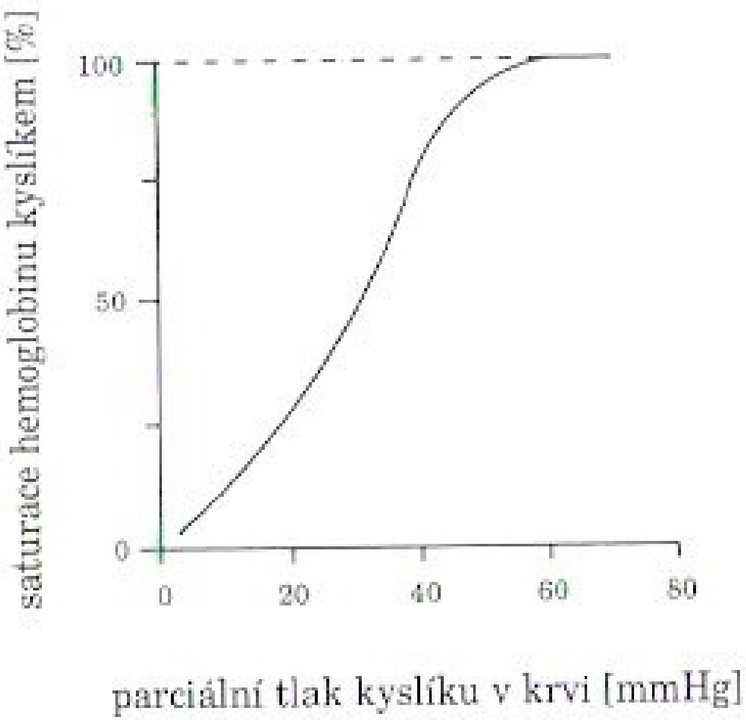
- oxygenation, not ventilation,
- inaccuracy 5%

Falsely low readings:

- hypoperfusion
- incorrect sensor application;
- highly calloused skin
- movement (such as shivering)

Falsely high:

- carbon monoxide poisoning



Obr. 46: *Disociační křivka hemoglobinu*

SpO2 and low temperature

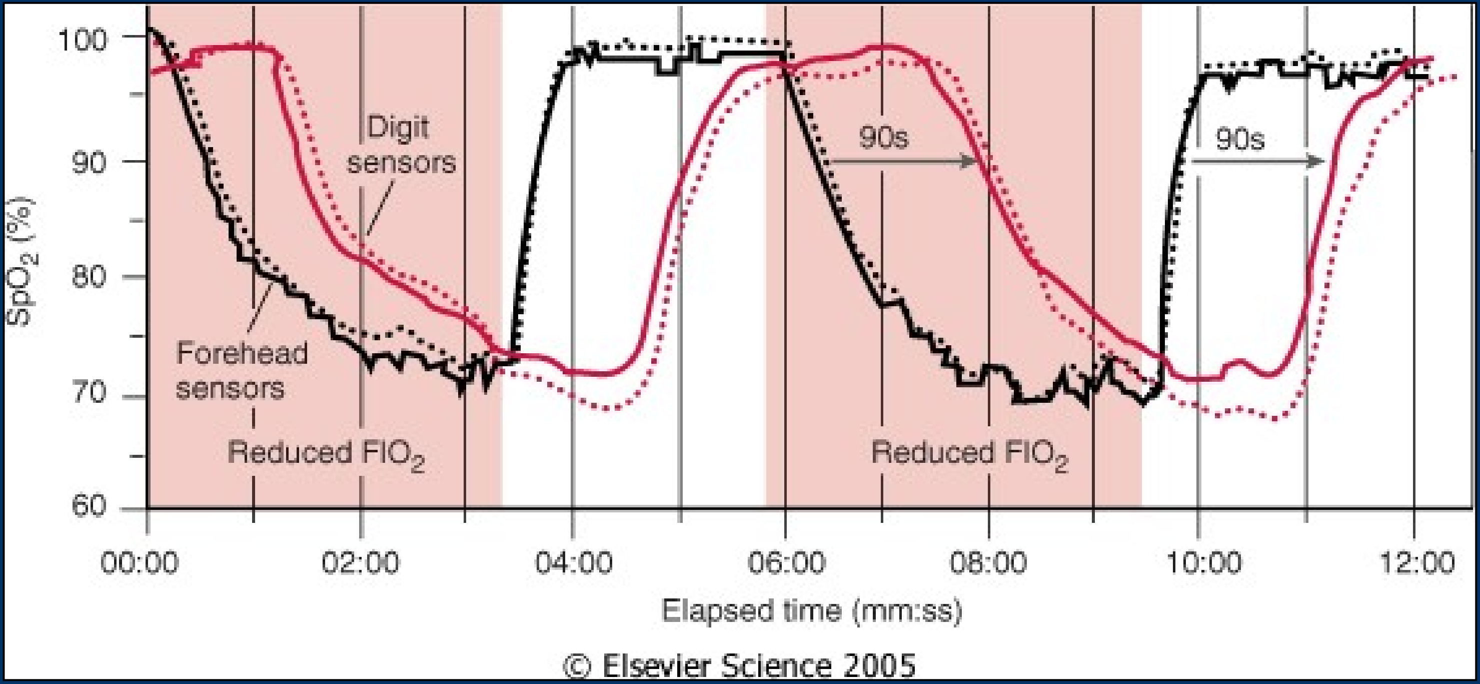
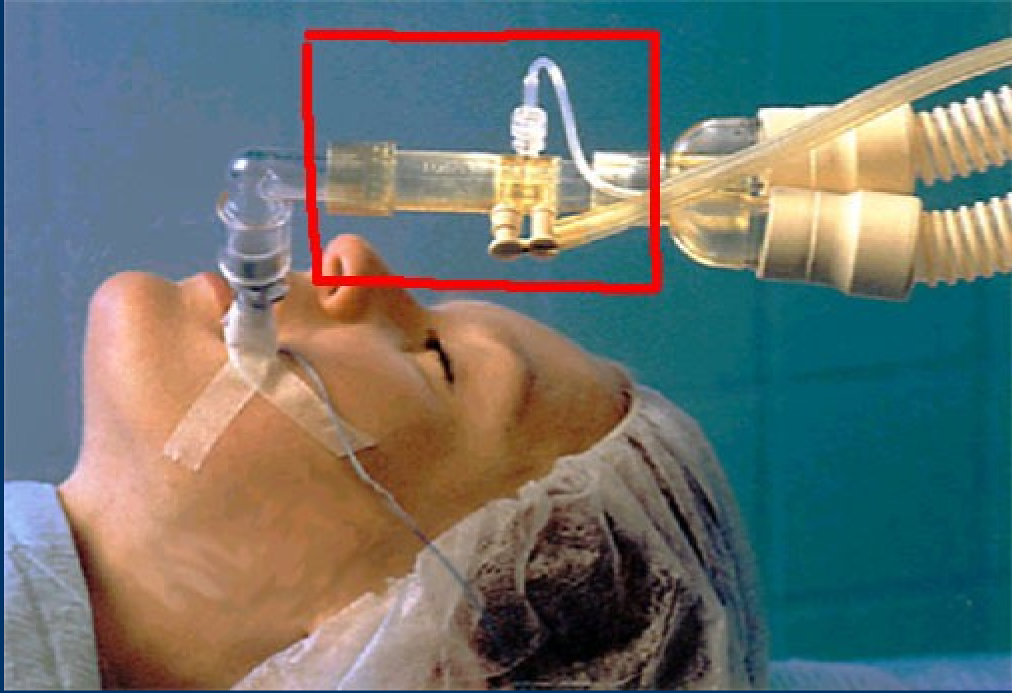


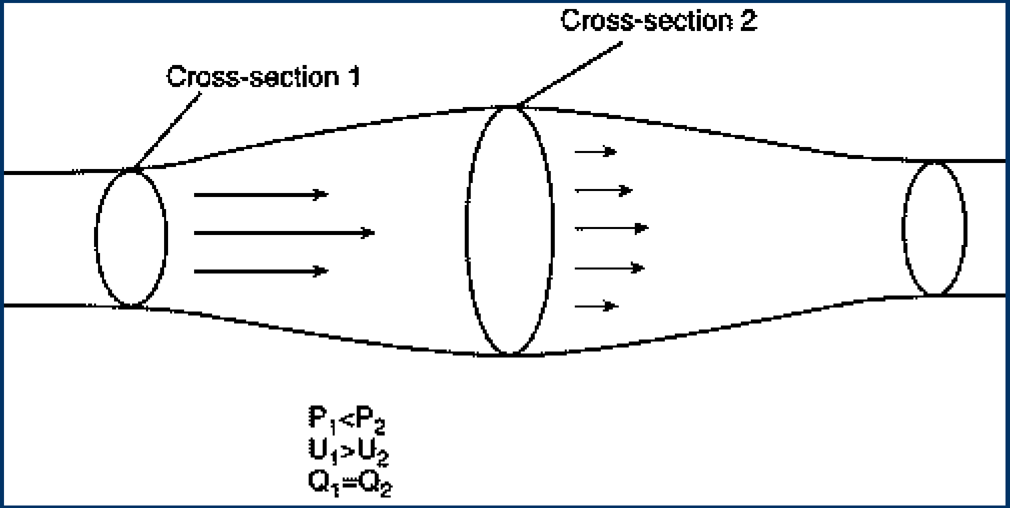
Figure 36-11 Effect of pulse oximeter probe replacement on delay from onset of hypoxemia to a drop in the measured Spo2. During cold-induced peripheral vasoconstriction in normal volunteers, the onset of hypoxemia was detected more quickly using an oximeter probe on the forehead compared with the finger. Other studies have shown a similar advantage for pulse oximeter probes placed on the ear. (From Bebout DE, Mannheimer PD, Wun C-C: Site-dependent differences in the time to detect changes in saturation during low perfusion. Crit Care Med 29:A115, 2002.)

Ventilation



- P,V, flow;
- PV curve
- Gas Analysis
  - O2,
  - EtCO2 – capnometry
  - N2O, [%] volatile anesthetics

Flow



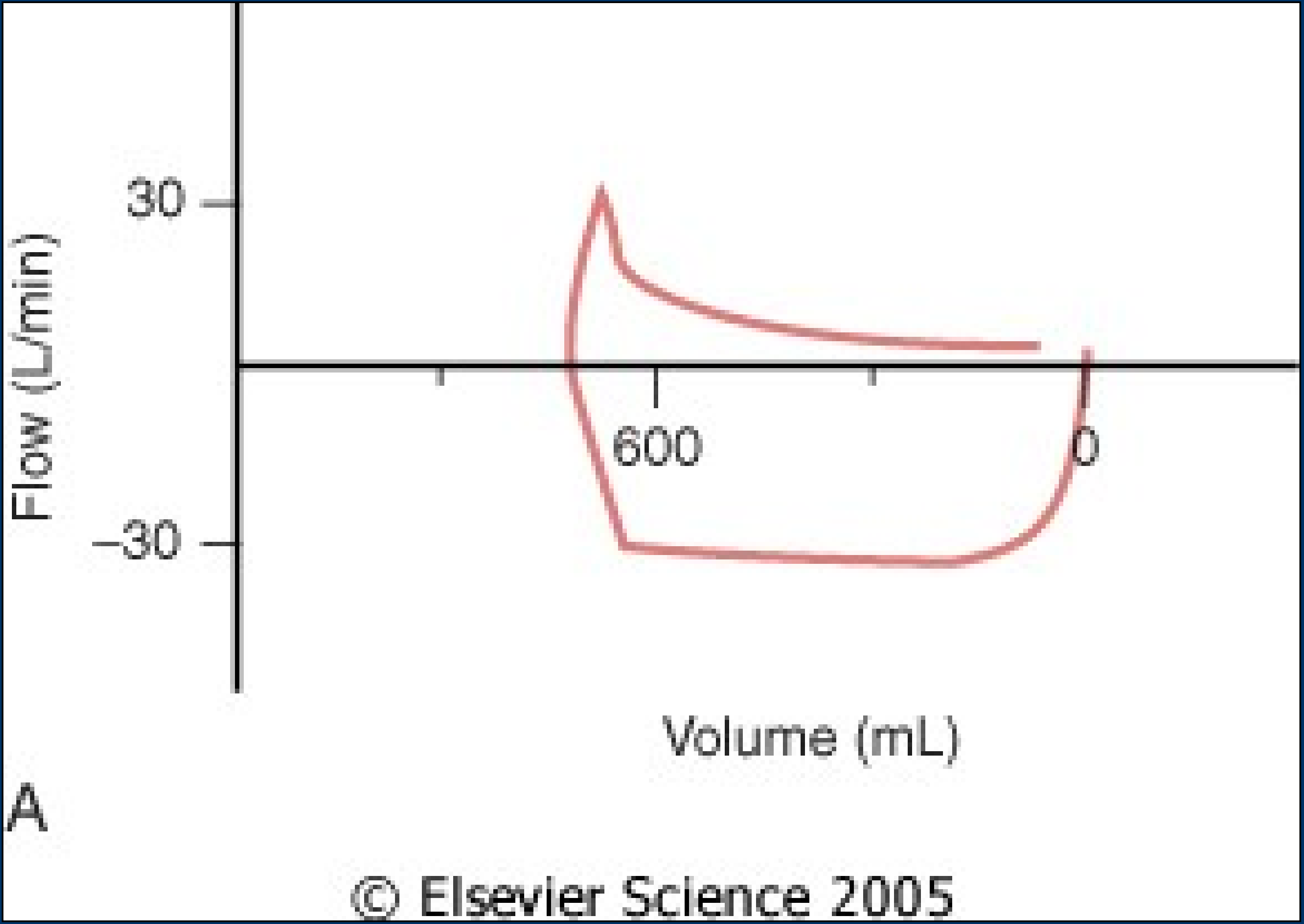
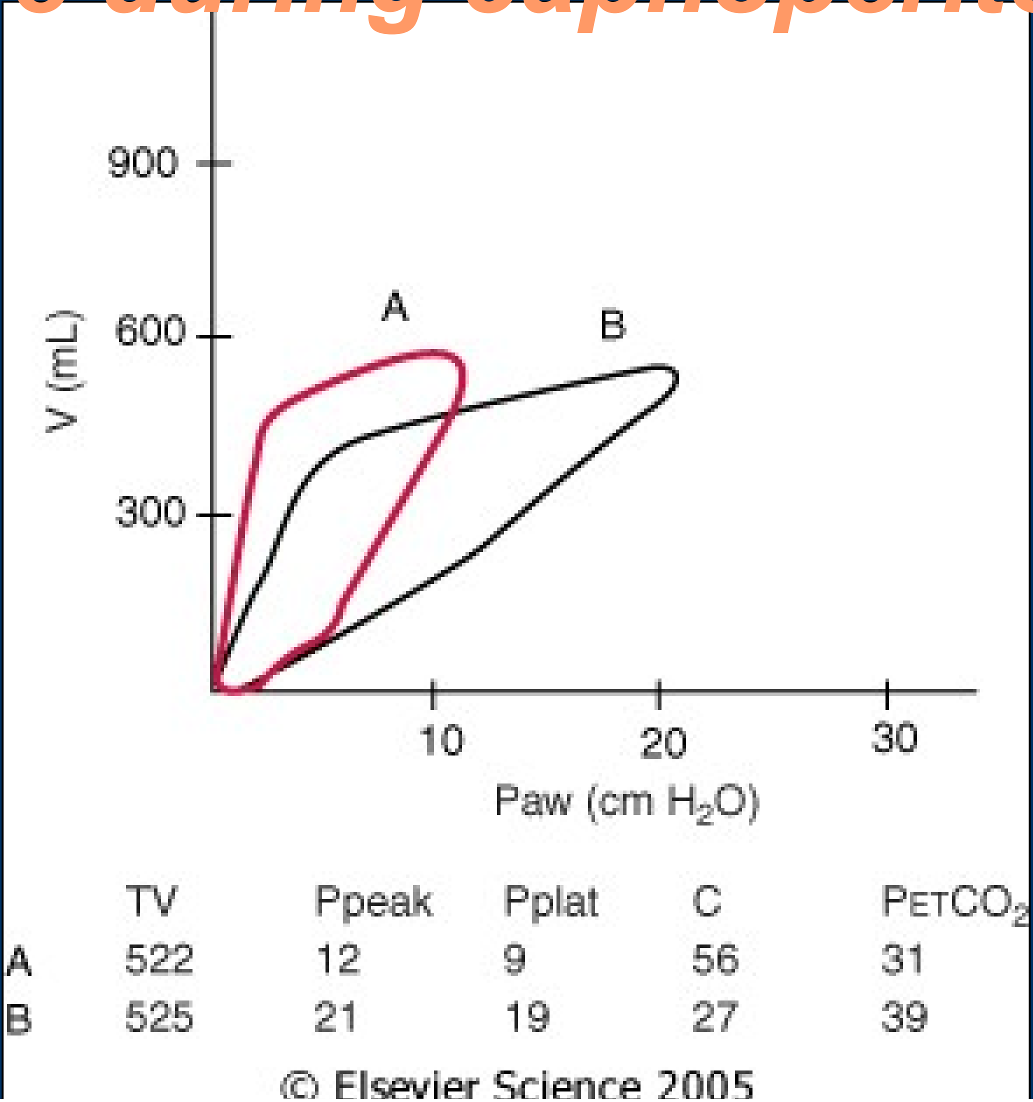


Figure 36-24 Flow (ordinate) versus volume (abscissa). A, Closed-chest positive-pressure ventilation under general anesthesia in a patient with severe airways obstruction and hyperinflation before surgery to reduce lung volume. The flow-volume curve shows inspiratory (negative) and expiratory (positive) flow on the ordinate, plotted clockwise from zero volume on the abscissa. Expiratory flow started with a sharp upward peak and then fell immediately to a low flow rate with convexity toward the volume axis, suggesting expiratory flow limitation. expiratory flow rate was so low that inflation of the next positive-pressure breath was initiated before expiratory flow reached zero. Because expiratory flow continued up to this point, there must have been intrinsic positive end-expiratory pressure (PEEPi). B, A similar closed-check flow-volume curve after lung resection shows that the characteristic pattern of expiratory flow limitation has disappeared and that expiratory flow rate fell to zero before inflation started for the next breath (i.e., no suggestion of PEEPi). (Adapted from Dueck R: Assessment and monitoring of flow limitation and other parameters from flow/volume loops. J Clin Monit Comput 16:425, 2000.)

PV curve during capnoperitoneum



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

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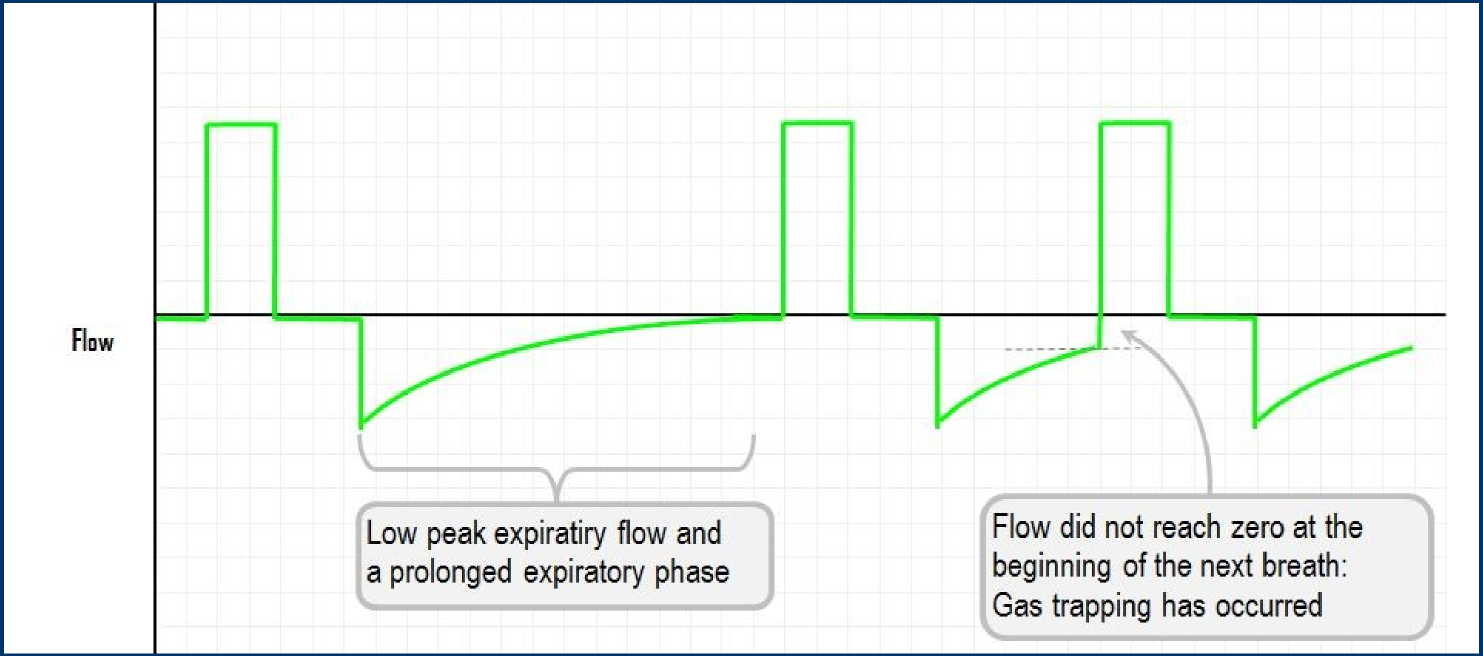
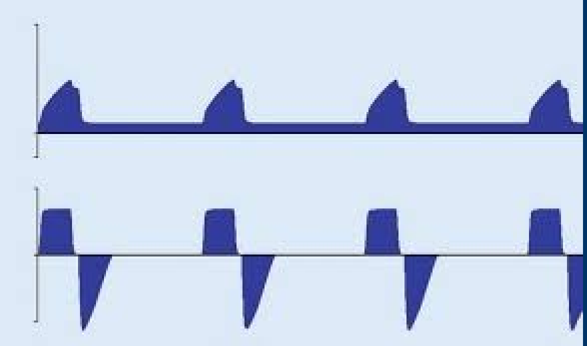
Figure 57-1 Change in total respiratory compliance during pneumoperitoneum for laparoscopic cholecystectomy. The intra-abdominal pressure was 14 mm Hg, and the head-up tilt was 10 degrees. The airway pressure (Paw) versus volume (V) curves and data were obtained from the screen of a Datex Ultima monitoring device. Curves are generated for before insufflation (A) and 30 minutes after insufflation (B). Values are given for tidal volume (TV, in mL); peak airway pressure (Ppeak, in cm H2O); plateau airway pressure (Pplat, in cm H2O); total respiratory compliance (C, in mL/cm H2O); and end-tidal carbon dioxide tension (PetCO2, in mm Hg).

Flow in time



Low peak expiratiry flow and a prolonged expiratory phase

Flow did not reach zero at the beginning of the next breath: Gas trapping has occurred



Pressure

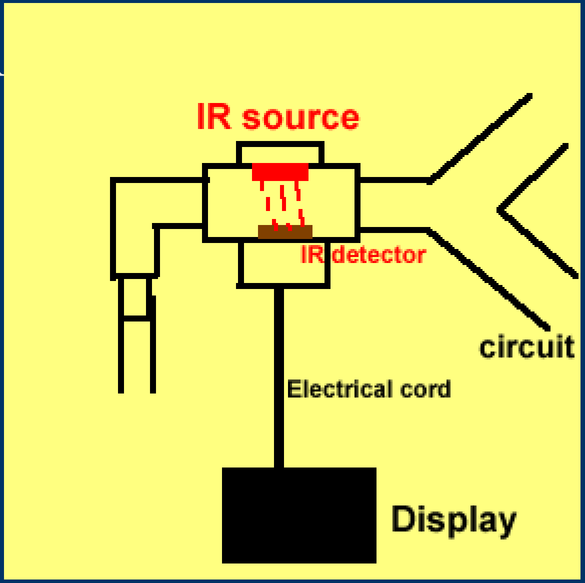
Flow

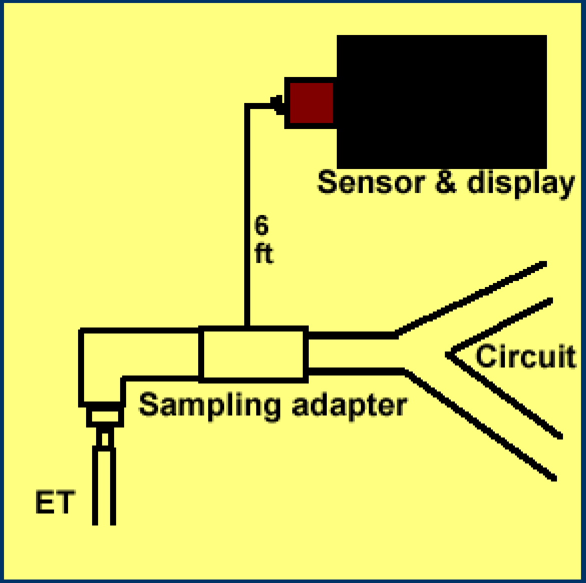
Gas analyzers

Main-stream Side-stream

only CO2, méně přesné zpoždění

l





Monitoring of gas

Main-stream

Side-stream

O2 paramagnetic gas (side stream monitor)

Minimal fiO2: 21%
safe 30%
usualy : up to 60%
in case of hypoxy: 100%
preoxygenation: 100%

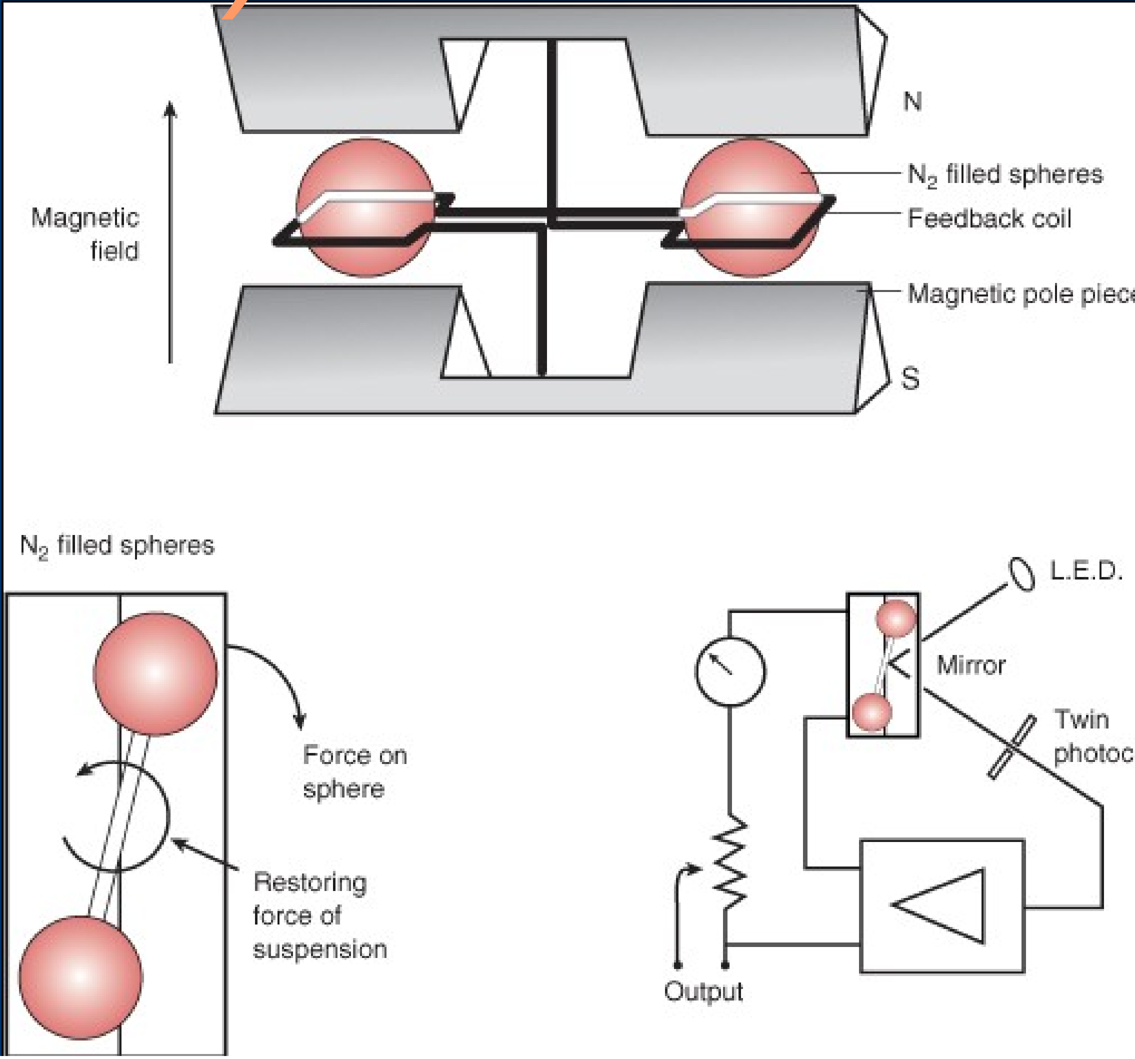
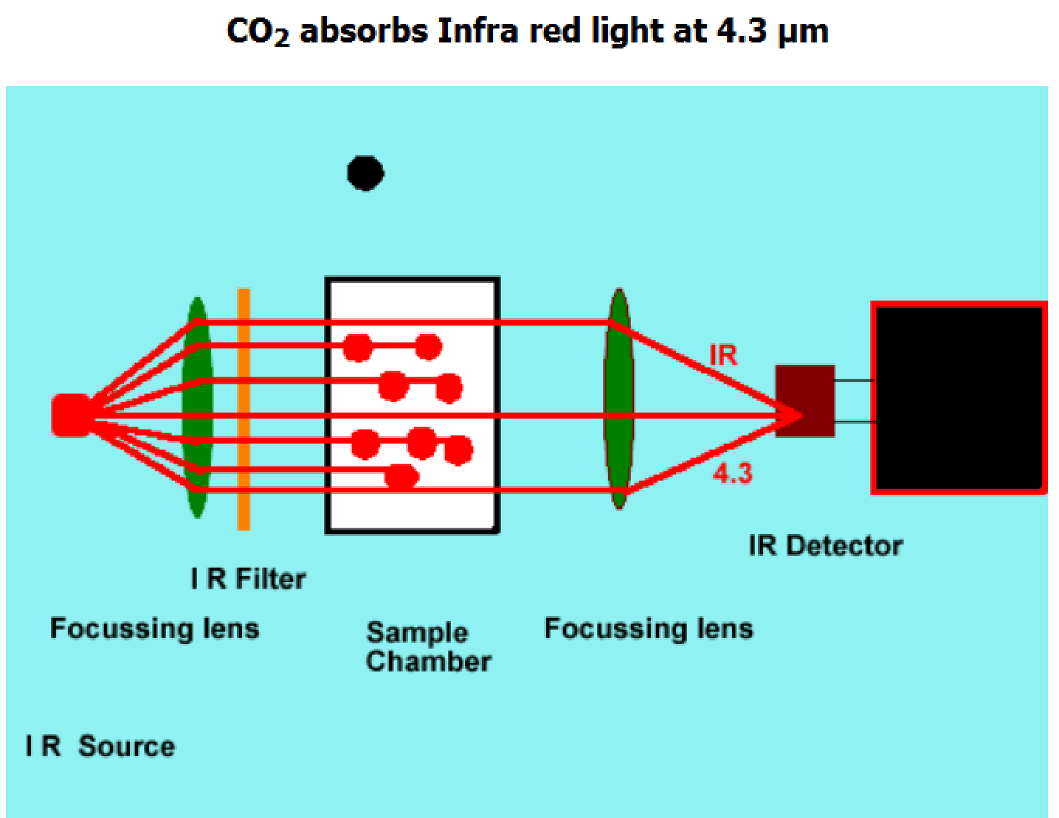


Figure 36-13 Paramagnetic oxygen analyzer. Two sealed spheres filled with nitrogen are suspended in a magnetic field. Nitrogen (N2) is slightly diamagnetic, and the resting position of the beam is such that the spheres are displaced away from the strongest portion of the field. If the surrounding gas contains oxygen, the spheres are pushed further out of the field by the relatively paramagnetic oxygen. The magnitude of the torque is related to the paramagnetism of the gas mixture and is proportional to the partial pressure of oxygen (Po2). Movement of the dumbbell is detected by photocells, and a feedback current is applied to the coil encircling the spheres, returning the dumbbell to the zero position. The restoring current and output voltage are proportional to the Po2. (Courtesy of Servomex Co., Norwood, MA.)

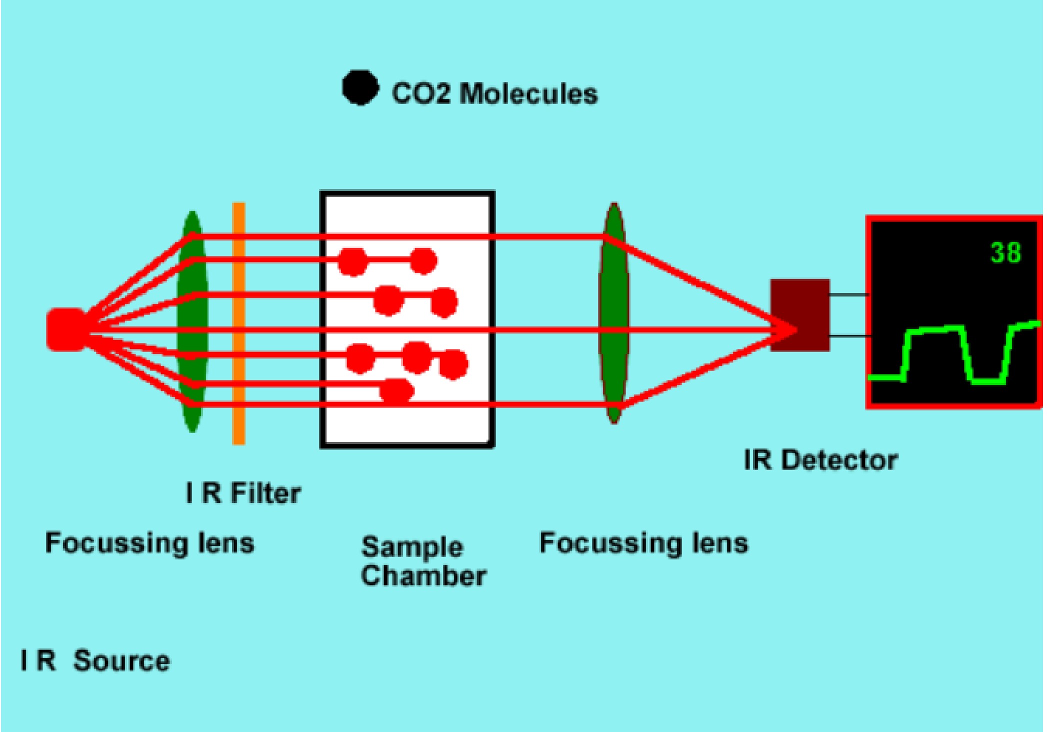
Capnometr, Capnograph



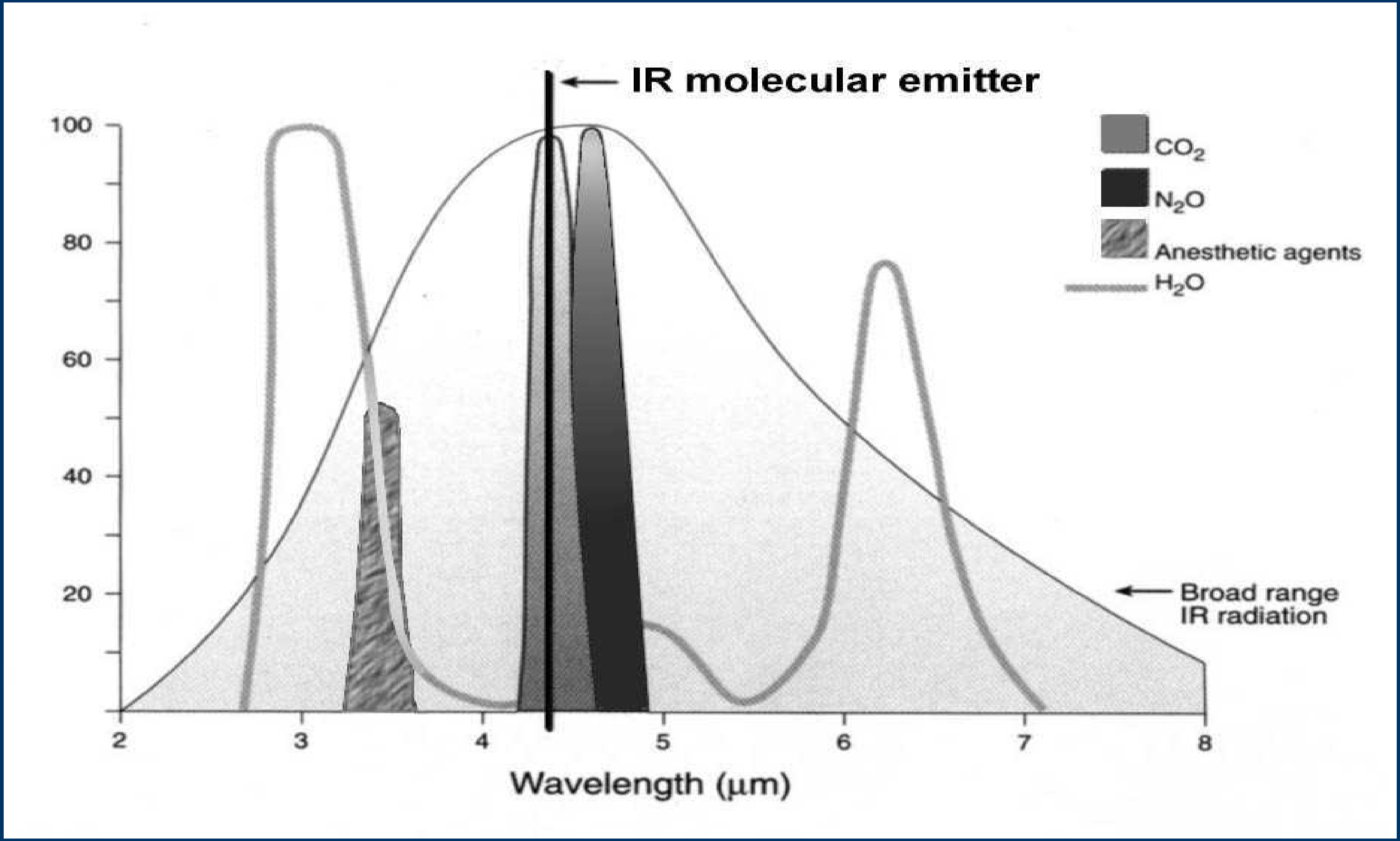
- Infra-red Spectrography

http://www.capnography.com/Physics/Physicsphysical.htm

CO_2 absorbs Infra red light at 4.3 μm



CO2 emits IR radiation



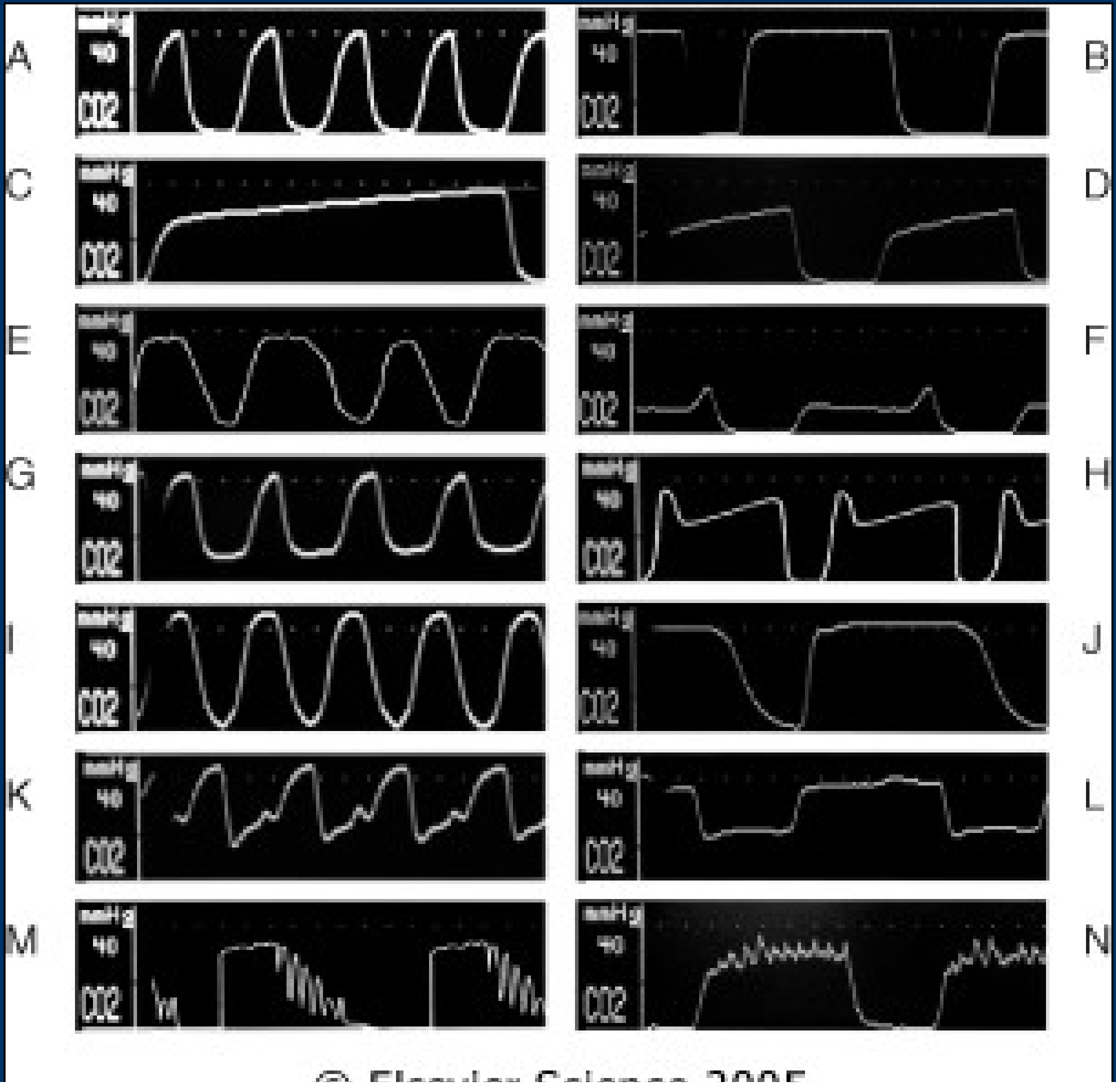
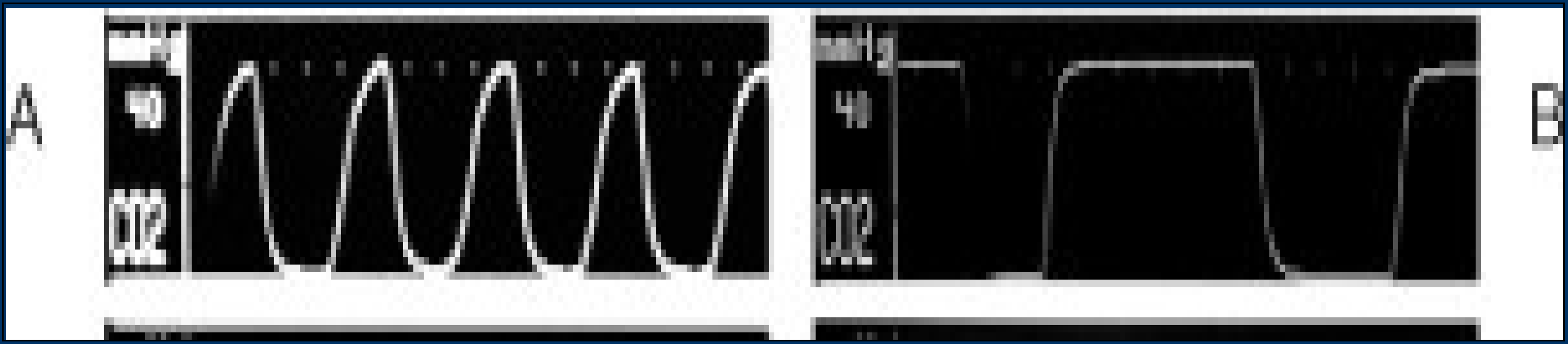
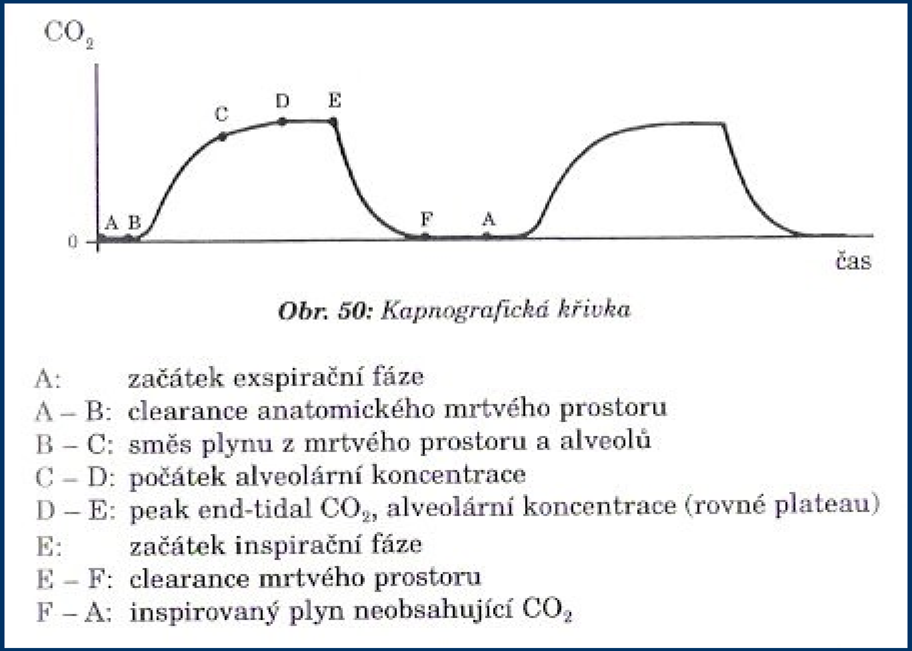


Figure 36-18 Examples of capnograph waves. A, Normal spontaneous breathing. B, Normal mechanical ventilation. C, Prolonged exhalation during spontaneous breathing. As CO2 diffuses from the mixed venous blood into the alveoli, its concentration progressively rises (see Fig. 36-19). D, Increased slope of phase III in a mechanically ventilated patient with emphysema. E, Added dead space during spontaneous ventilation. F, Dual plateau (i.e. tails-up pattern) caused by a leak in the sample line.325 The alveolar plateau is artifactually low because of dilution of exhaled gas with air leaking inward. During each mechanical breath, the leak is reduced because of higher pressure within the airway and tubing, explaining the rise in the CO2 concentration at the end of the alveolar plateau. This pattern is not seen during spontaneous ventilation because the required increase in airway pressure is absent. G, Exhausted CO2 absorbent produces an inhaled CO2 concentration greater than zero. H, Double peak for a patient with a single lung transplant. The first peak represents CO2 from the transplanted (normal) lung. CO2 exhalation from the remaining (obstructed) lung is delayed, producing the second peak. I, Inspiratory valve stuck open during spontaneous breathing. Some backflow into the inspired limb of the circuit causes a rise in the level of inspired CO2. J, Inspiratory valve stuck open during mechanical ventilation. The "slurred" downslope during inspiration represents a small amount of inspired CO2 in the inspired limb of the circuit. K and L, Expiratory valve stuck open during spontaneous breathing or mechanical ventilation. Inhalation of exhaled gas causes an increase in inspired CO2. M, Cardiogenic oscillations, when seen, usually occur with sidestream capnographs for spontaneously breathing patients at the end of each exhalation. Cardiac action causes to-and-fro movement of the interface between exhaled and fresh gas. The CO2 concentration in gas entering the sampling line therefore alternates between high and low values. N, Electrical noise resulting from a malfunctioning component. The seemingly random nature of the signal perturbations (about three per second) implies a nonbiologic cause.

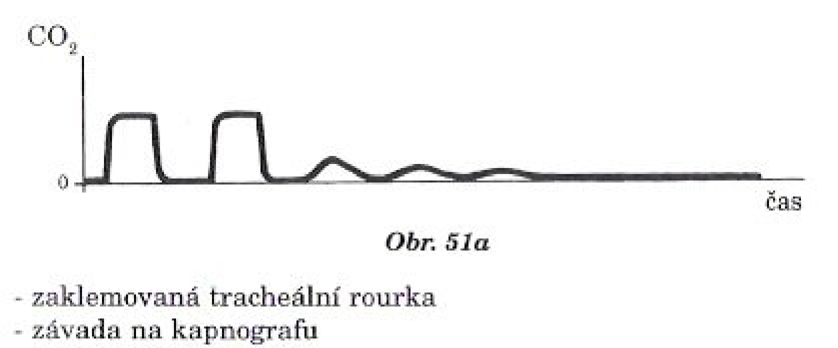
Normal ventilation
spont. mandatory





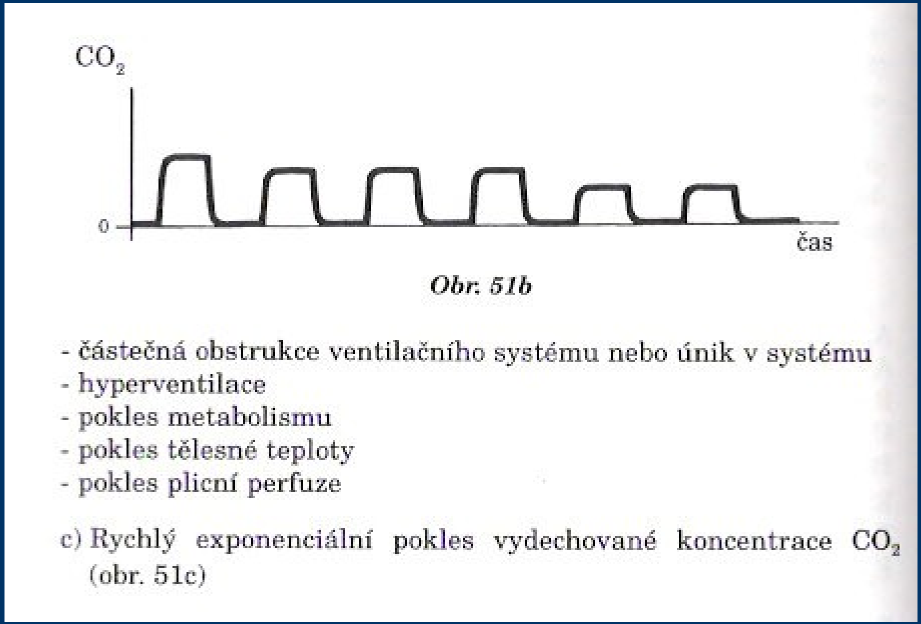
***Obr. 50:** Kapnografická křivka*

A: začátek exspirační fáze
A – B: clearance anatomického mrtvého prostoru
B – C: směs plynu z mrtvého prostoru a alveolů
C – D: počátek alveolární koncentrace
D – E: peak end-tidal CO_2, alveolární koncentrace (rovné plateau)
E: začátek inspirační fáze
E – F: clearance mrtvého prostoru
F – A: inspirovaný plyn neobsahující CO_2



Obr. 51a

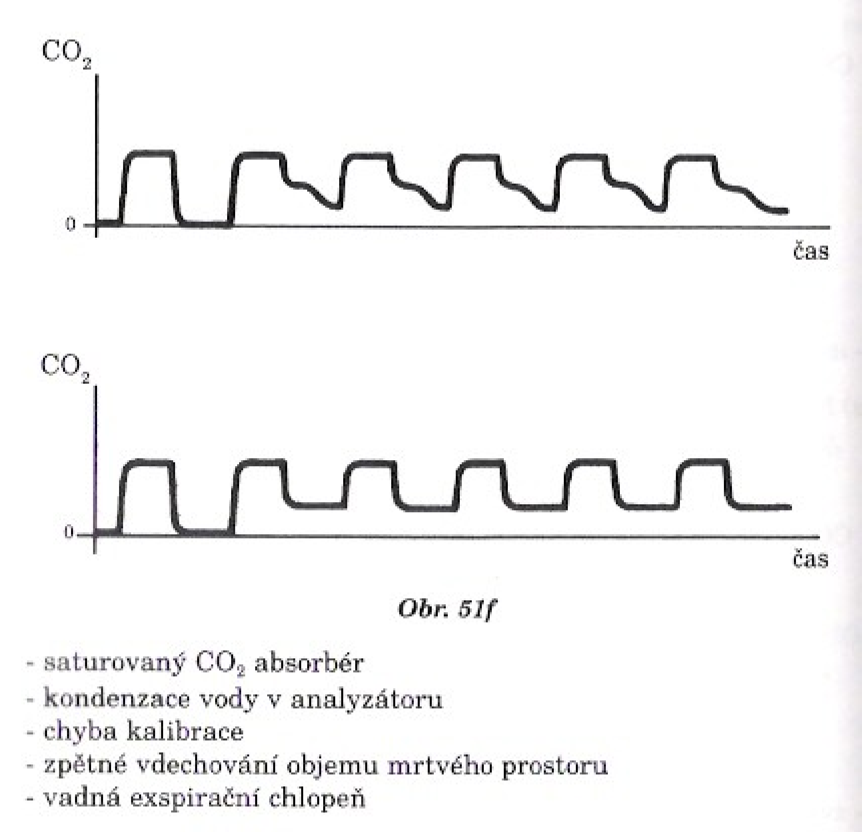
- zaklemovaná tracheální rourka
- závada na kapnografu



Obr. 51b

- částečná obstrukce ventilačního systému nebo únik v systému
- hyperventilace
- pokles metabolismu
- pokles tělesné teploty
- pokles plicní perfuze

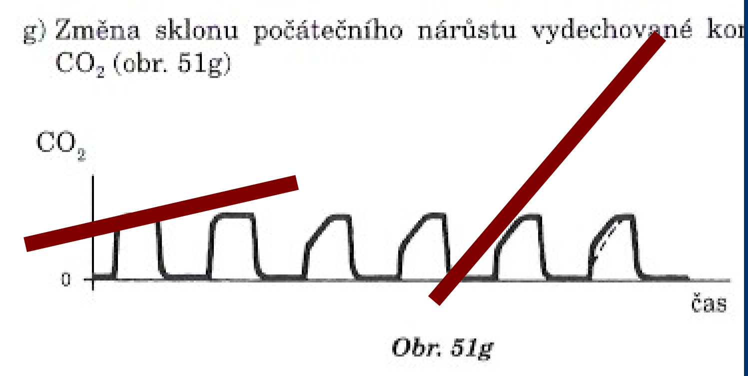
c) Rychlý exponenciální pokles vydechované koncentrace CO_2 (obr. 51c)



Obr. 51f

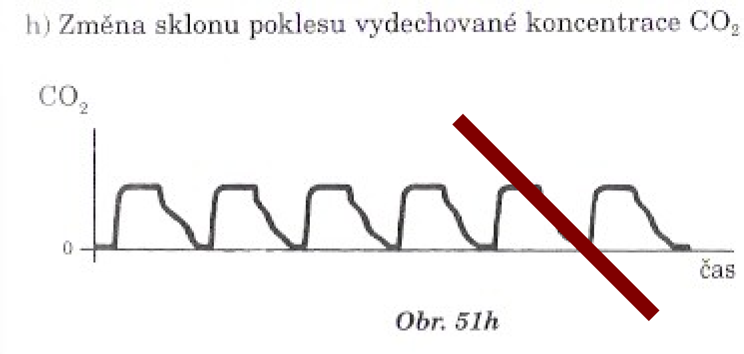
- saturovaný CO_2 absorbér
- kondenzace vody v analyzátoru
- chyba kalibrace
- zpětné vdechování objemu mrtvého prostoru
- vadná exspirační chlopeň

obstruction of airway



g) Změna sklonu počátečního nárůstu vydechované ko
CO_2 (obr. 51g)

Obr. 51g



h) Změna sklonu poklesu vydechované koncentrace CO_2

Obr. 51h

expirium

inspirium

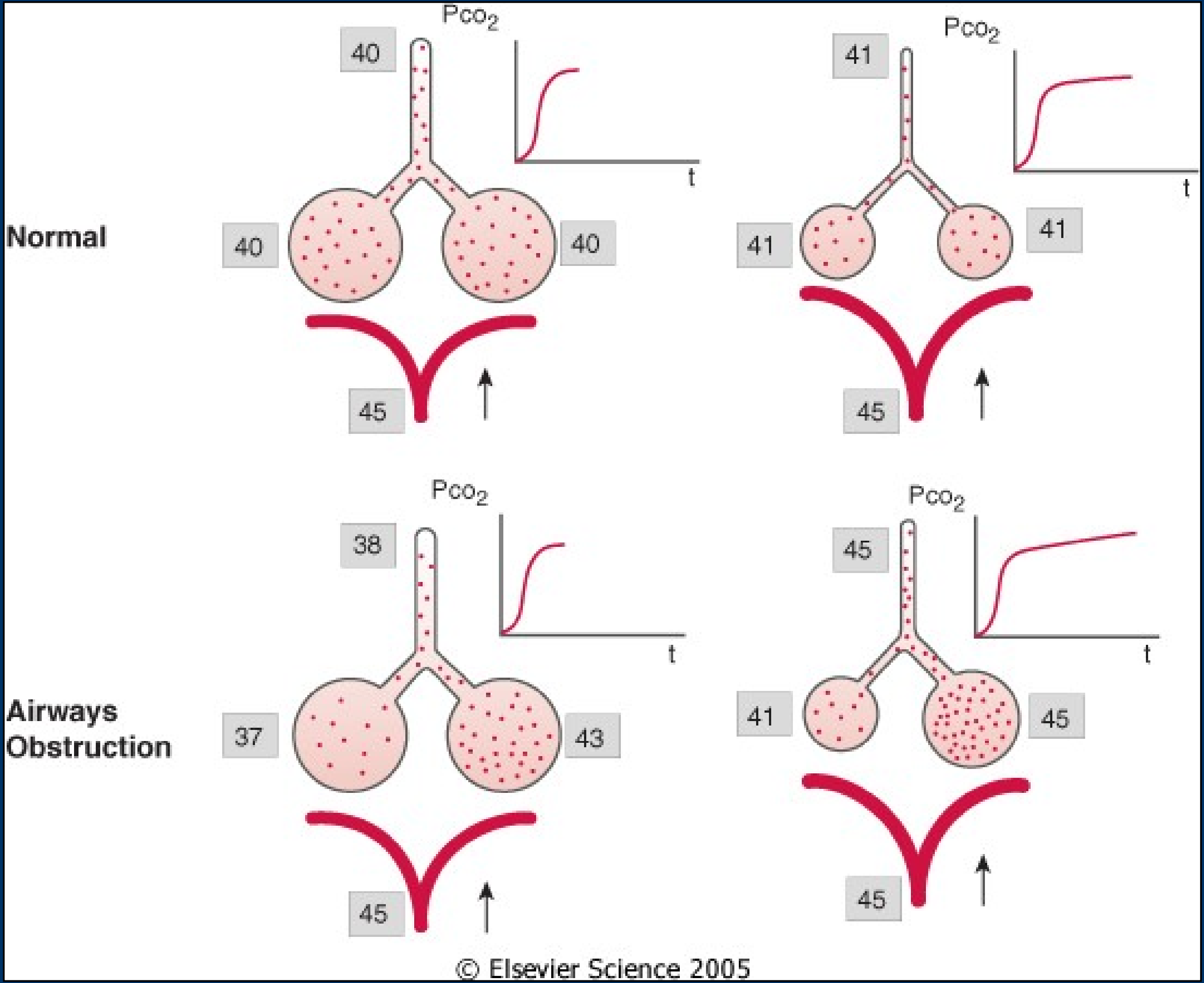


Figure 36-19 Mechanisms of airways obstruction producing an upsloping phase III capnogram. In a normal, healthy person (upper panel), there is a narrow range of [Vdot]a/[Qdot] ratios with values close to 1. Gas exchange units therefore have similar Pco2 and tend to empty synchronously, and the expired Pco2 remains relatively constant. During the course of exhalation, the alveolar Pco2 slowly rises as CO2 continuously diffuses from the blood. This causes a slight increase in Pco2 toward the end of expiration, and this increase can be pronounced if the exhalation is prolonged (see Fig. 36-18C). In a patient with diffuse airways obstruction (lower panel), the airway pathology is heterogeneous, with gas exchange units having a wide range of [Vdot]a/[Qdot] ratios. Well-ventilated gas exchange units, with gas containing a lower Pco2, empty first; poorly ventilated units, with a higher Pco2, empty last. In addition to the continuous rise in Pco2 mentioned previously, there is a progressive increase caused by asynchronous exhalation.

CO2 during Capnoperitoneum

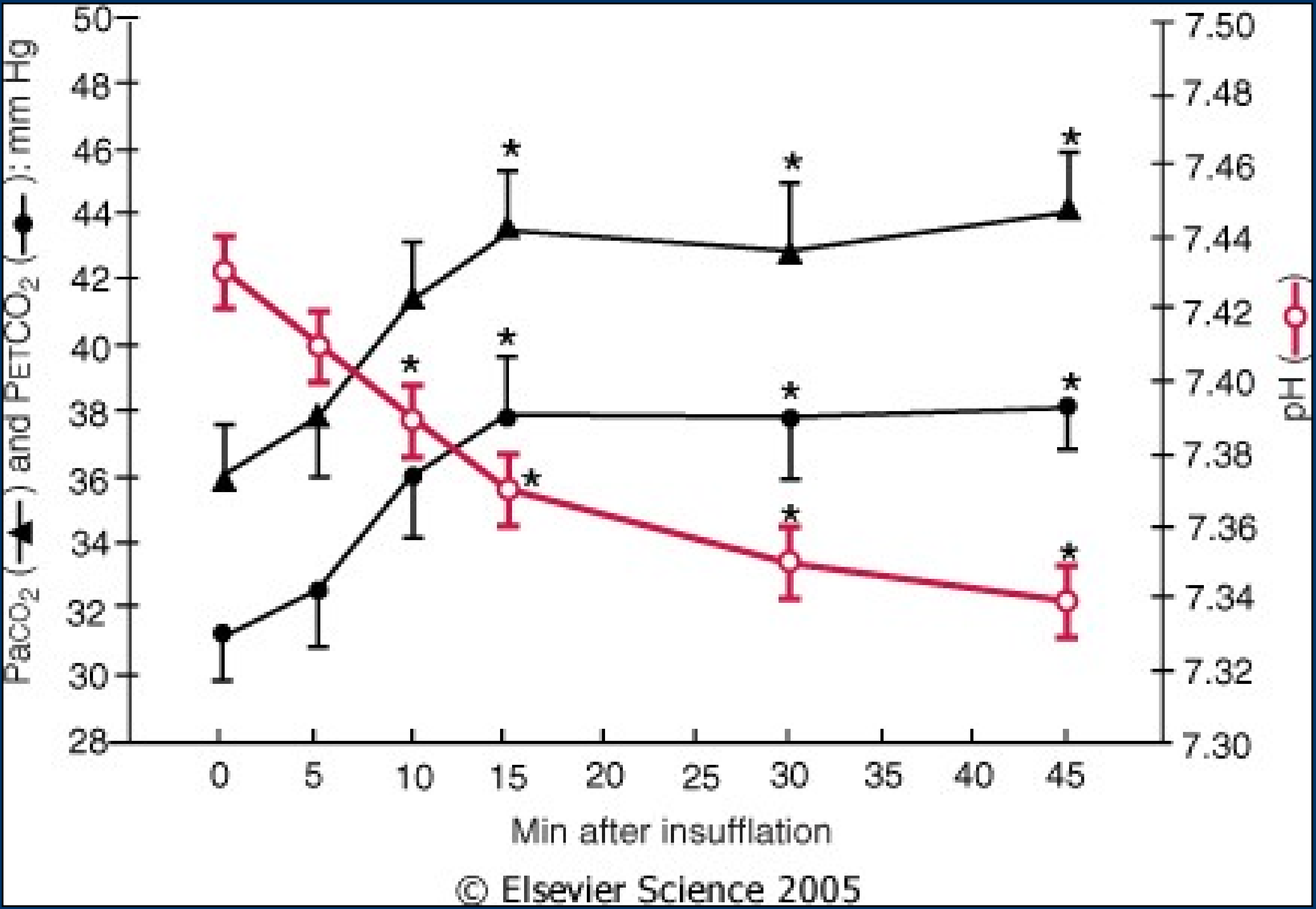


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Figure 57-2 Ventilatory changes (pH, Paco2, and PetCO2) during CO2 pneumoperitoneum for laparoscopic cholecystectomy. For 13 American Society of Anesthesiologists (ASA) class I and II patients, minute ventilation was kept constant at 100 mL/kg/min with a respiratory rate of 12 per minute during the study. Intra-abdominal pressure was 14 mm Hg. Data are given as the mean ± SEM.*, P .05 compared with time 0.

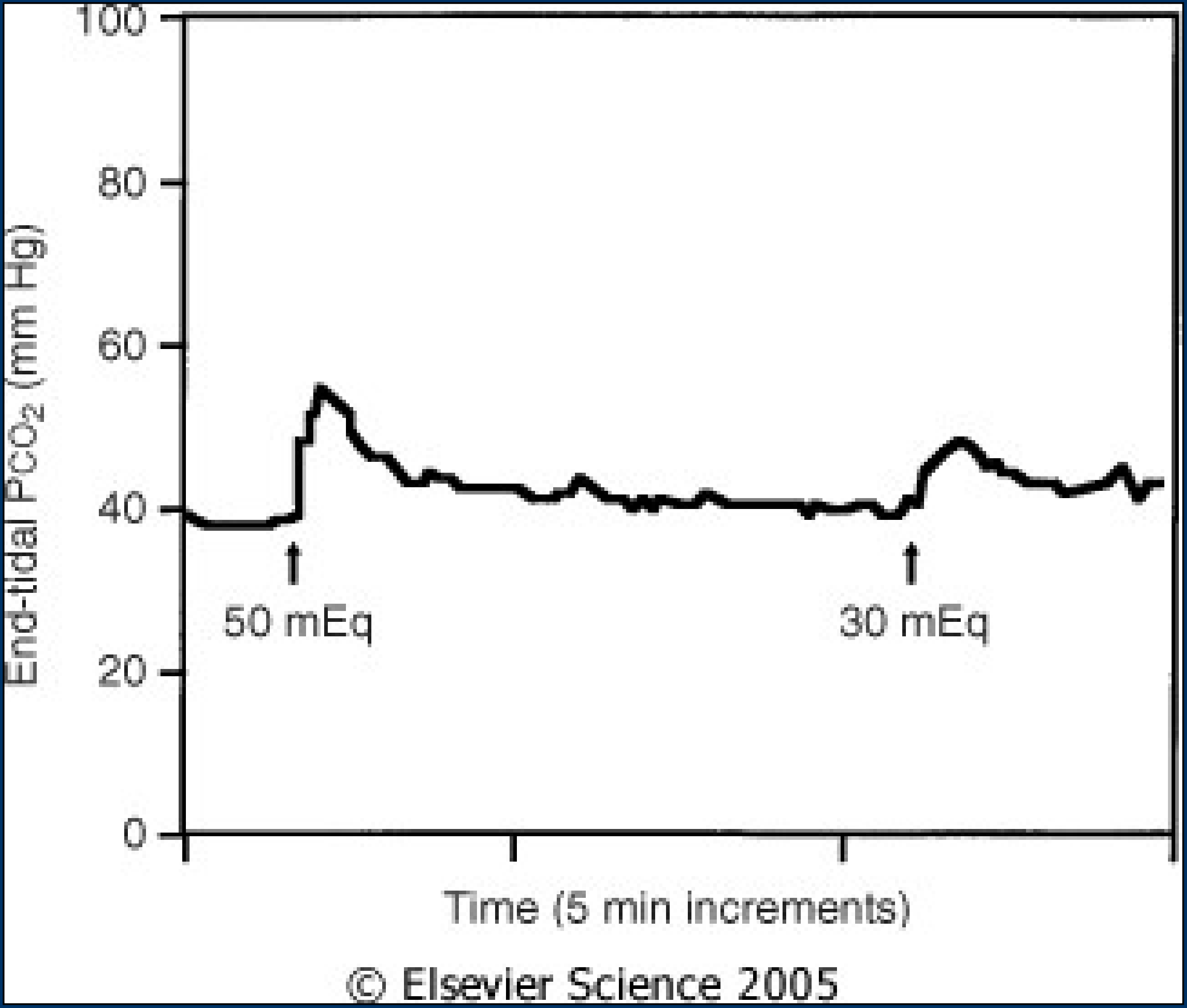


Figure 36-20 The effect ofNaHCO3- administration on end-tidal Pco2. A continuous tracing of end-tidal Pco2 is shown as a function of time. Intravenous administration of 50 mEq followed by 30 mEq of NaHCO3 results in an abrupt increase in expired CO2 because of neutralization of bicarbonate by hydrogen ions.

Capnograph

Sudden fall to 0:

- no ventilation - obstruction
- error

gradual decrease:

- partial obstruction
- hyperventilation
- decrease of metabolism
- decrease of perfusion of the lung

0 etCO2

- intubation to oesophagus

Body temperature

- > 60 minut in anesthesia
- children
- active warming – bed, warm air

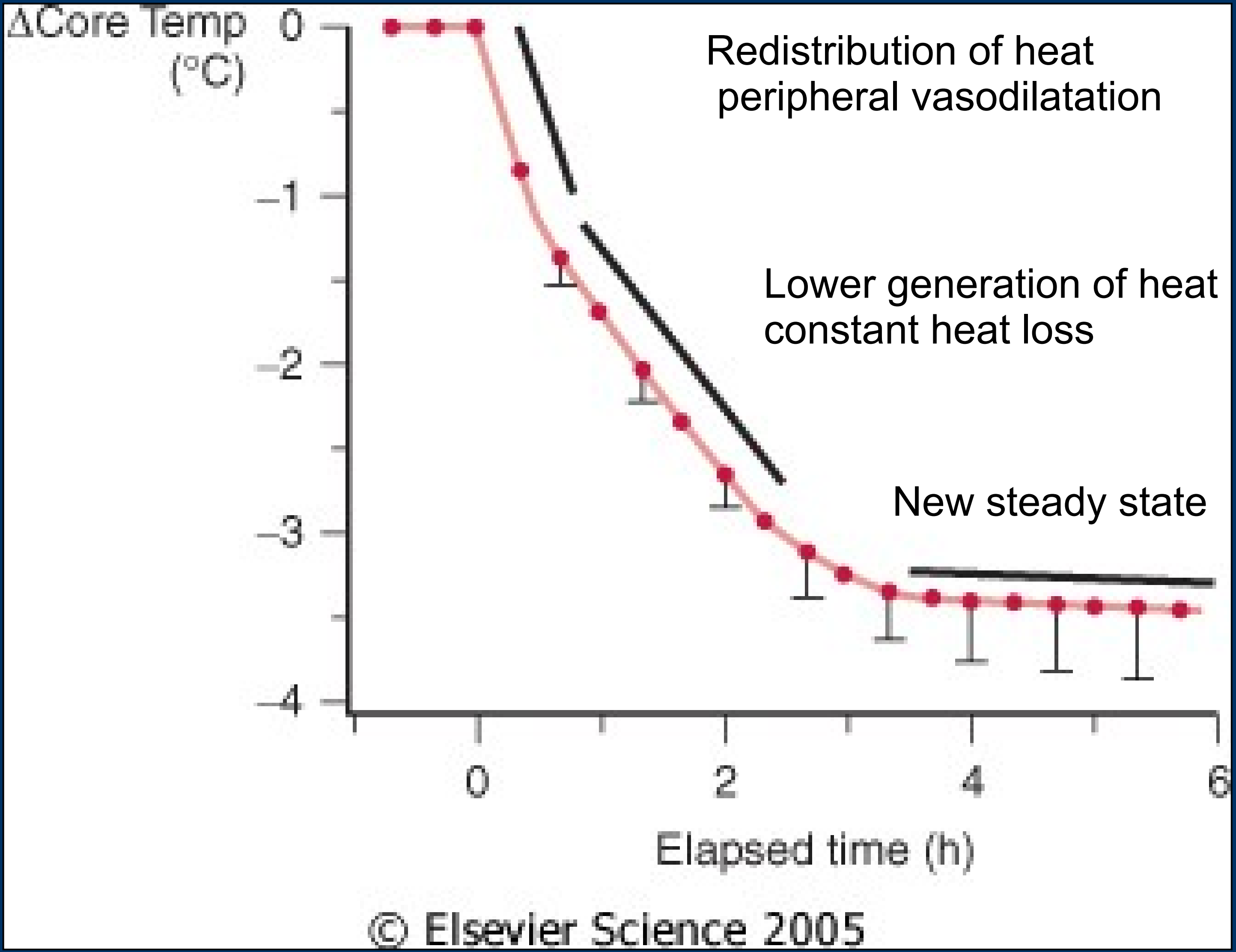
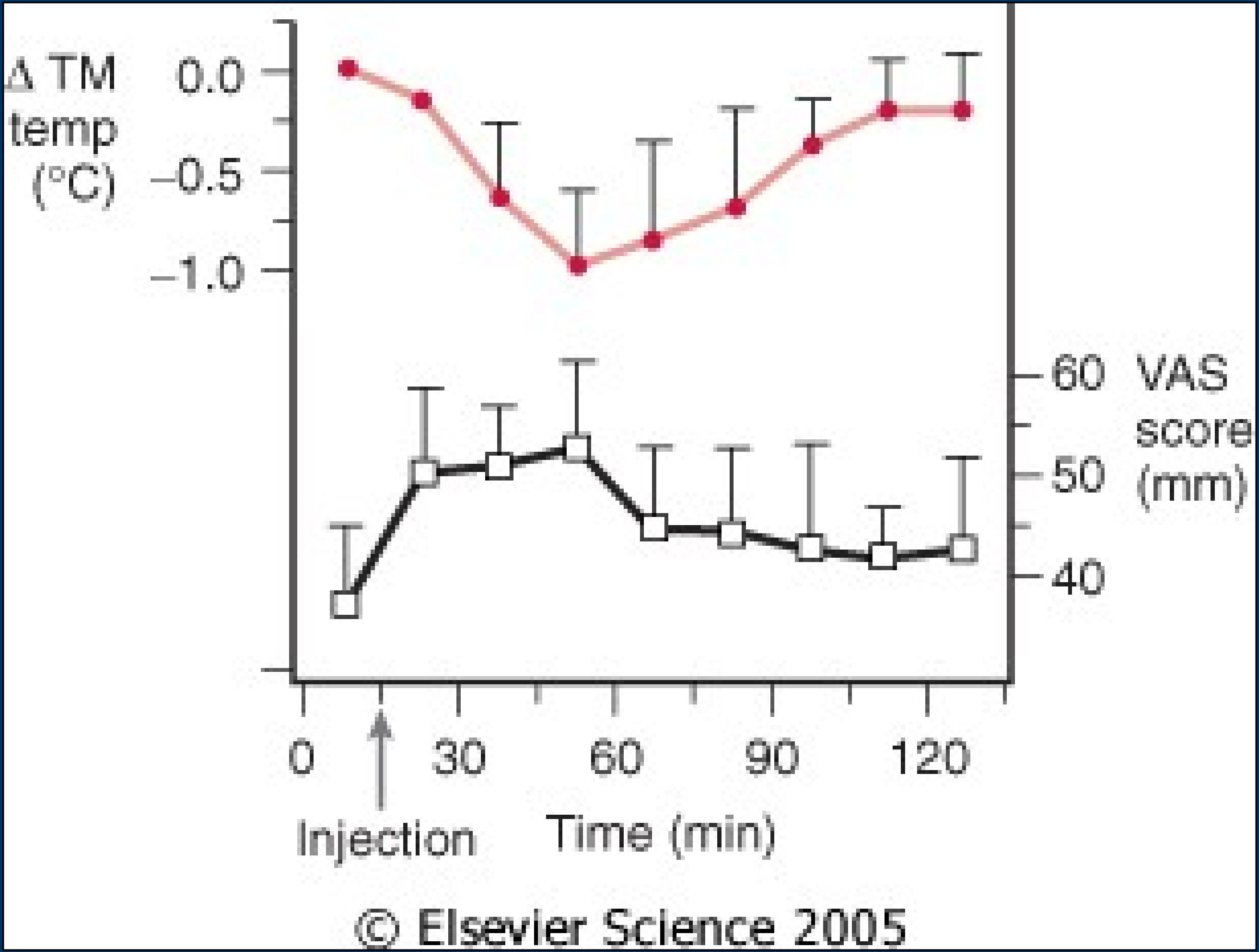


Figure 40-7 Hypothermia during general anesthesia develops with a characteristic pattern. An initial rapid decrease in core temperature results from a core-to-peripheral redistribution of body heat. This redistribution is followed by a slow, linear reduction in core temperature that results simply from heat loss exceeding heat production. Finally, core temperature stabilizes and subsequently remains virtually unchanged. This plateau phase may be a passive thermal steady state or might result when sufficient hypothermia triggers thermoregulatory vasoconstriction. Results are presented as means ± SD.



15 minutes after EPI anestesia: decrease in core temperature, increase in feeling of thermal comfort (visual analog scale -VAS). Interestingly, however, maximal thermal comfort coincided with the minimum core temperature. Tympanally measured temperature. (Redrawn with modification from Sessler DI, Ponte J: Shivering during epidural anesthesia. Anesthesiology 72:816-821, 1990.)

Monitoring of muscle block

- single-twitch
- train-of-four (TOF)
- tetanic, post-tetanic count (PTC)
- double-burst stimulation (DBS)

Single-twitch

- 1Hz .. 0,1Hz, continually

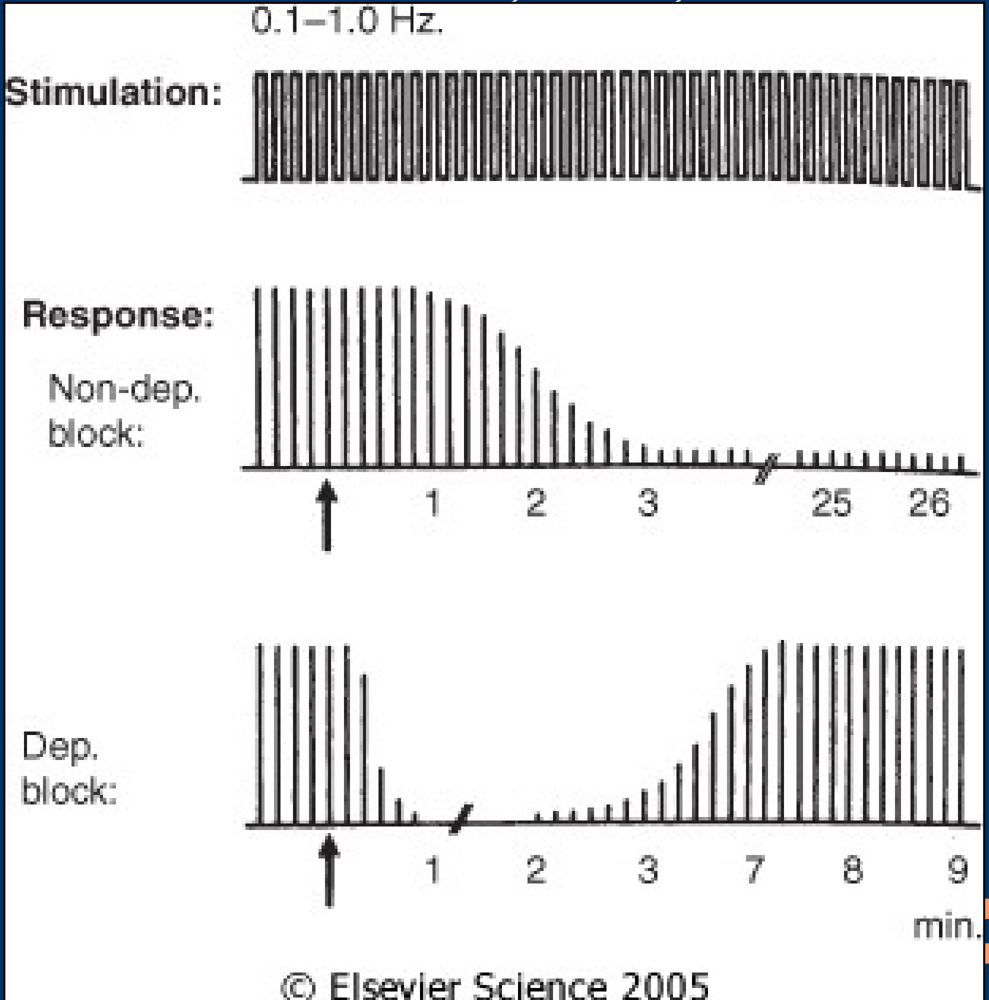


Figure 39-1 Pattern of electrical stimulation and evoked muscle responses to single-twitch nerve stimulation (at frequencies of 0.1 to 1.0 Hz) after injection of nondepolarizing (Non-dep) and depolarizing (Dep) neuromuscular blocking drugs (arrows). Note that except for the difference in time factors, no differences in the strength of the evoked responses exist between the two types of block.

TOF

- 4 stimuls á 0,5s (2Hz)

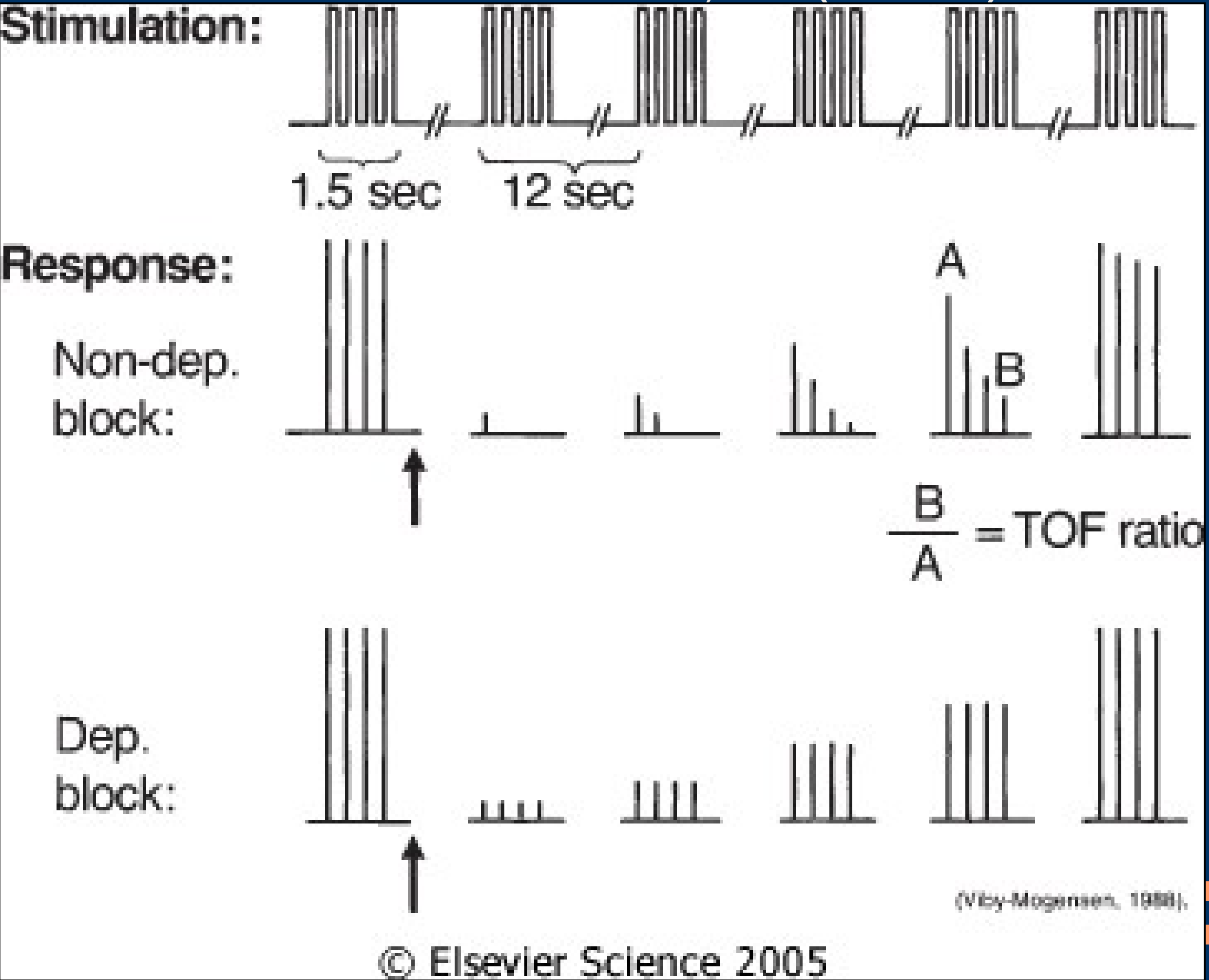


Figure 39-2 Pattern of electrical stimulation and evoked muscle responses to TOF nerve stimulation before and after injection of nondepolarizing (Non-dep) and depolarizing (Dep) neuromuscular blocking drugs (arrows).

Tetanic stimulation

- painfull;
- 50Hz na 5s

Posttetanic facilitation

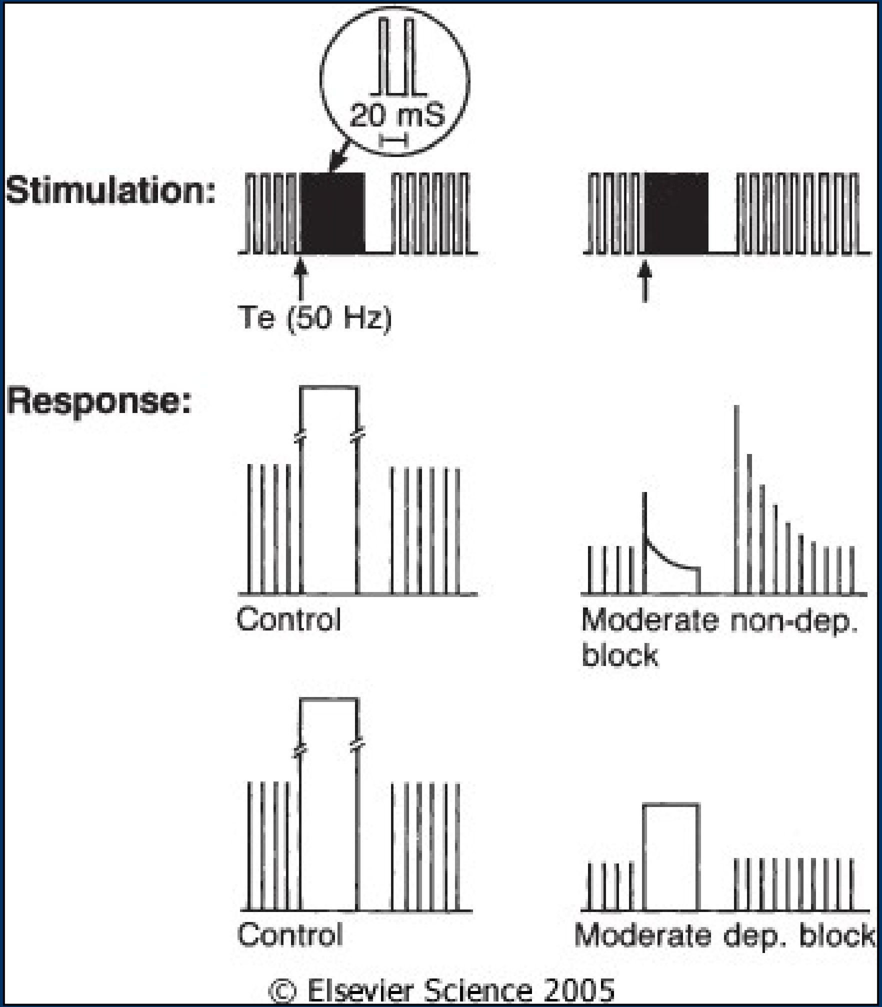


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Figure 39-3 Pattern of stimulation and evoked muscle responses to tetanic (50-Hz) nerve stimulation for 5 seconds (Te) and post-tetanic stimulation (1.0-Hz) twitch. Stimulation was applied before injection of neuromuscular blocking drugs and during moderate nondepolarizing and depolarizing blocks. Note fade in the response to tetanic stimulation, plus post-tetanic facilitation of transmission during nondepolarizing blockade. During depolarizing blockade, the tetanic response is well sustained and no post-tetanic facilitation of transmission occurs.

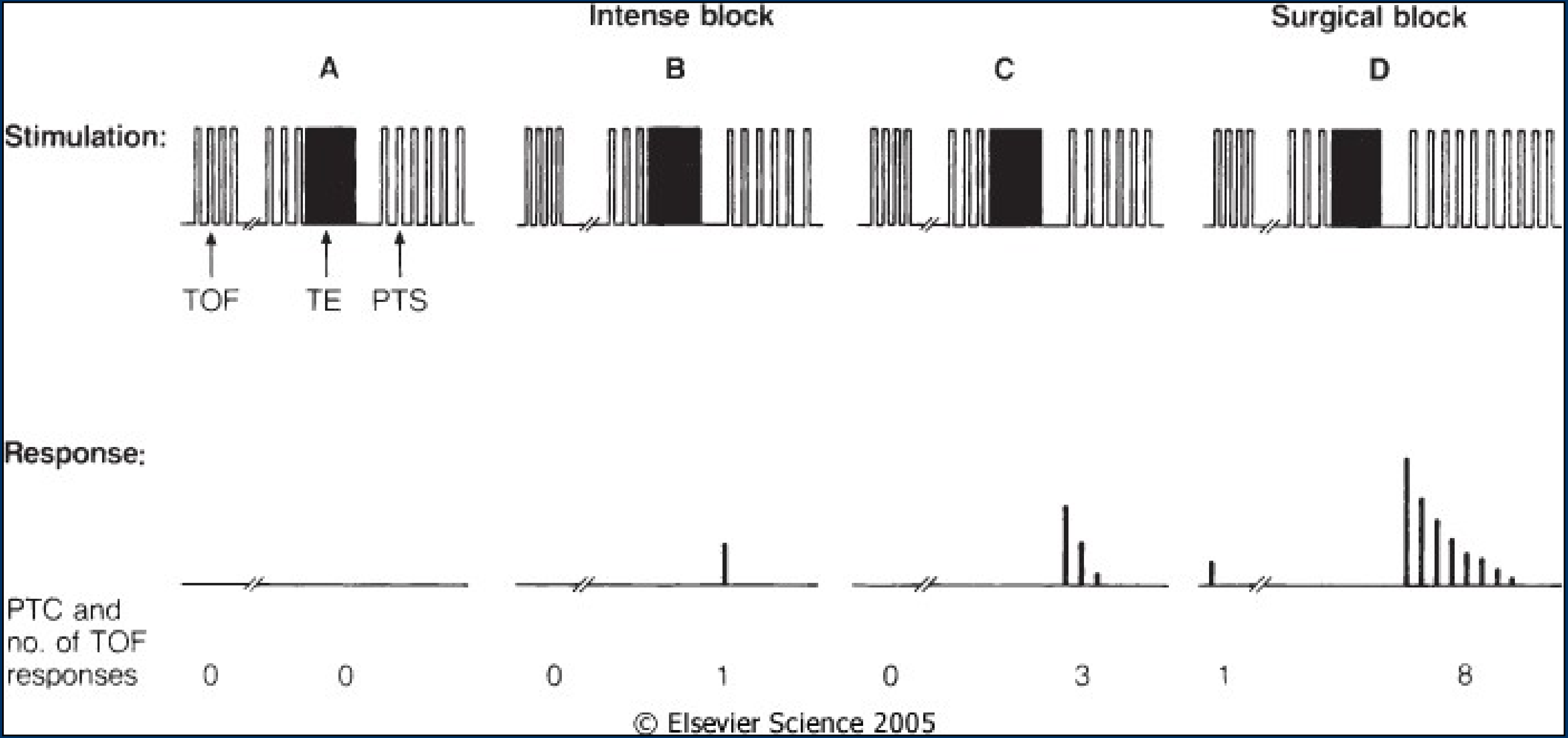


Figure 39-4 Pattern of electrical stimulation and evoked muscle responses to TOF nerve stimulation, 50-Hz tetanic nerve stimulation for 5 seconds (TE), and 1.0-Hz post-tetanic twitch stimulation (PTS) during four different levels of nondepolarizing neuromuscular blockade. During very intense blockade of the peripheral muscles (A), no response to any of the forms of stimulation occurs. During less pronounced blockade (B and C), there is still no response to stimulation, but post-tetanic facilitation of transmission is present. During surgical block (D), the first response to TOF appears and post-tetanic facilitation increases further. The post-tetanic count (see text) is 1 during intense block (B), 3 during less intense block (C), and 8 during surgical block (D).

Double-burst stimulation

- 2 short sequences of 50-Hz tetanic stimulation, separated by 750 ms pause
- nonrelaxed muscle – 2 equal contractions
- patialy relaxed m. – 2nd contr. is weaker

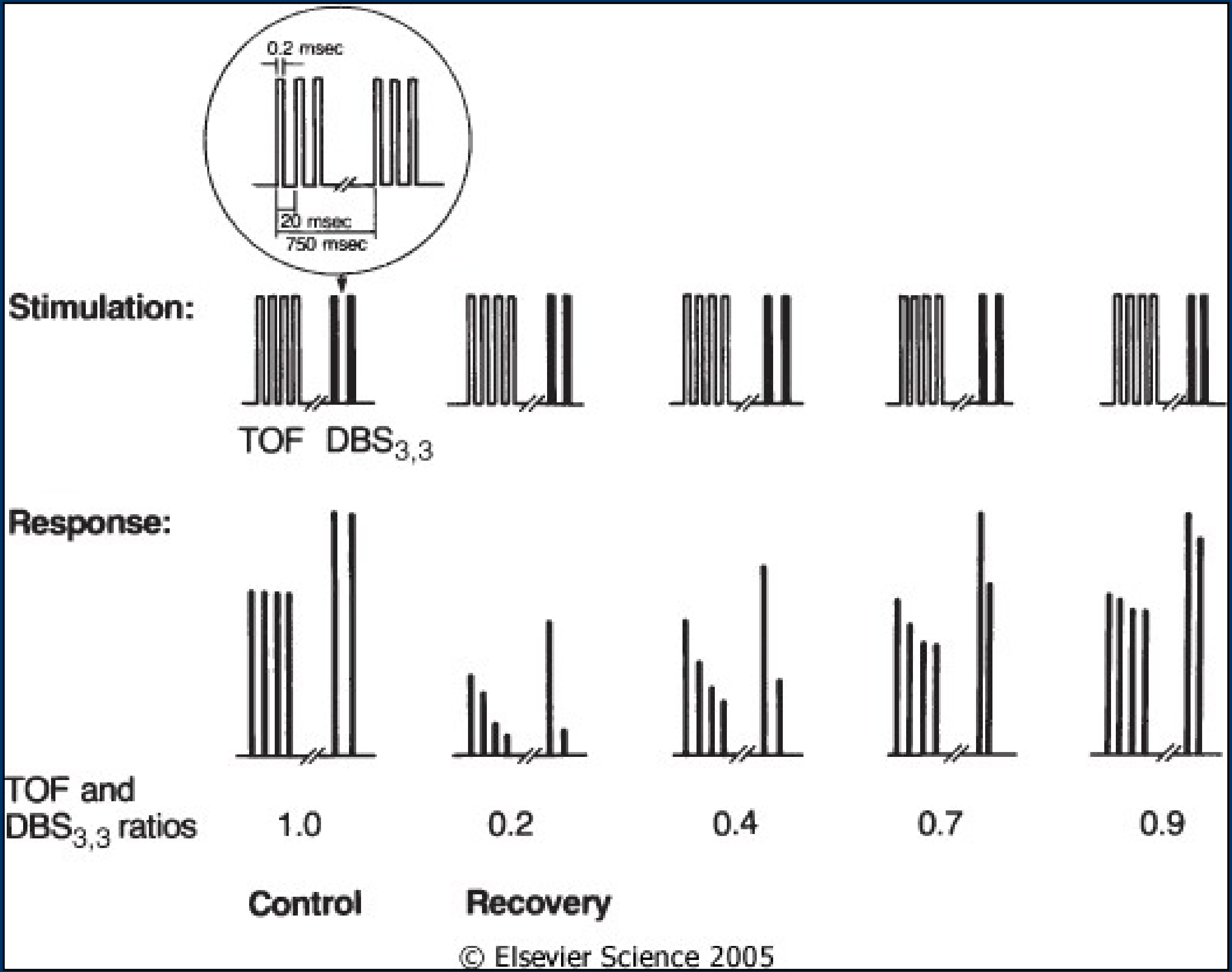


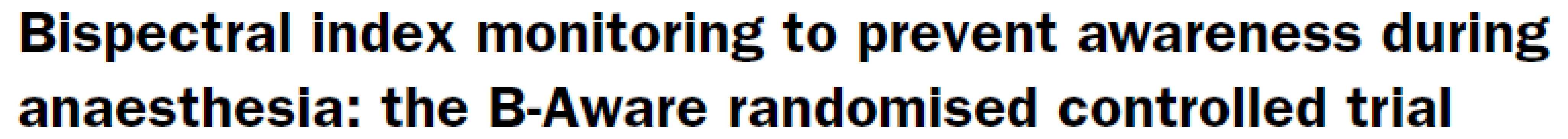
Figure 39-7 Pattern of electrical stimulation and evoked muscle responses to TOF nerve stimulation and double-burst nerve stimulation (i.e., three impulses in each of two tetanic bursts, DBS3,3) before injection of muscle relaxants (control) and during recovery from nondepolarizing neuromuscular blockade. TOF ratio is the amplitude of the fourth response to TOF divided by the amplitude of the first response. DBS3,3 ratio is the amplitude of the second response to DBS3,3 divided by the amplitude of the first response. (See text for further explanation.)

Awarrenes during GA

- to remember moments of GA
- 0,1 – 0,2% population (1:800)
  - Extracorporal circulation
  - Caesarean operation
  - trauma

report:

  - filling of weakness, unable to move
  - conversation
  - anxiety, pain, powerlessness



Bispectral index monitoring to prevent awareness during anaesthesia: the B-Aware randomised controlled trial

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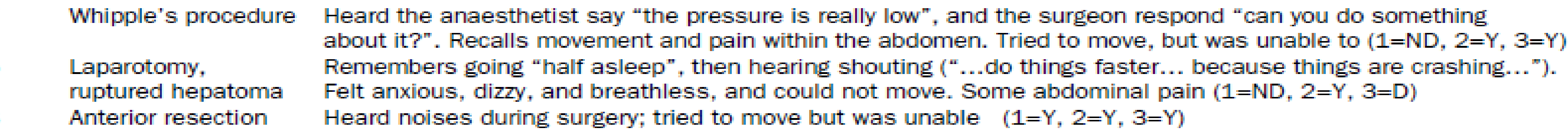
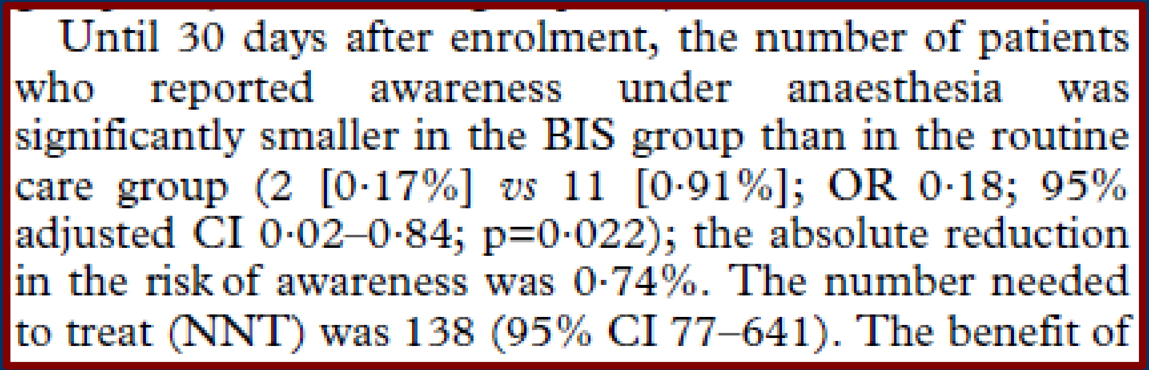


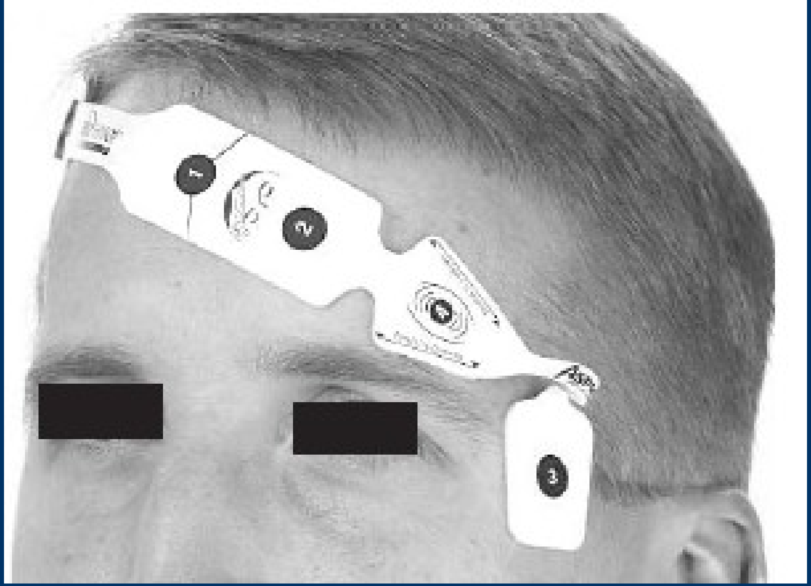
Whipple's procedure	Heard the anaesthetist say "the pressure is really low", and the surgeon respond "can you do something about it?". Recalls movement and pain within the abdomen. Tried to move, but was unable to (1=ND, 2=Y, 3=Y)
Laparotomy, ruptured hepatoma	Remembers going "half asleep", then hearing shouting ("...do things faster... because things are crashing..."). Felt anxious, dizzy, and breathless, and could not move. Some abdominal pain (1=ND, 2=Y, 3=D)
Anterior resection	Heard noises during surgery; tried to move but was unable (1=Y, 2=Y, 3=Y)



Until 30 days after enrolment, the number of patients who reported awareness under anaesthesia was significantly smaller in the BIS group than in the routine care group (2 [0·17%] *vs* 11 [0·91%]; OR 0·18; 95% adjusted CI 0·02–0·84; p=0·022); the absolute reduction in the risk of awareness was 0·74%. The number needed to treat (NNT) was 138 (95% CI 77–641). The benefit of

Monitoring of depth of anaesthesia

- EEG – matematics → BIS .. Level of awareness 100 .. 0



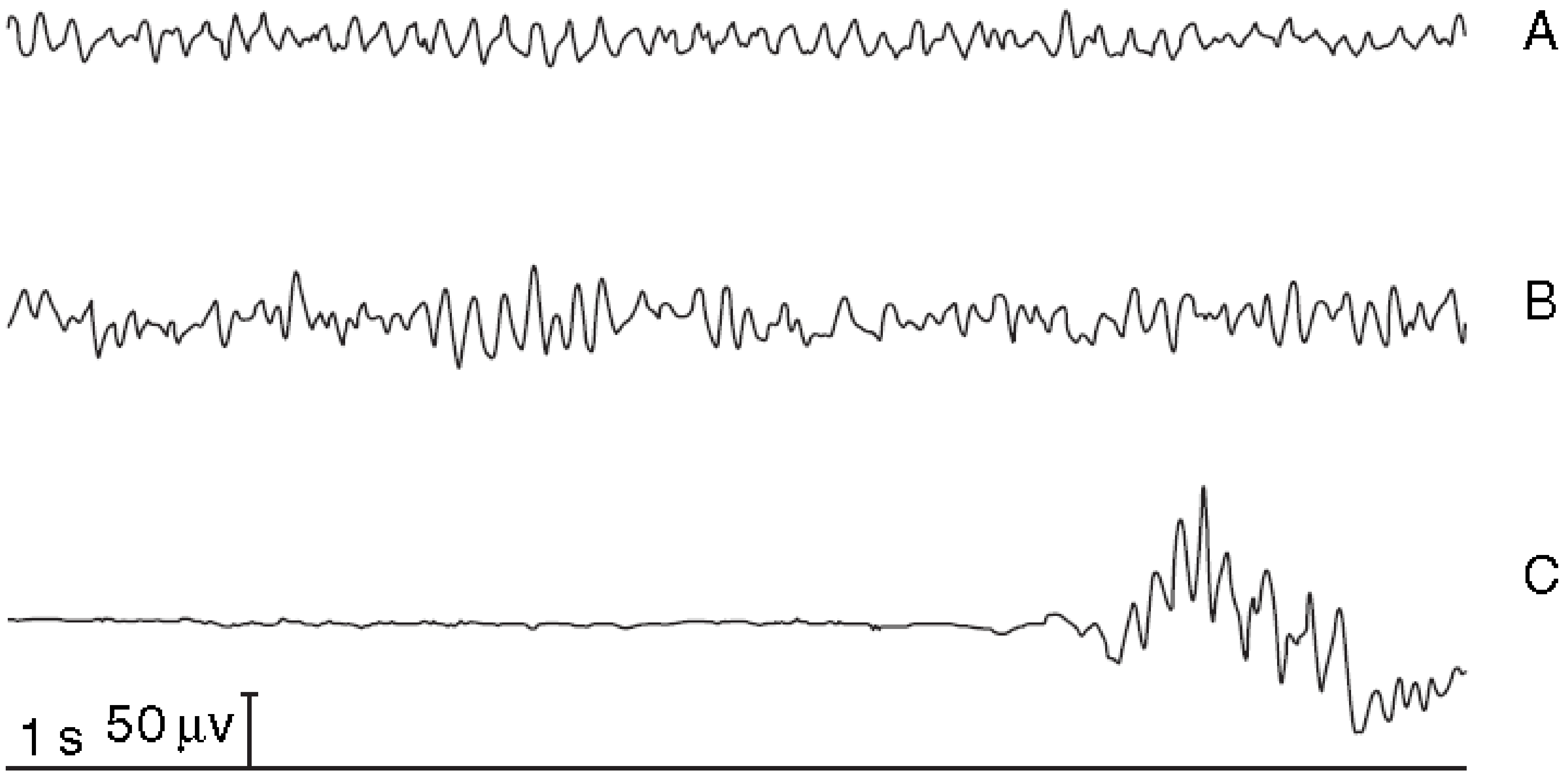


Fig 5 Raw EEG waves. A, awake state; B, *β*-activation; C, burst suppression.

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Depth of anaesthesia monitoring: what's available, what's validated and what's next?

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Next? ... pharmacology