ASYOD Eğitim Toplantıları 2019

İleri Mekanik Ventilasyon Uygulamaları Kursu

SOLUNUM MEKANİKLERİ: NASIL ÖLÇERİM?

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09.11.2019

SOLUNUM MEKANİKLERİ

“Akciğer fonksiyonlarının basınç, akım,volüm ölçümleri ile ifade edilmesi”

SOLUNUM MEKANİKLERİ

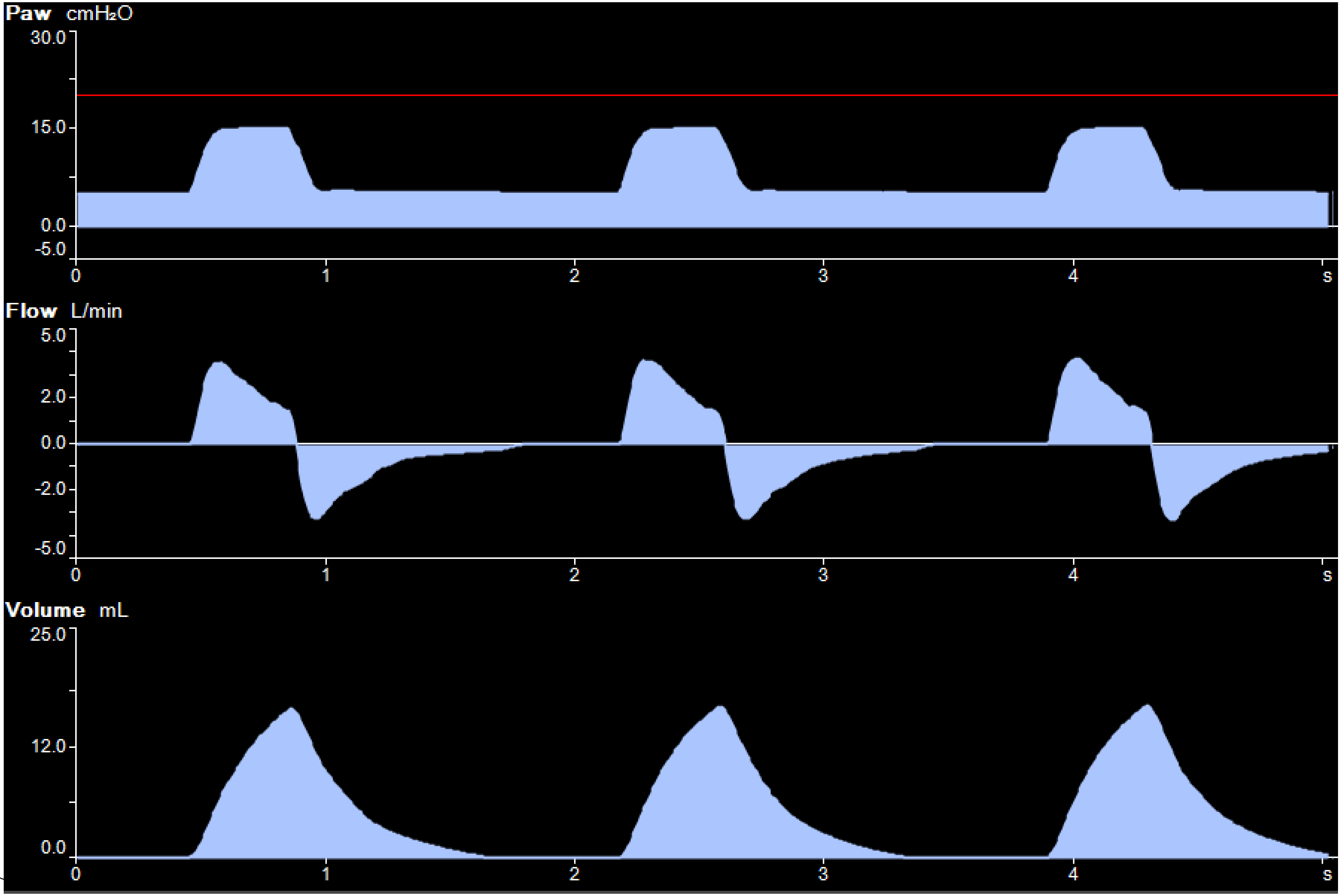
- **Neden önemli?**
  - Akut solunum yetmezliğinin altta yatan patofizyolojisini anlamak
  - Hastalığın durumunu ve seyrini değerlendirmek
  - Tedavi yaklaşımını belirlemek (PEEP, bronkodilatörler, sıvı tedavisi)
  - Hasta ventilatör uyumunu sağlamak
  - Ventilatör ilişkili komplikasyonları önlemek
  - Mekanik ventilasyonun sonlandırılmasına karar verebilmek

SOLUNUM MEKANİKLERİNİ NASIL DEĞERLENDİRELİM?

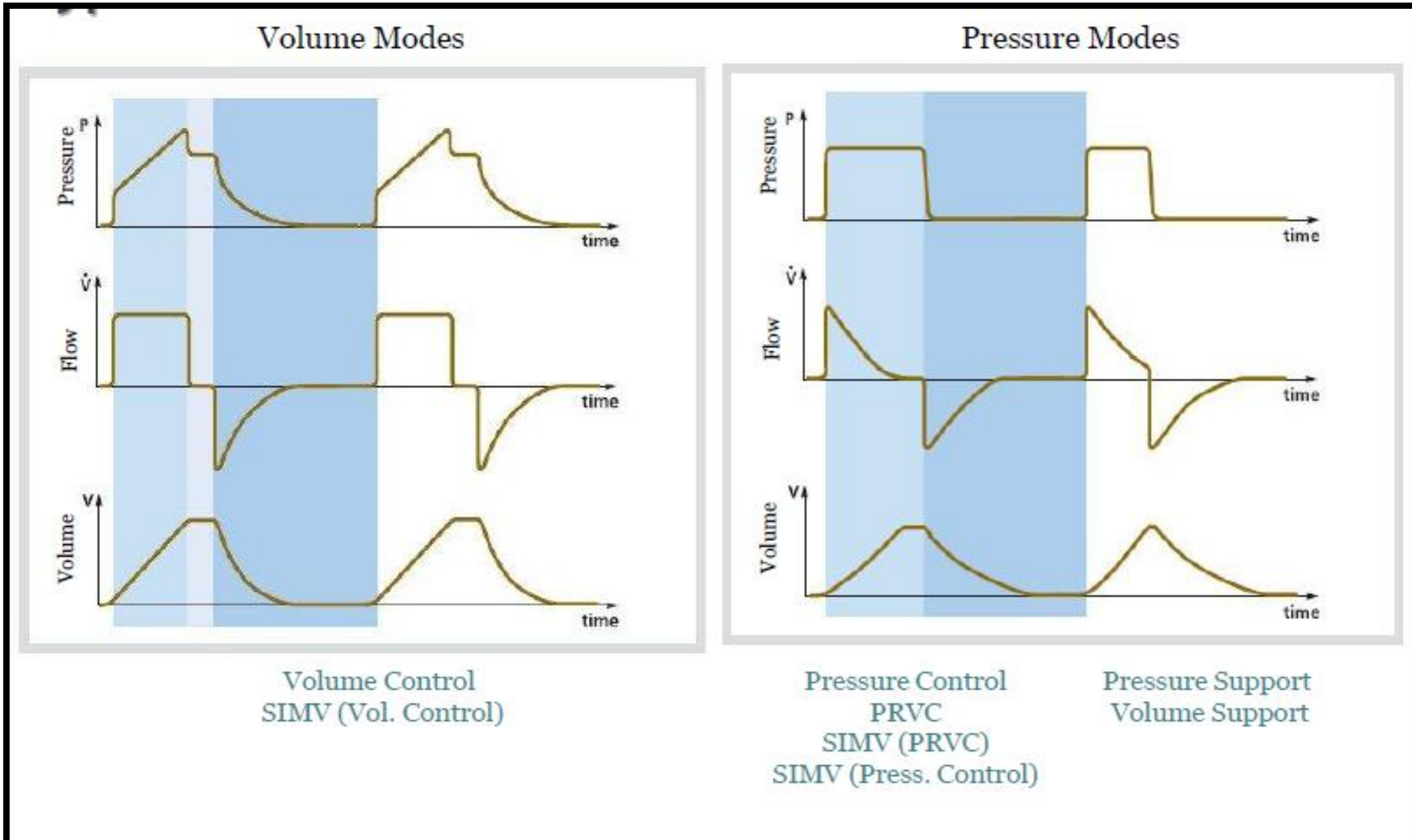
Ventilatör Grafikleri:

- Basınç, akım ve volüm eğrileri
- Özafageal (plevral) ve gastrik (abdominal) basınçlar
- Ölçümler
  - Komplians
  - Rezistans
- Zaman ilişkili grafikler (waveforms)
  - Basınç
  - Akım
  - Volüm
- Döngüler
  - Basınç volüm
  - Akım Volüm

BASINÇ-AKIM-VOLÜM EĞRİLERİ



DALGA FORMLARI



BASINÇ DALGA FORMU

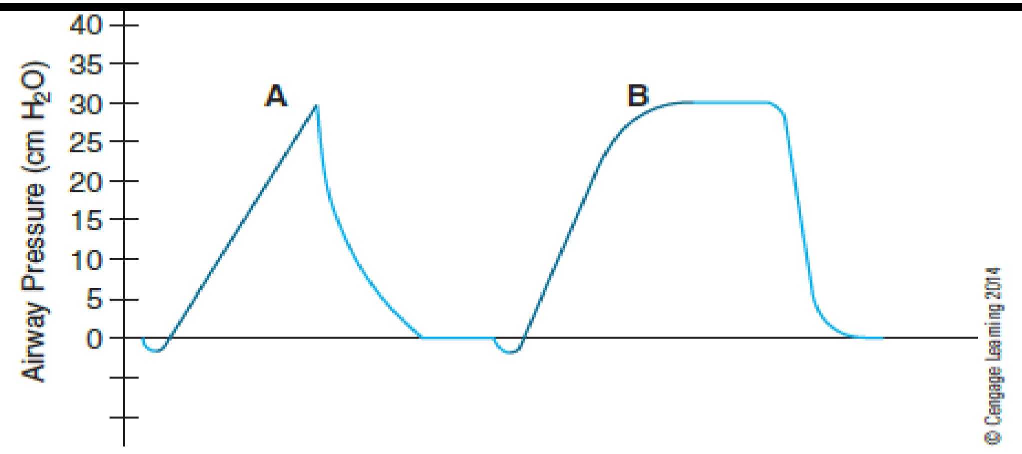
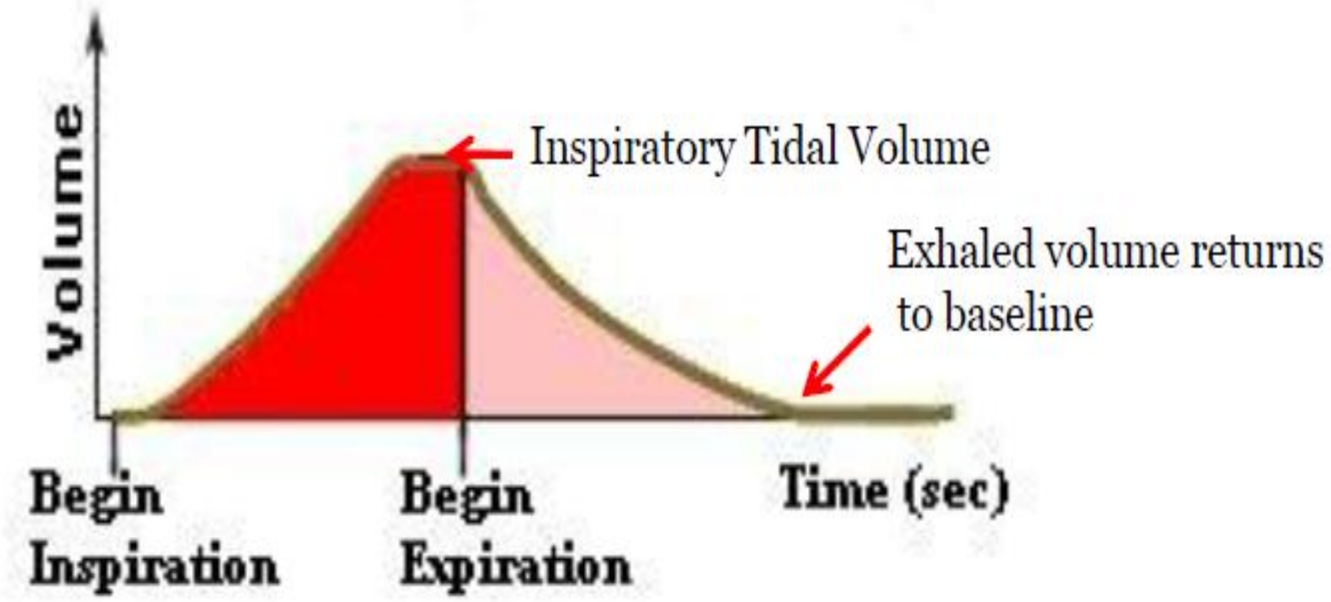


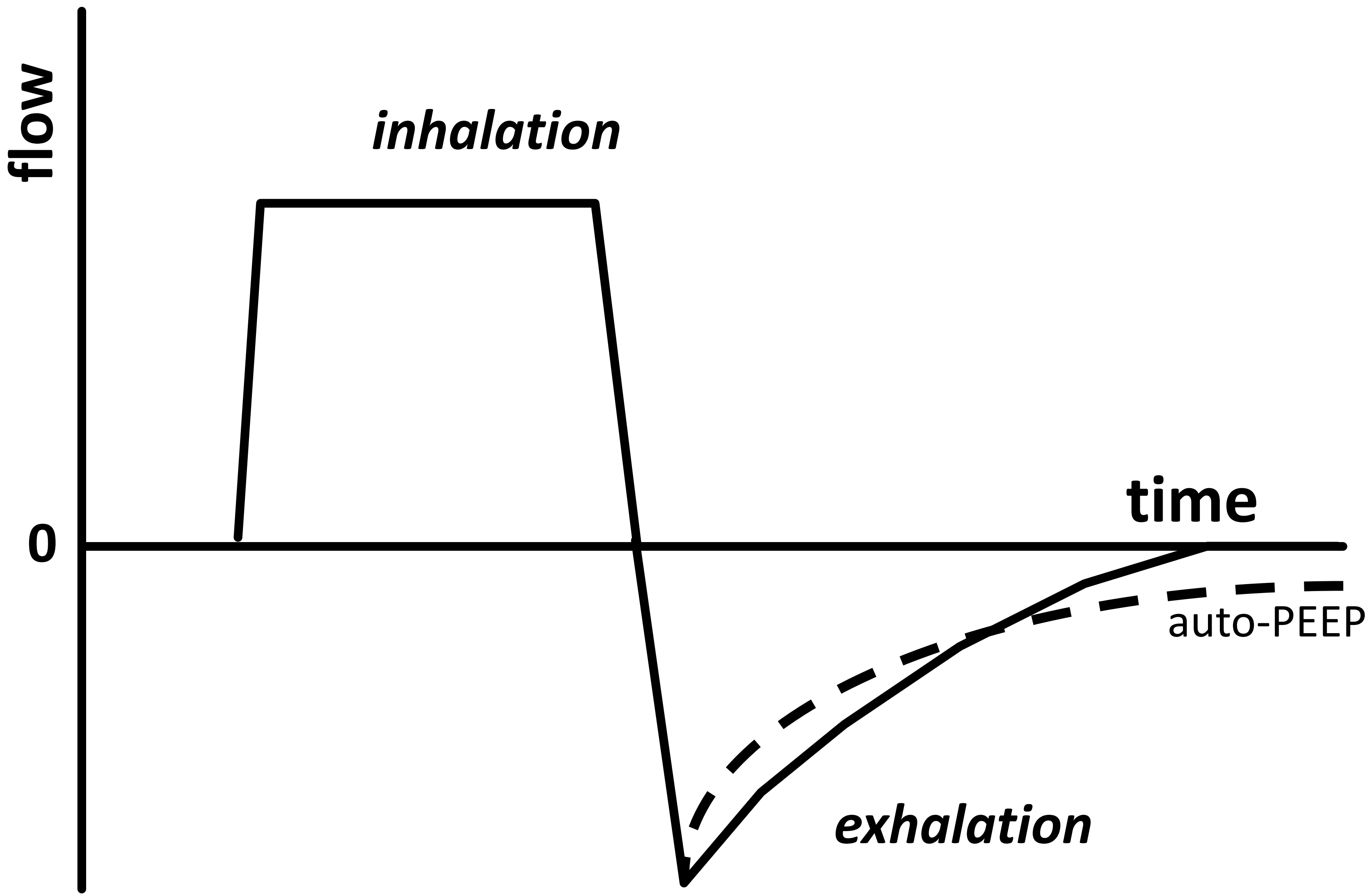
FIGURE 4-10 (A) Pressure tracing of a volume-controlled mechanical breath; (B) Pressure tracing of a pressure-controlled mechanical breath; note the prolonged inspiratory pressure plateau in pressure-controlled ventilation.

Clinical Application of Mechanical Ventilation, Fourth Edition
David W. Chang

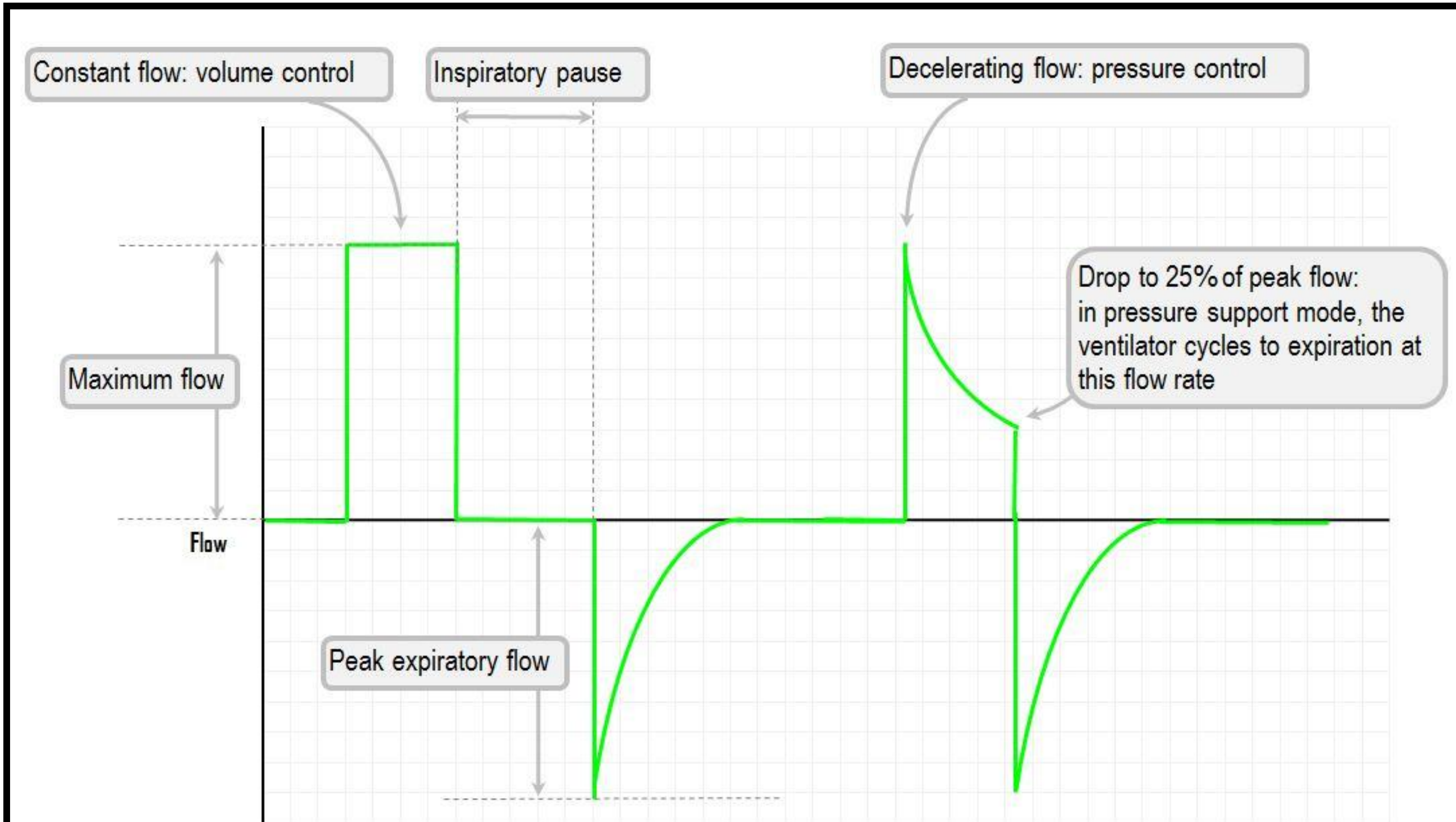
VOLÜM DALGA FORMU



AKIM DALGA FORMU



AKIM DALGA FORMU



ÖLÇÜMLER

(KOMPLİANS,ELASTANS,REZİSTANS,WOB)

SOLUNUM MEKANİKLERİ

KOMPLİANS

Volüm değişikliği / Basınç değişikliği

«Akciğerin genişleyebilme kolaylığı»

Belirli bir basınç artışına bağlı olarak oluşan hacim artışının ölçüsü (1/elastans)

Pilbeam SP. Basic terms and concepts of mechanical ventilation.,in Mechanical Ventilation:Physiological and Clinical Applications ed 4, St Louis 2006, Mosby

SOLUNUM MEKANİKLERİ

ELASTANS (1/KOMPLİANS)

Volüm değişikliği / Basınç değişikliği

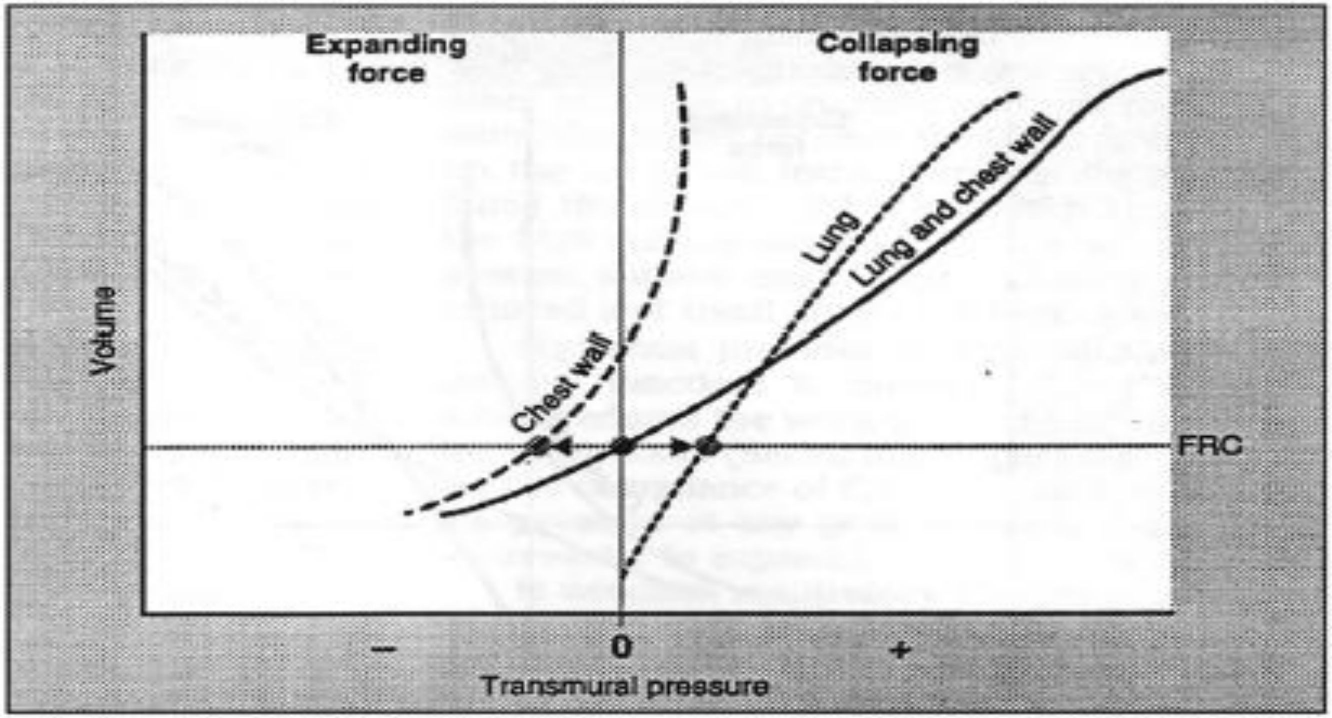
«Gerilen akciğerlerin eski şekline dönebilmesi»

Akciğerin elastik özellikleri (1/3)

Sıvı içeriğinin yüzey gerilimi (2/3)

Pilbeam SP. Basic terms and concepts of mechanical ventilation.,in Mechanical Ventilation:Physiological and Clinical Applications ed 4, St Louis 2006, Mosby

Figure 2

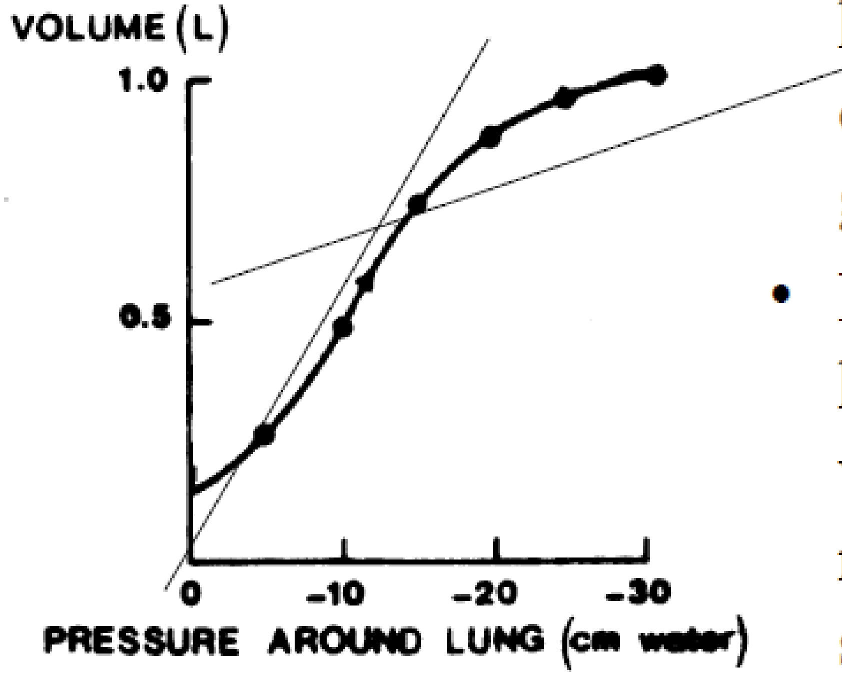


Compliance of the lungs, chest wall, and the combined lung–chest wall system. At the functional residual capacity, the forces of expansion and collapse are in equilibrium. Reprinted from [3] with permission from Elsevier.

Normal toplam komplians:(akciğer+göğüs duvarı)= 200 ml/cm H20

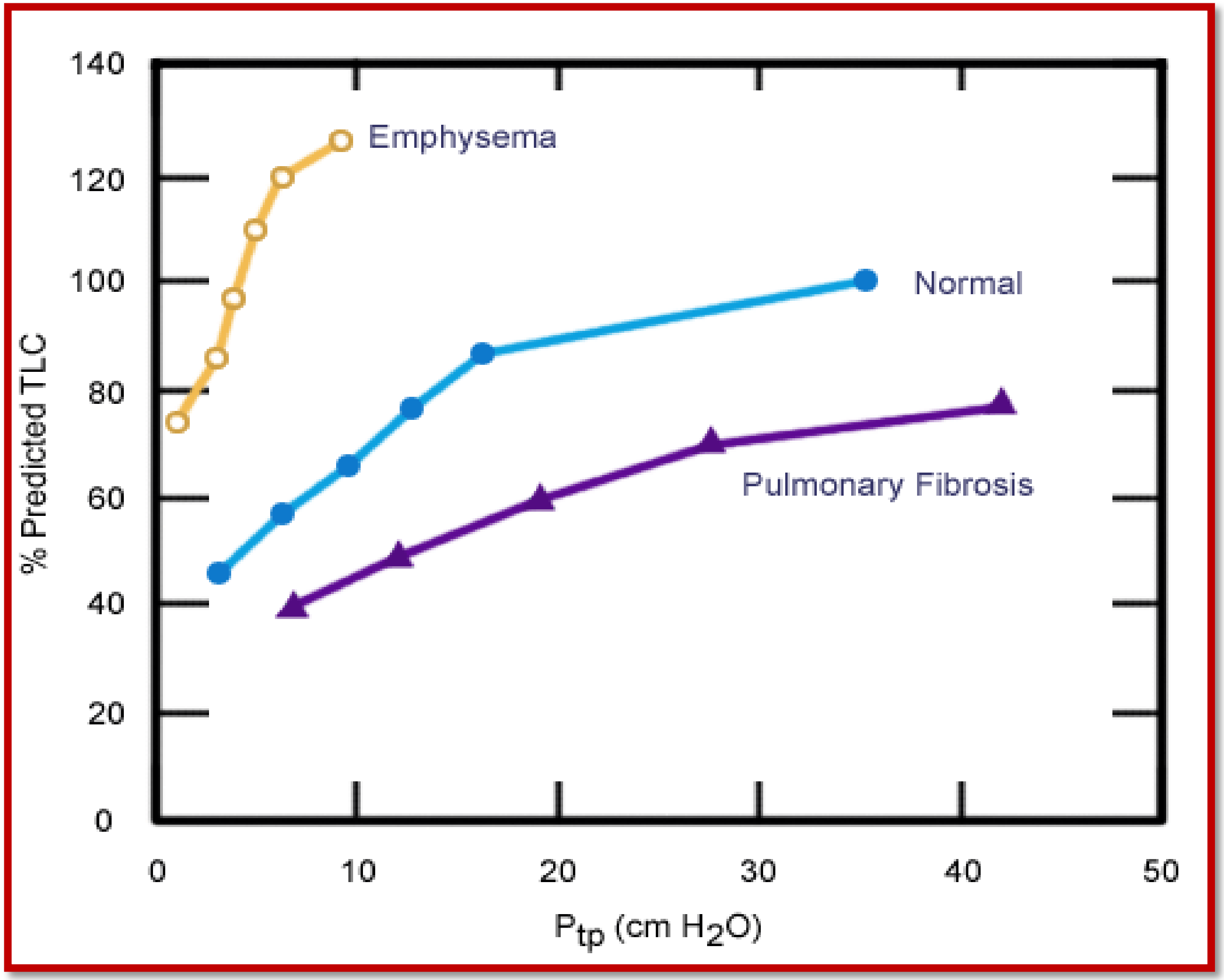
Basınç 1 cmH20 arttığında akciğerler 200ml genişler

AC'lerin kompliyansı



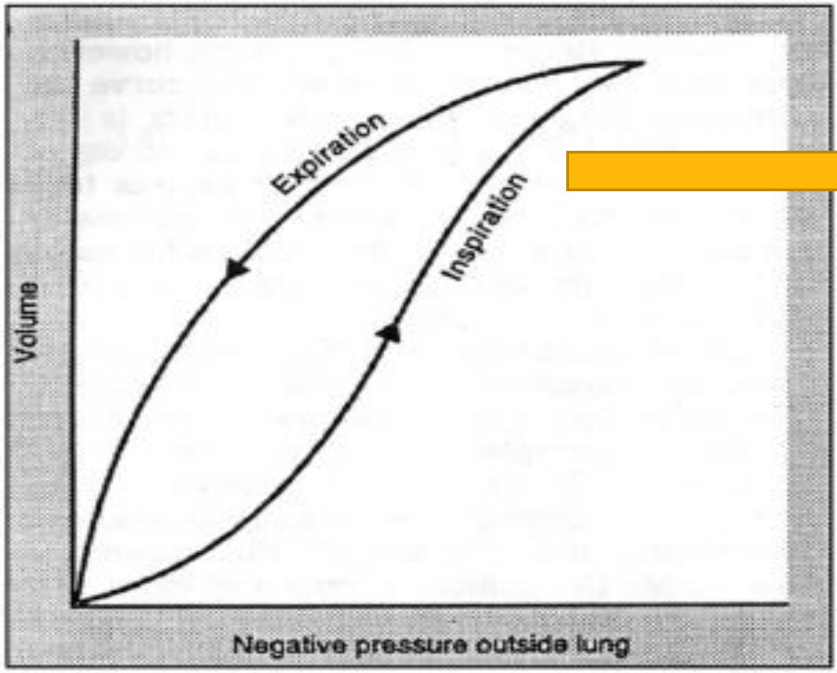
- Eğrinin dik olması yüksek kompliyansı, yatık olması düşük kompliyansı gösterir.
- Dolayısıyla AC kompliyansı yüksek volümlerde en düşük, rezidüel volüm seviyelerinde en yüksek noktasındadır.

KOMPLİANS



Emphysema
Normal
Pulmonary Fibrosis
% Predicted TLC
140
120
100
80
60
40
20
0
0
10
20
30
40
50
P_{tp} (cm H_2O)

KOMPLİANS

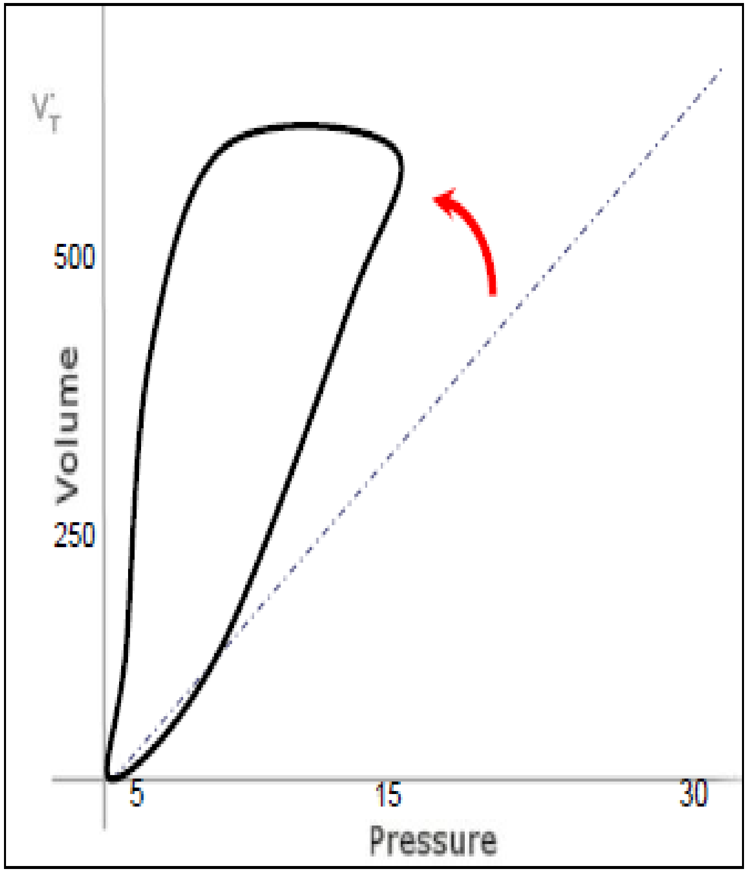


Pressure–volume curve. Shown is a pressure–volume curve developed from measurements in isolated lung during inflation (inspiration) and deflation (expiration). The slope of each curve is the compliance. The difference in the curves is hysteresis. Reprinted from [3] with permission from Elsevier.

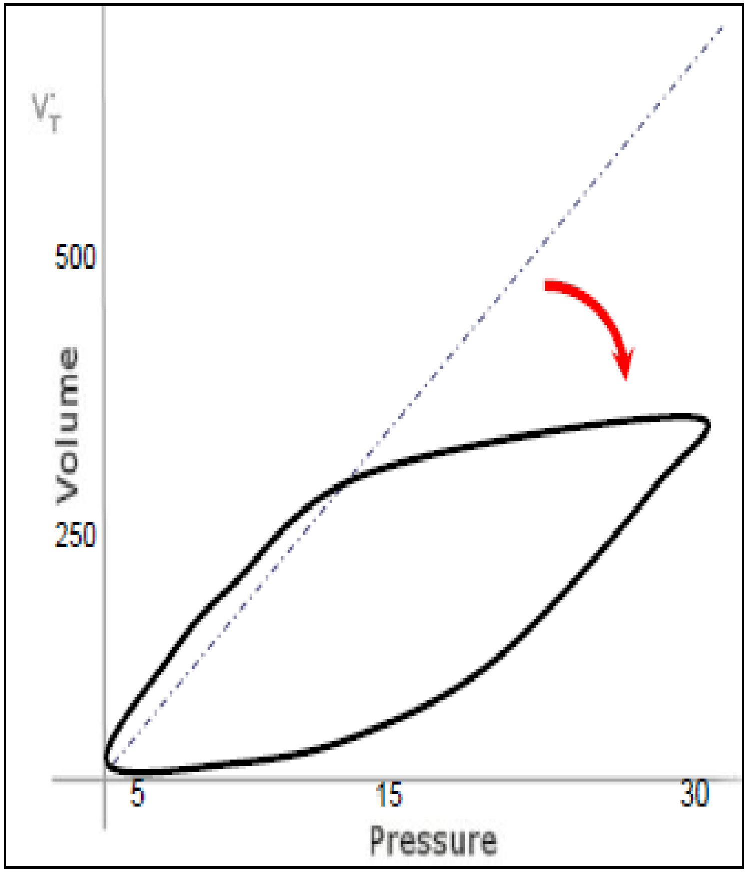
Histerezis; elastik yapılarda uygulanan kuvvet sonrası oluşan volüm değişikliğinin kuvvet ortadan kalktıktan sonra belirli bir zaman korunması

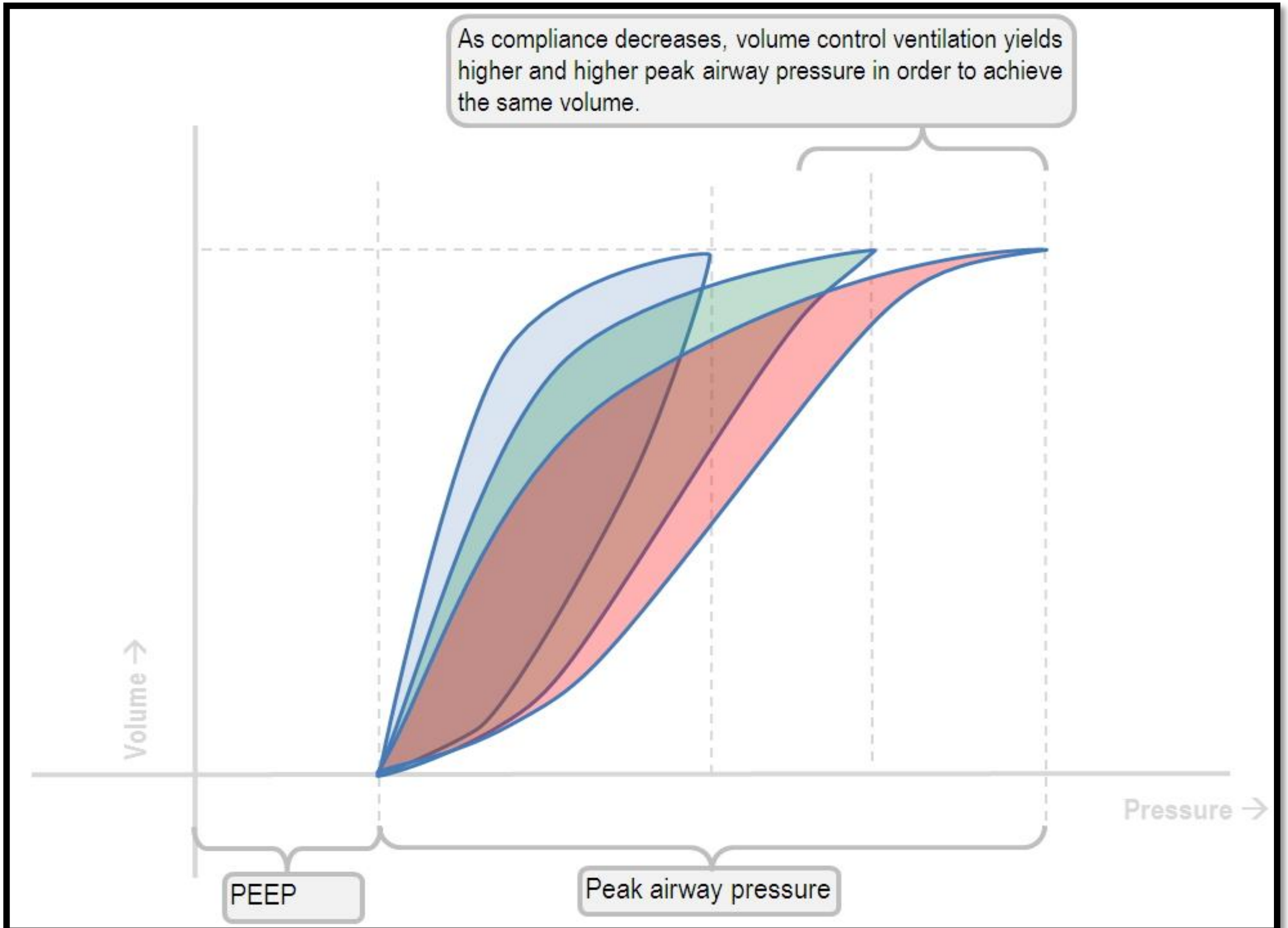
P-V Eğrisi- Eğrinin eğimi kompliansı verir

ARTMIŞ KOMPLİANS



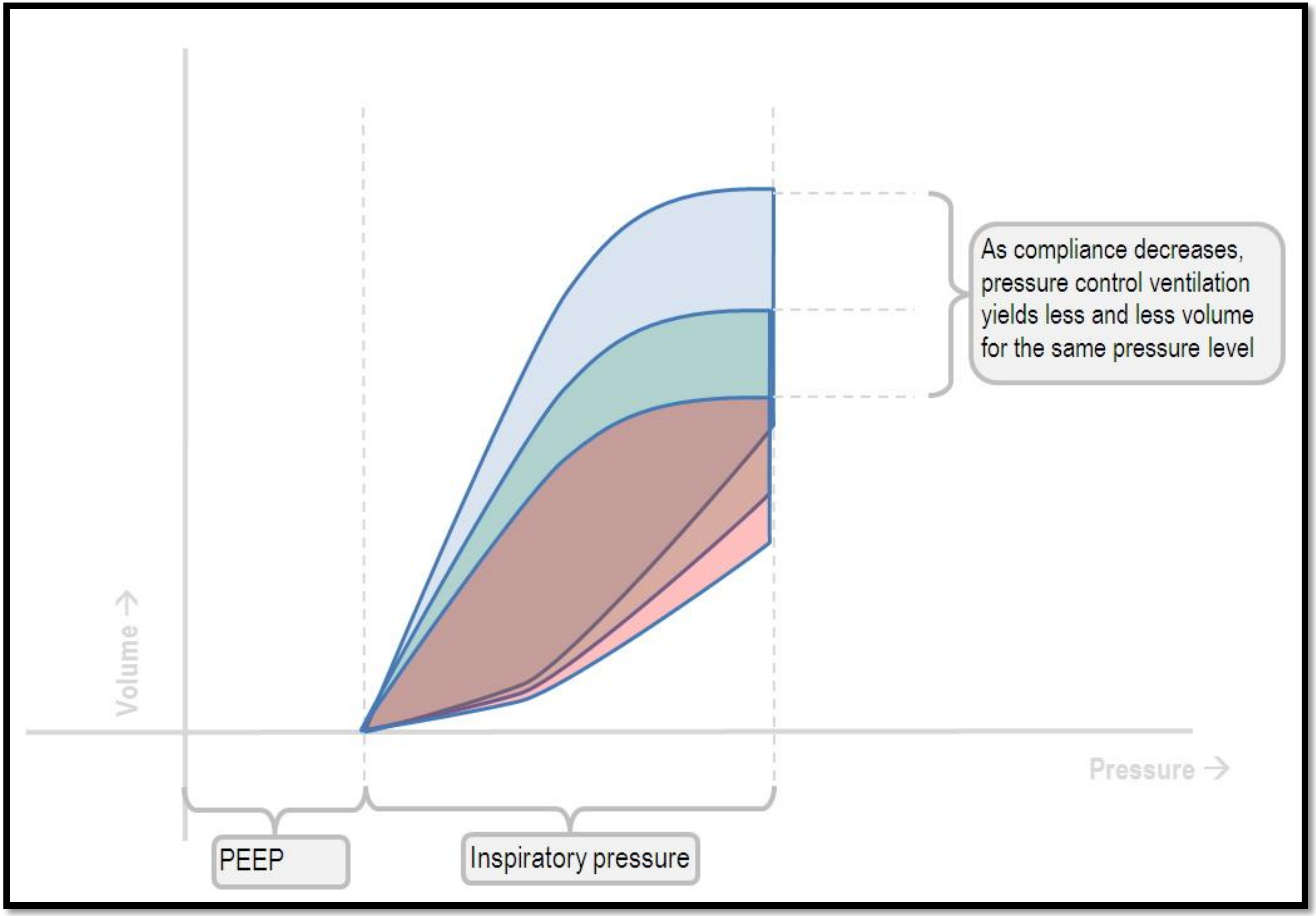
AZALMIŞ KOMPLİANS





Volüm Kontrollü Ventilasyonda P-V Eğrisi ile Kompliansın Değerlendirilmesi

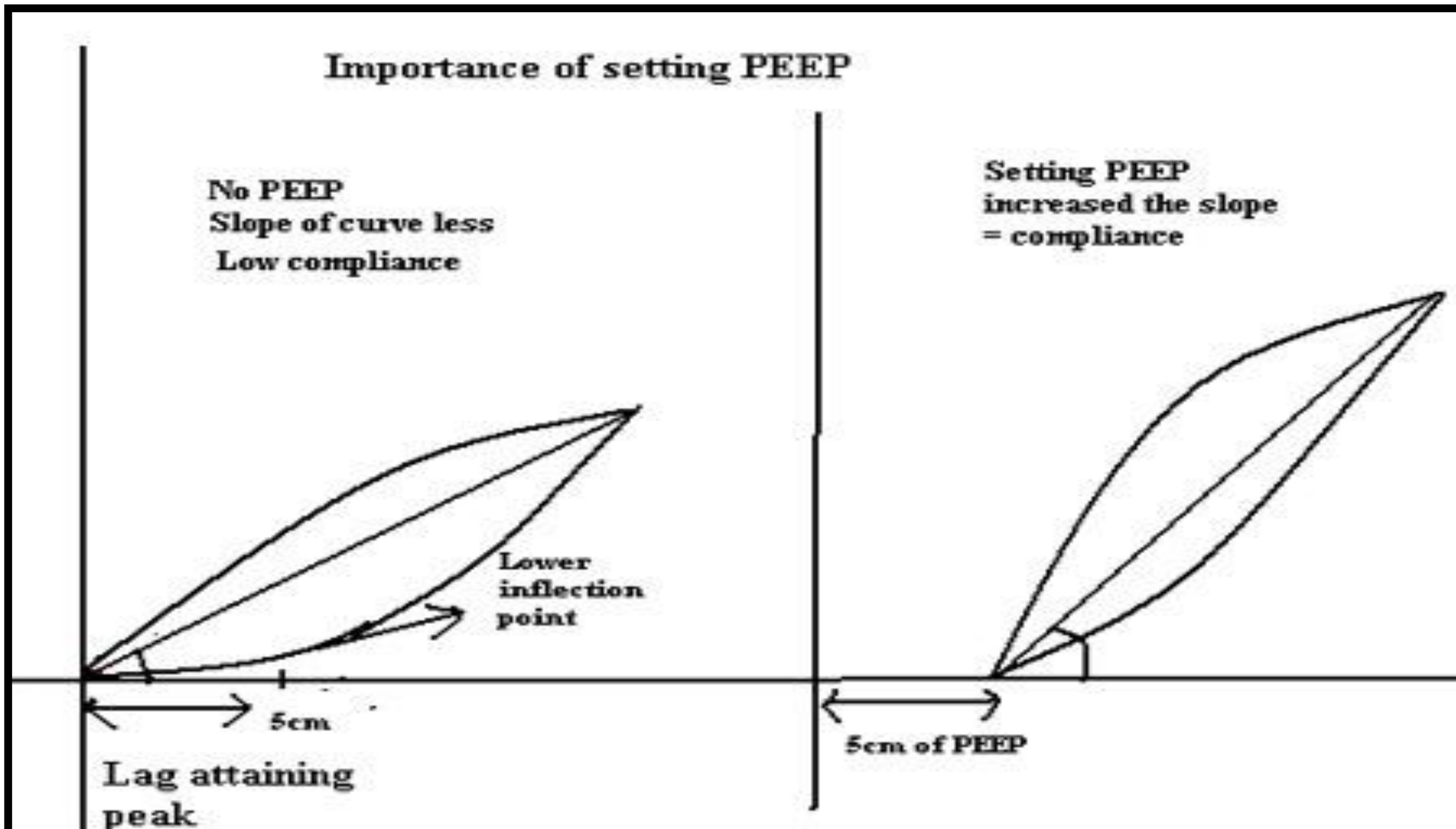
http://www.derangedphysiology.com/



Basınç Kontrollü Ventilasyonda P-V Eğrisi ile Kompliansın Değerlendirilmesi

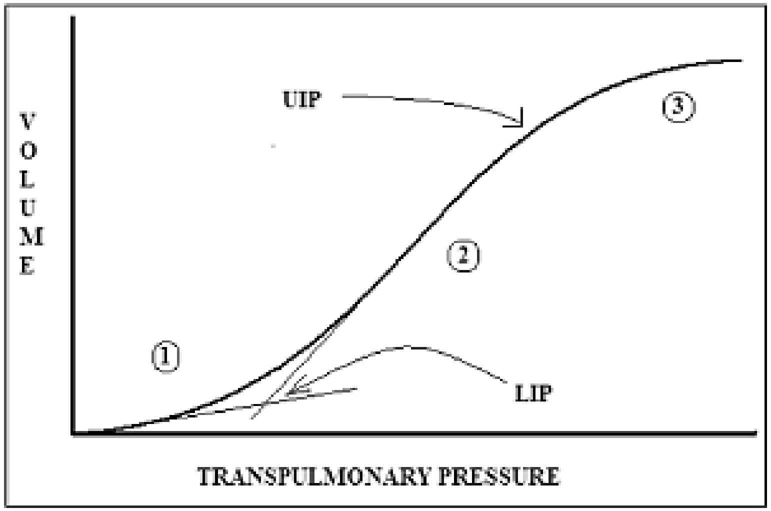
http://www.derangedphysiology.com/

PEEP VE KOMPLİANSA ETKİSİ



KOMPLİANS- PV EĞRİSİ

Figure 5



The inspiratory limb of the pressure–volume curve (dark line) divided into three sections. Section 1 (low compliance) and section 2 (high compliance) are separated by the lower inflection point (LIP). Section 2 (high compliance) and section 3 (low compliance) are separated by the upper inflection point (UIP). In this example, the LIP is marked at the point of crossing of the greatest slope in section 2 and the lowest slope of section 1. The UIP is marked at the point of 20% decrease from the greatest slope of section 2 (a calculated value).

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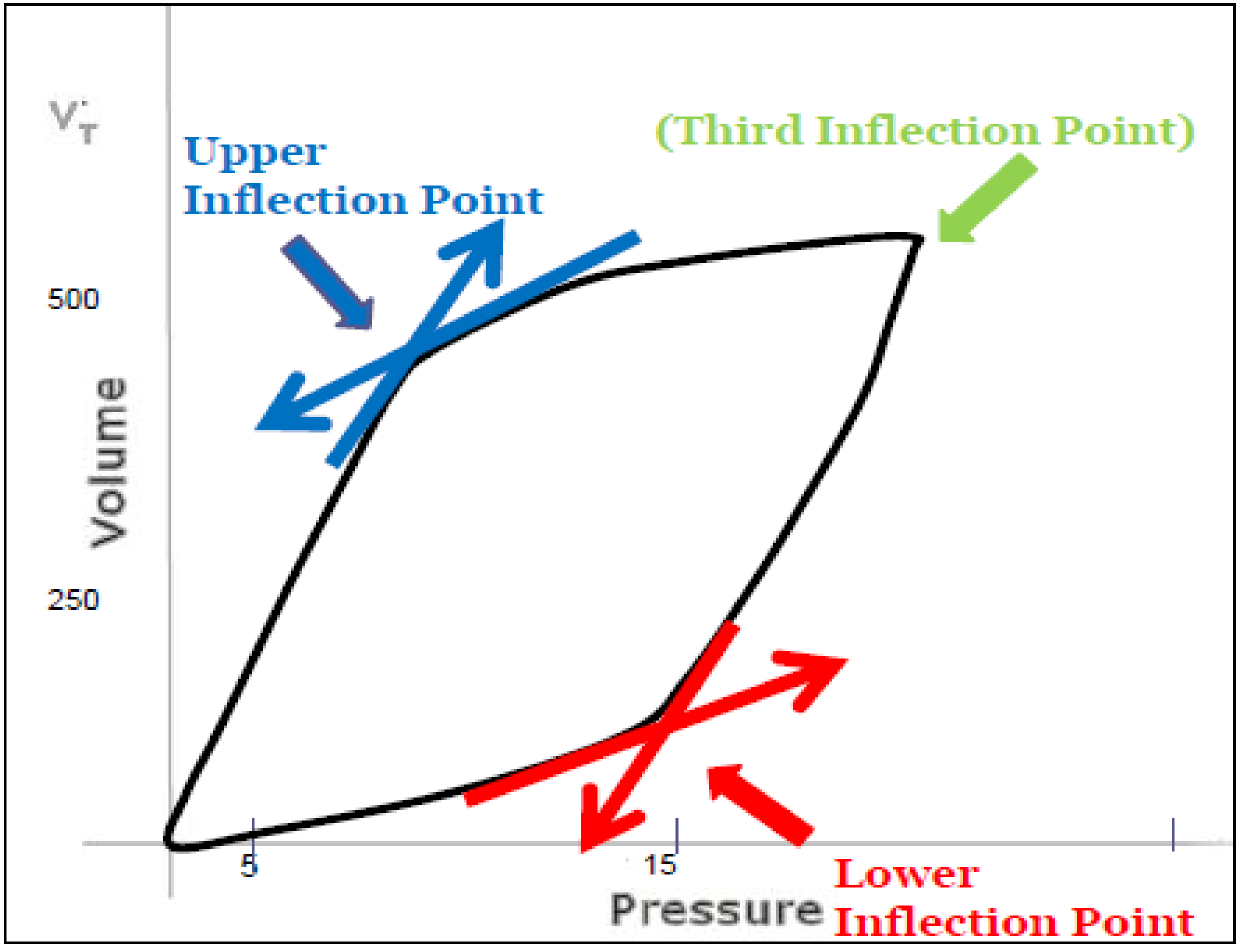
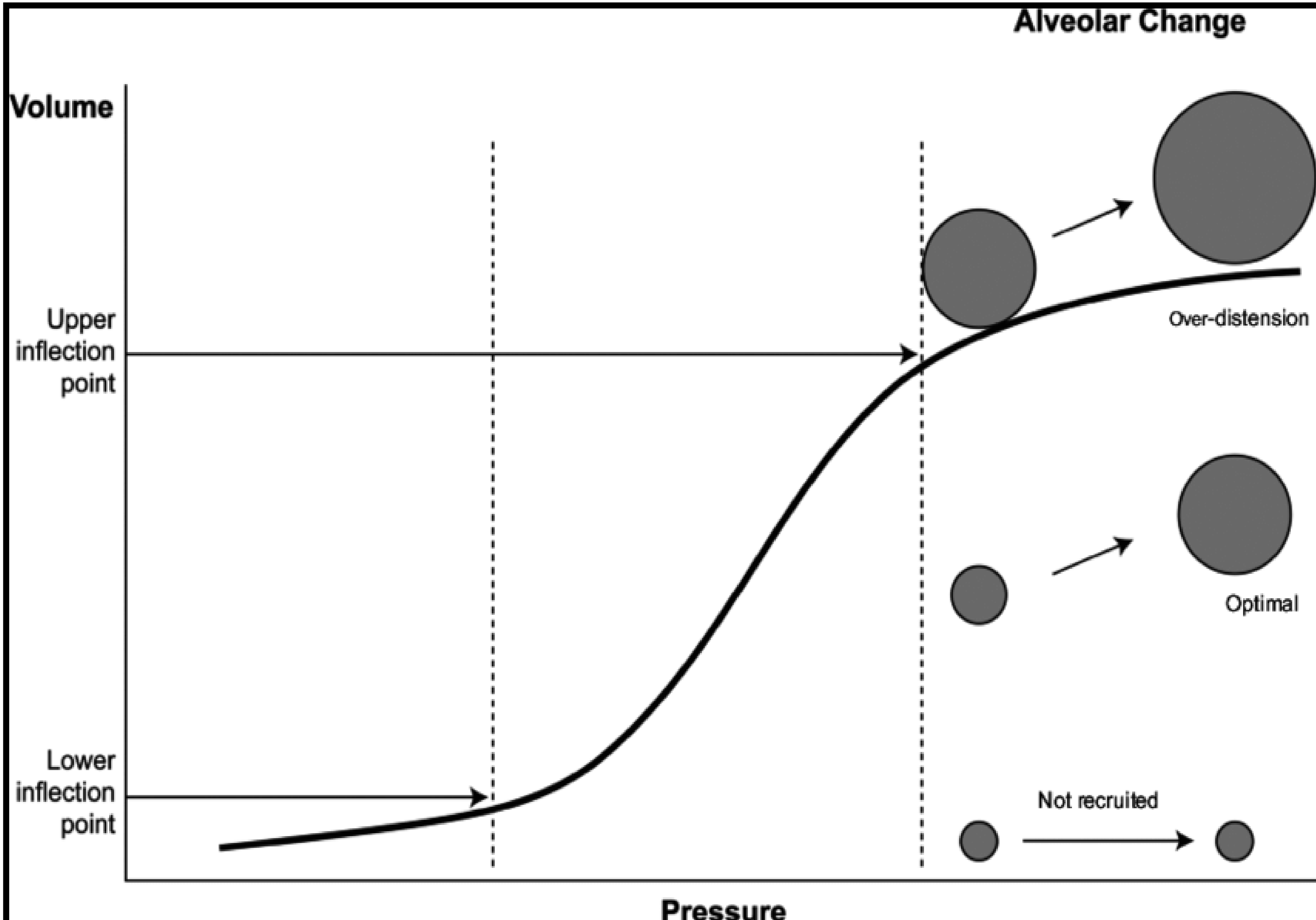
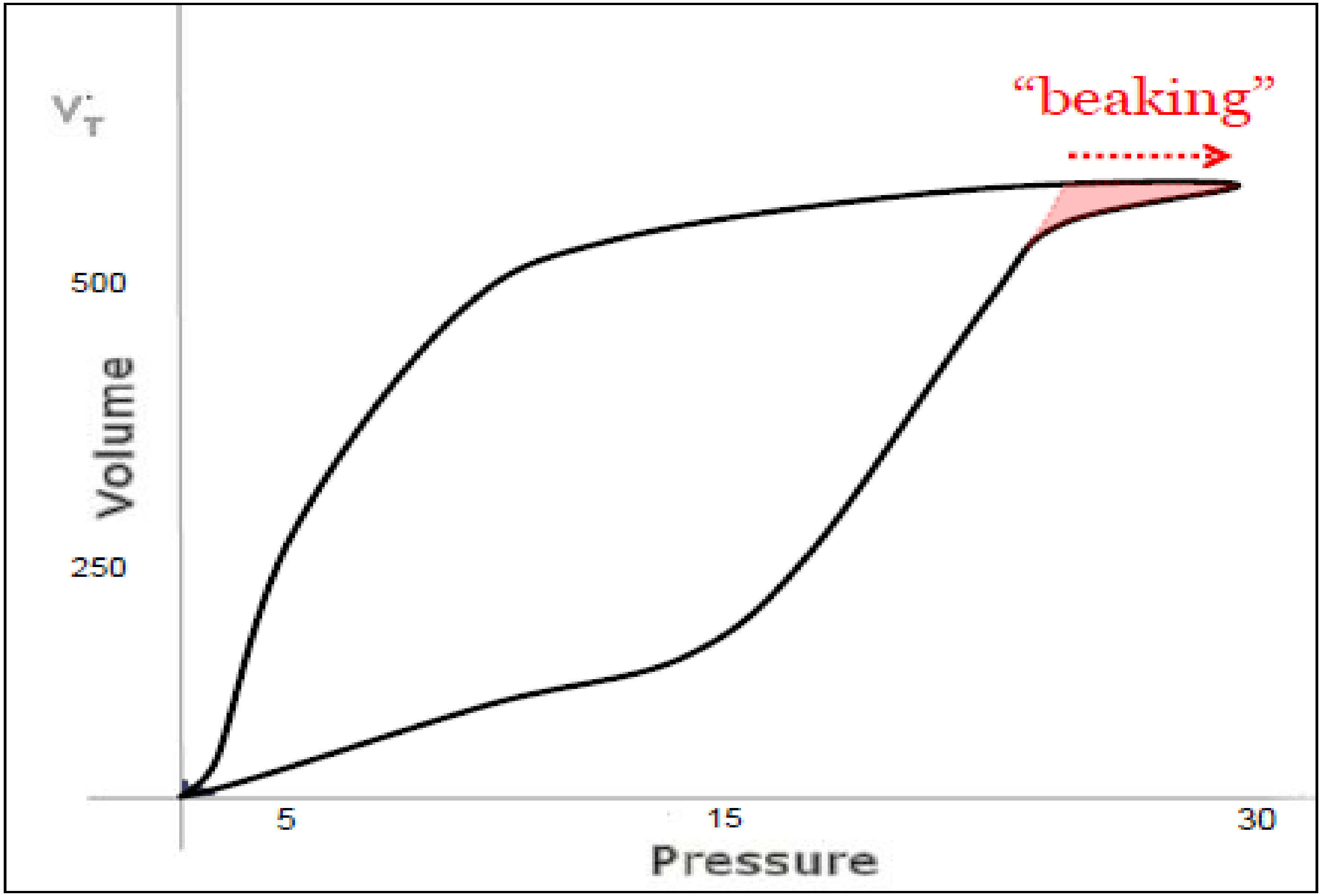
ALT VE ÜST KIRILMA NOKTASI





Alveolar Change
Volume
Upper inflection point
Lower inflection point
Over-distension
Optimal
Not recruited
Pressure

AŞIRI DİSTANSİYON



KOMPLİANS

Table 1

Causes of decreased intrathoracic compliance

Causes of decreased measured chest wall compliance	Causes of decreased measured lung compliance
Obesity	Tension pneumothorax
Ascites	Mainstem intubation
Neuromuscular weakness (Guillain–Barre, steroid myopathy, etc.)	Dynamic hyperinflation
Flail chest (mediastinal removal)	Pulmonary edema
Kyphoscoliosis	Pulmonary fibrosis
Fibrothorax	Acute respiratory distress syndrome
Pectus excavatum	Langerhans cell histiocytosis
Chest wall tumor	Hypersensitivity pneumonitis
Paralysis	Connective tissue disorders
Scleroderma	Sarcoidosis
	Cryptogenic organizing pneumonitis
	Lymphangitic spread of tumor

Shown are the causes of decreased intrathoracic compliance, partitioned into causes of decreased measured chest wall compliance and causes of decreased measured lung compliance.

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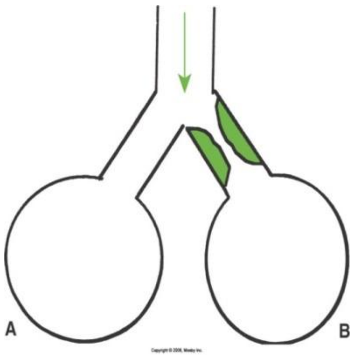
SOLUNUM MEKANİKLERİ

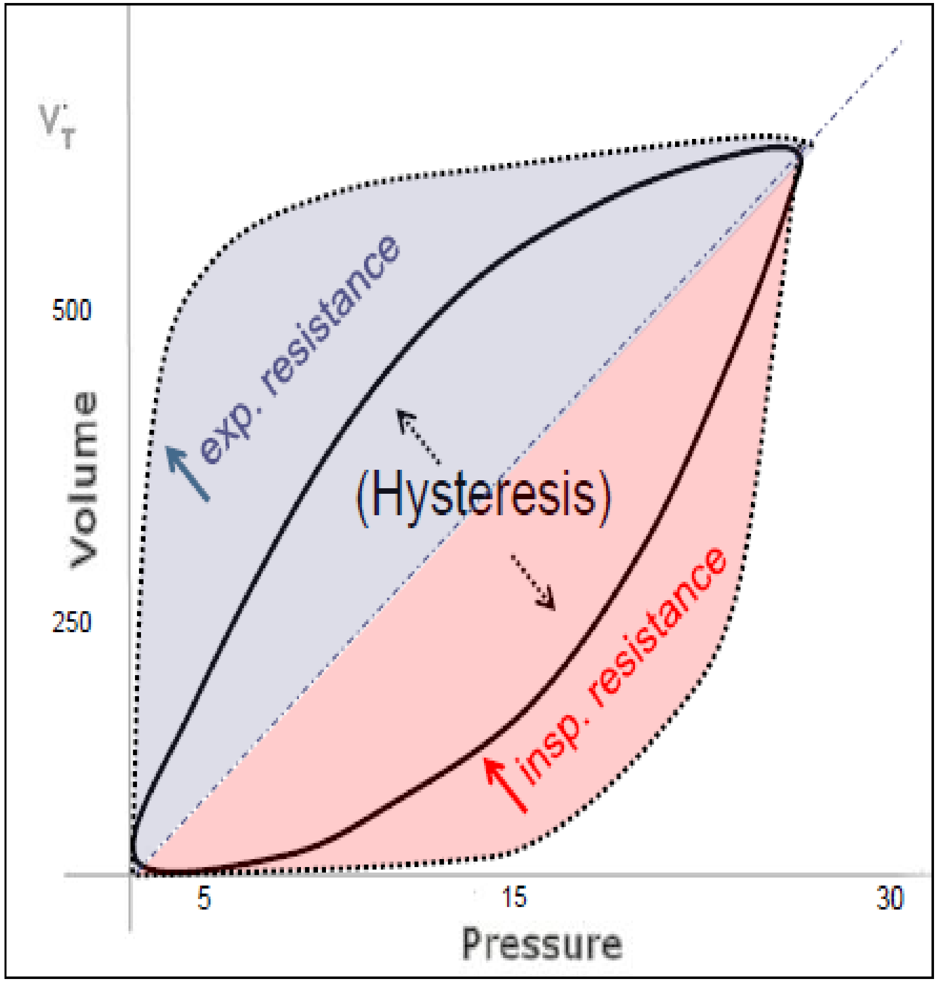


- **Rezistans: «Akıma karşı direnç»**
  - İletici hava yolları sorumludur
    - Akım Hızı: Tidal Volüm / İnspirasyon süresi
    - **Rezistans: Ppeak-Pplato/ Akım Hızı**
  - **Raw (cmH20/L/sn):**
    - Entübe olmayanlarda: 0.6-2.4 cmH20/L/sn
    - Entübelerde ≥ 6cmH20/L/sn
    - **Endotrakeal tüp rezistans artışında önemli!!**
    - Tüp ne kadar küçük olursa, rezistans o kadar fazla olur
    - Hava yolu hastalıkları rezistansı artırır

Pilbeam SP. Basic terms and concepts of mechanical ventilation.,in Mechanical Ventilation:Physiological and Clinical Applications ed 4, St Louis 2006, Mosby

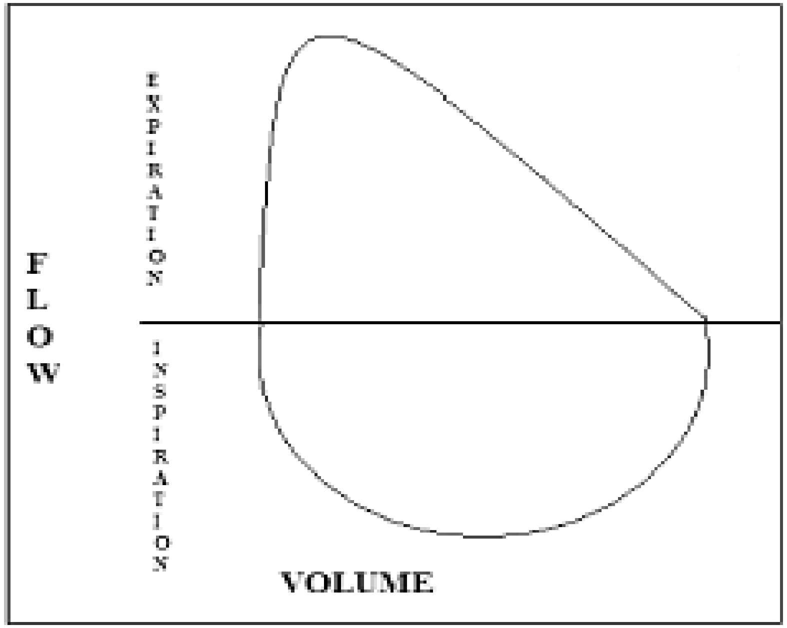
PV Eğrisi

<u>Increased expiratory resistance:</u> secretions, bronchospasms, etc.



<u>Increased inspiratory resistance</u>: kinked ET tube, patient biting tube

SOLUNUM MEKANİKLERİ
AKIM VOLÜM EĞRİSİ



Flow–volume loop. A flow–volume loop is shown, with exhalation above the horizontal axis and inspiration below.

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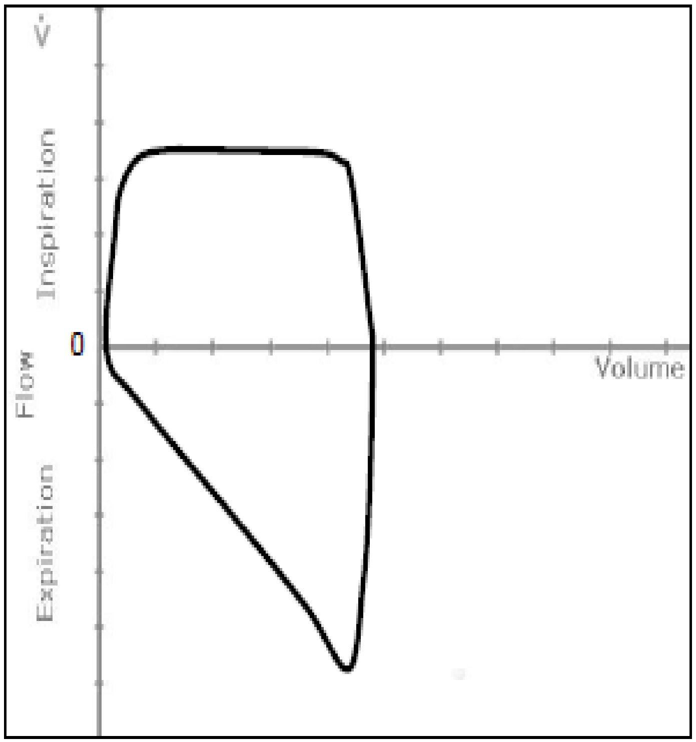
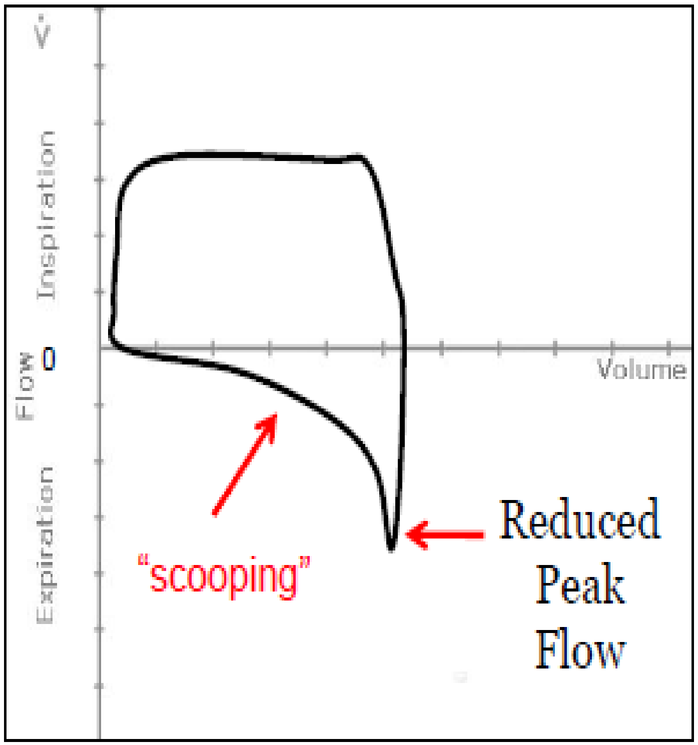
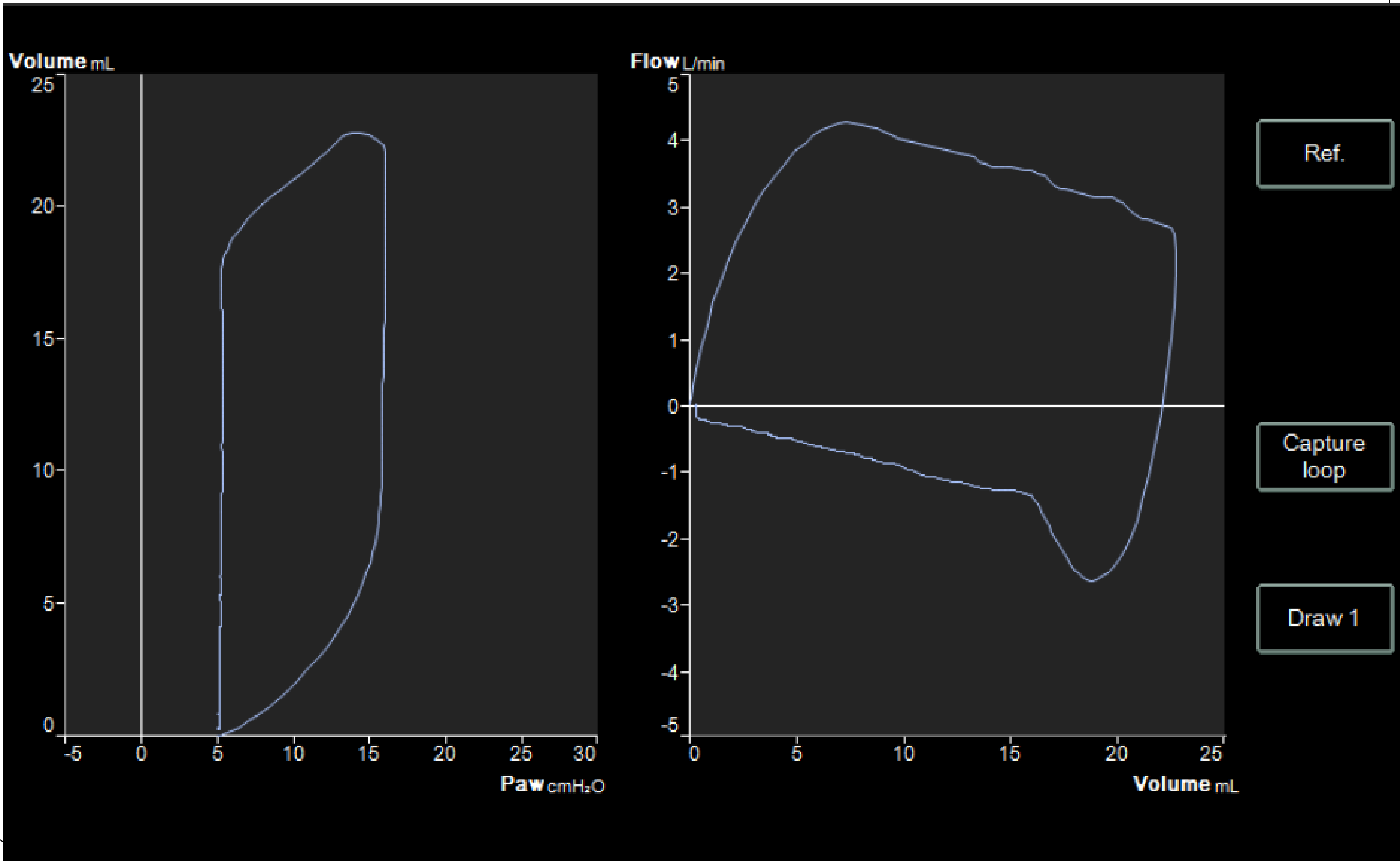
HAVAYOLU OBSTRÜKSİYONU



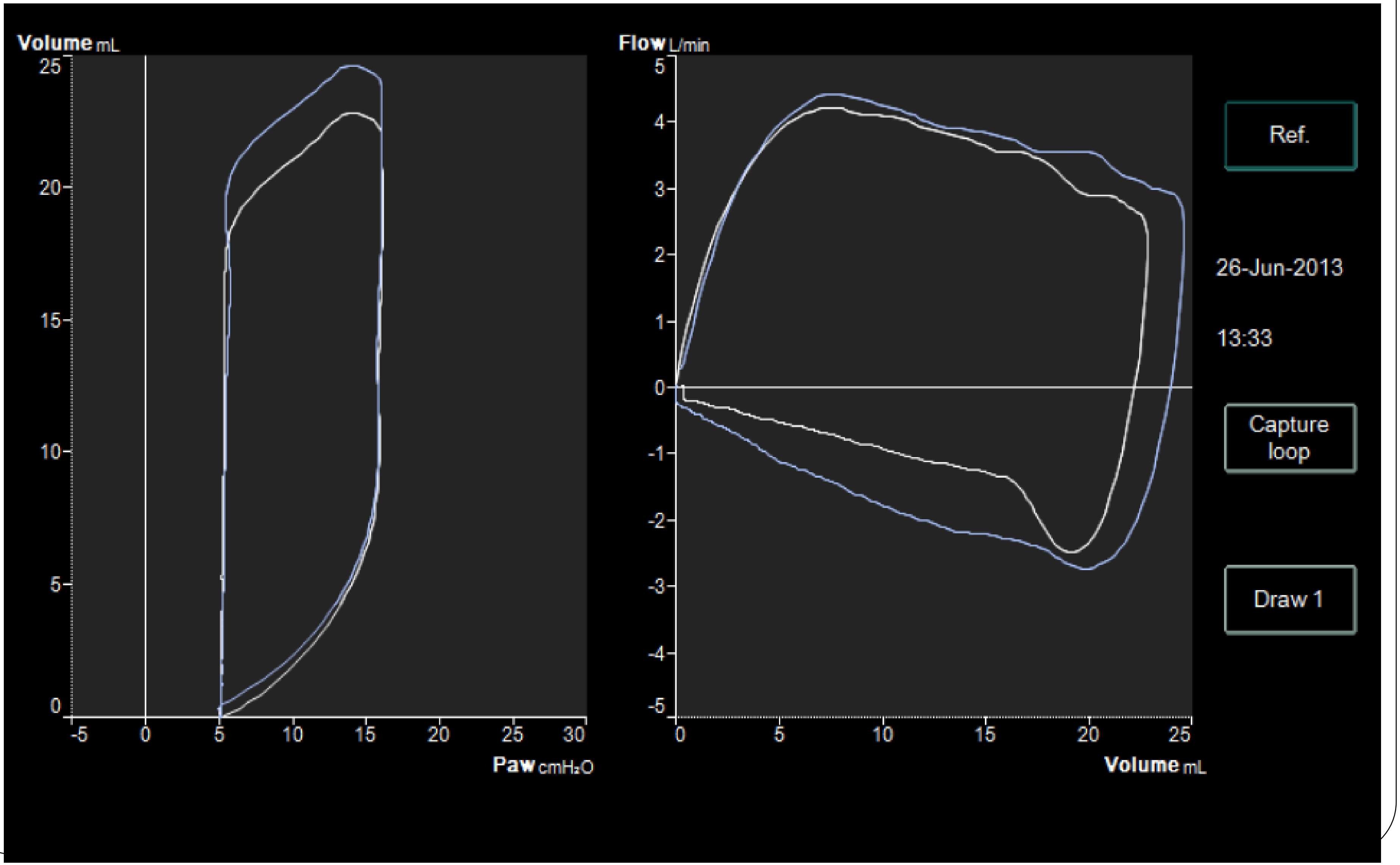
"normal vent graphic view"



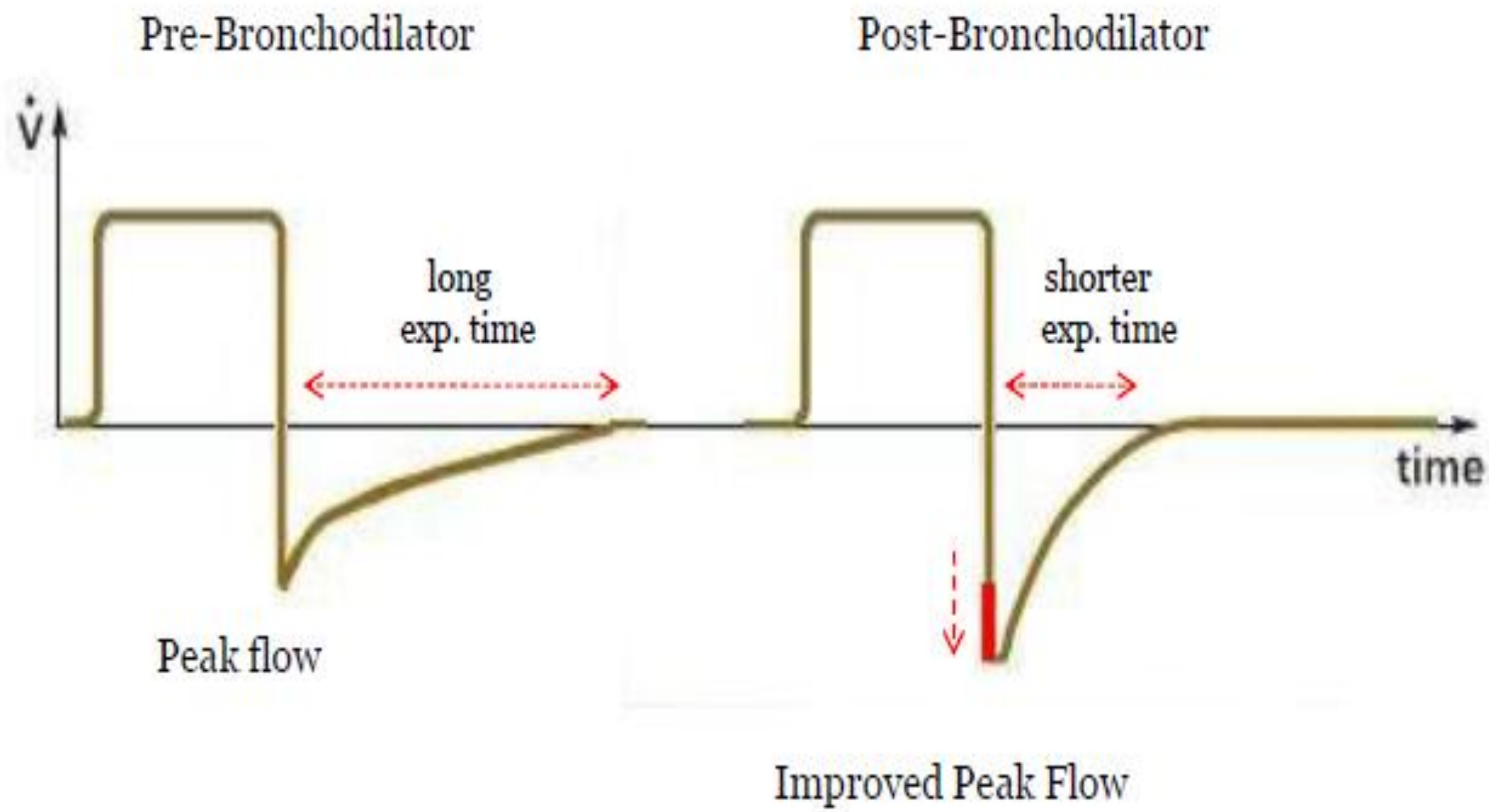
BRONKOKONSTRİKSİYON

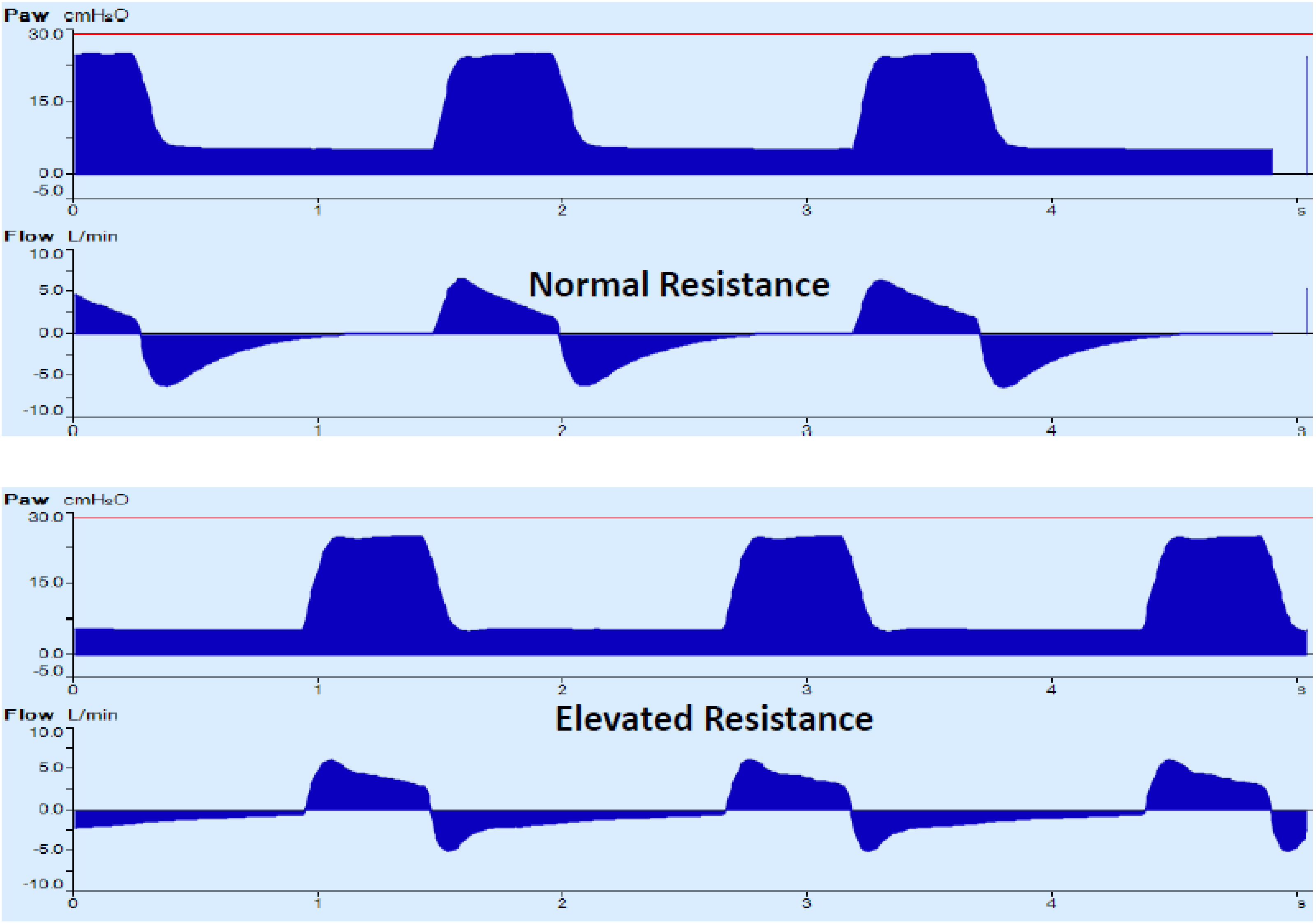


BRONKODİLATÖR TEDAVİ SONRASI



BRONKODİLATÖR CEVABI



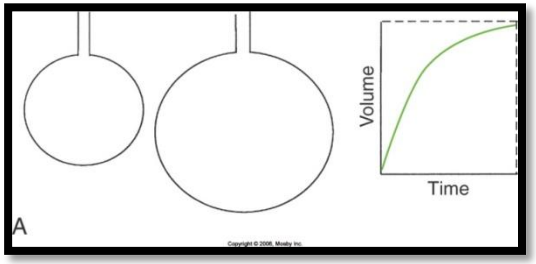


Paw cmH₂O
30.0
15.0
0.0
-5.0
0
1
2
3
4
s
Flow L/min
10.0
5.0
0.0
-5.0
-10.0
Normal Resistance
Paw cmH₂O
Flow L/min
Elevated Resistance

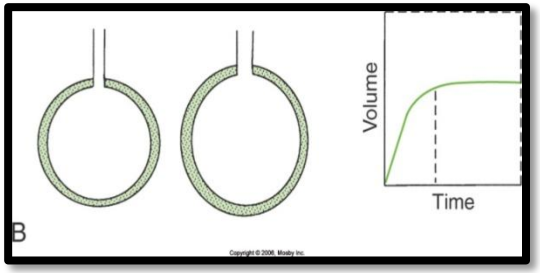
SOLUNUM MEKANİKLERİ

Zaman Sabiti: Komplians x Rezistans

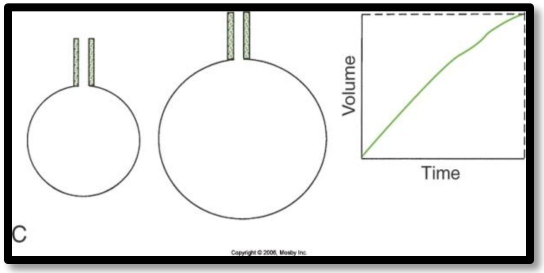
A: Normal AC



B: Düşük komplians;
alveoller hızlıca dolar ama daha az hava girer
(Kısa zaman sabiti; örn ARDS)



C: Artmış rezistans;
alveoller yavaş dolar, daha yavaş boşalır.
(Uzun zaman sabiti; örn KOAH)



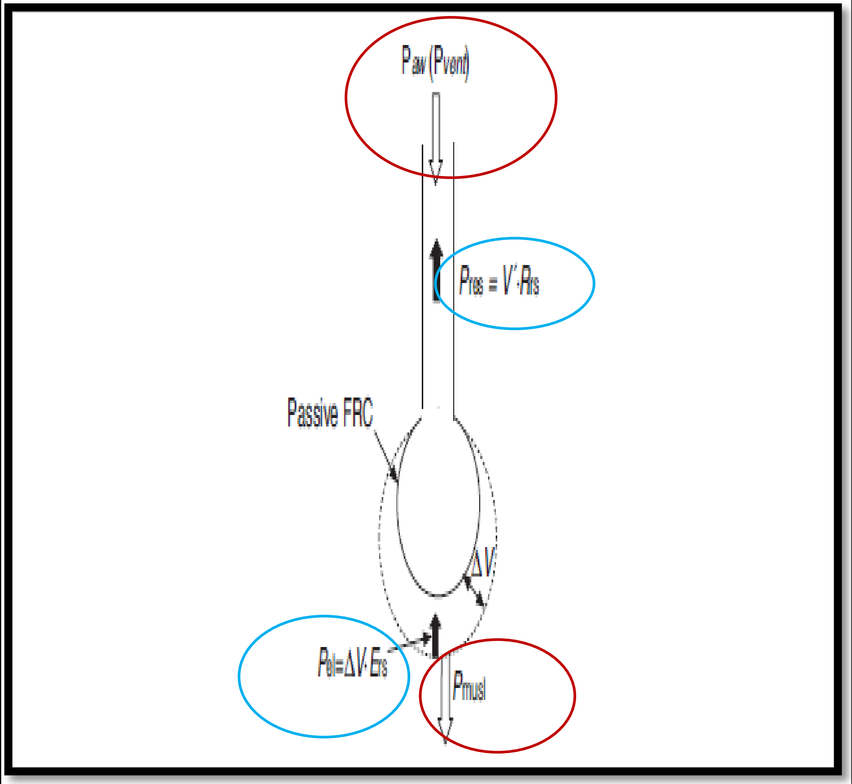
SOLUNUM MEKANİKLERİ

Pozitif Basınçlı Ventilasyonda Gaz Akımı Temel Denklemi

= (Ventilatör tarafından oluşturulan pozitif basınç)+ (inspiratuar kaslar tarafından oluşturulan negatif plevral basınç)

= P elastans + P resistive

=(Elastans x Volüm)+(Rezistans x Akım)



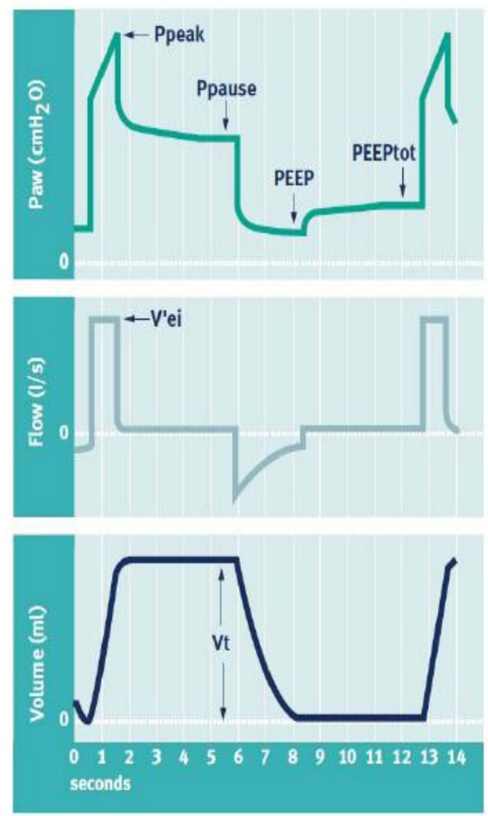
Ptot (t)= Pmus(t)+Paw(t)=V'(t).Rrs+VT(t).Ers+PEEPi

Pilbeam SP. Basic terms and concepts of mechanical ventilation.,in Mechanical Ventilation:Physiological and Clinical Applications ed 4, St Louis 2006, Mosby

SOLUNUM MEKANİKLERİNİN YATAK BAŞINDA DEĞERLENDİRİLMESİ

SOLUNUM MEKANİKLERİ

- **Peak İnspiratuar Basınç (PIP):**
  - İnspiratuar fazdaki en yüksek basınç
  - Belirleyen faktörler
    - AC-Göğüs duvarı kompliansı
    - Havayolu rezistansı
    - Verilen tidal volüm
    - İnspiratuar akım hızı
    - End ekspiratuar basınç(PEEP)
    - Solunum iş yükü (WOB)
- **İnspiratuar pause:**
  - Amaç: AC'de havanın dağılımını düzeltmek
  - Optimum V/Q uyumunu sağlamak
  - VD/VT oranını azaltmak



In ventilated adults with normal airway resistance, Ri,max is usually 5-8 cmH2O/l/s (including the effect of an unobstructed endotracheal tube of appropriate size)
The clinical interpretation of measurements of respiratory system compliance is easier when referred to the ideal body weight (normal value: 1 –1.2 ml/cmH2O/kg)

Ppeak = peak airway pressure
Ppause = static end-inspiratory pressure
PEEP = positive end-expiratory pressure
PEEPtot = total intrapulmonary PEEP
V'ei = end-inspiratory flow
Vt = tidal volume

$$Ri,max = \frac{Ppeak - Ppause}{V'ei}$$

$$Cqs = \frac{Vt}{Ppause - PEEPtot}$$

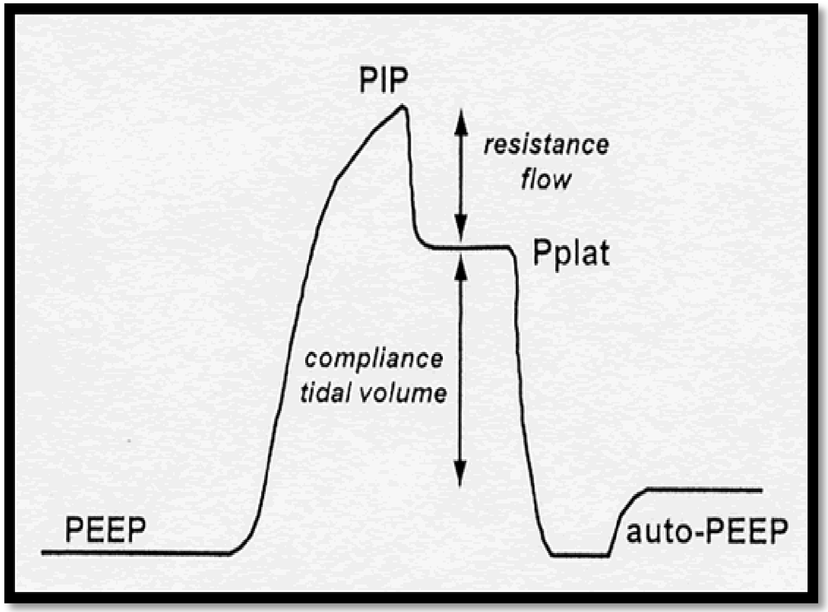
$$RC = Ri,max \cdot Cqs$$

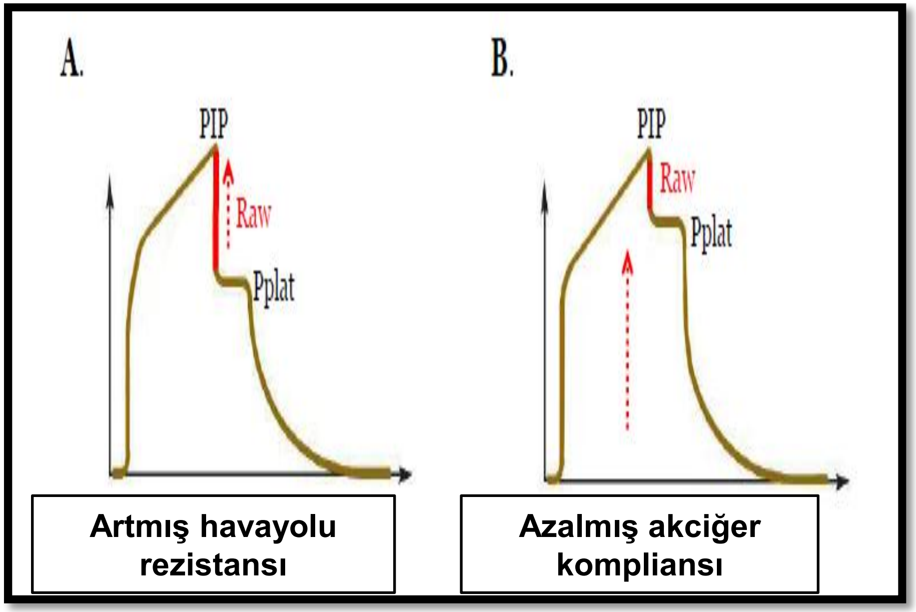
$$PEEPi = PEEPtot - PEEP$$

Frozen curves during passive VCV with constant inspiratory flow and double hold manoeuvre, for manual measurement of passive respiratory system mechanics

ESICM PACT- Mechanical Ventilation Skills and techniques. Patroniti N, Update 2011

SOLUNUM MEKANİKLERİ





$$C_{strs} = \frac{V_T}{P_{plat} - PEEP_{total}} \qquad R_{aw} = \frac{PIP - P_{plat}}{\dot{V}_i}$$

Pplato ≤ 30cmH20 tutulmalı

Benjamin D. Singer, MD; Thomas C. Corbridge, MD South Med 2009;102(12):12381245.

Driving Pressure-Plato Pressure

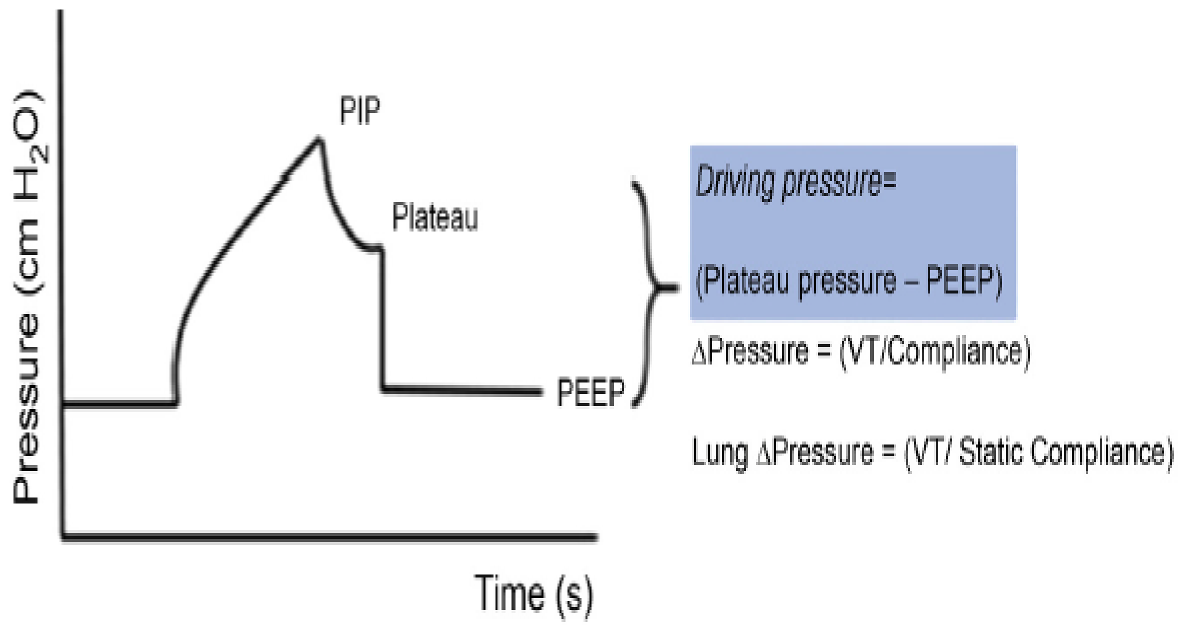


Fig. 21. DP is the difference between P_{plat} and PEEP, and is a correlate of the ratio between VT and the compliance of the respiratory system.

Driving Pressure-Plato Pressure

- **ΔP (Driving Pressure);**
  - Tidal volumun akciğerde ne kadar mekanik bozulma (dinamik strain) yarattığını tahmin eder,
- **Plato basıncı (Pplato);**
  - Akciğere uygulanan basıncı (akciğer stresi) yansıtır.
- Her ikisi de barotravma riskini ölçer.

Stres İndeks

- Sabit akımlı volüm kontrol ventilasyon sırasında basınç zaman eğrisinin şekli değerlendirilerek elde edilir

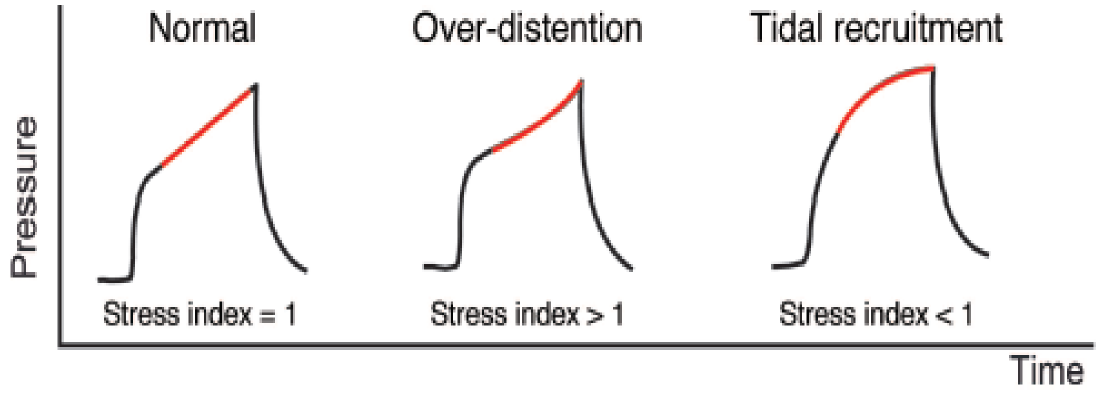


Fig. 10. Normal stress index, stress index with over-distention, and stress index with tidal recruitment.

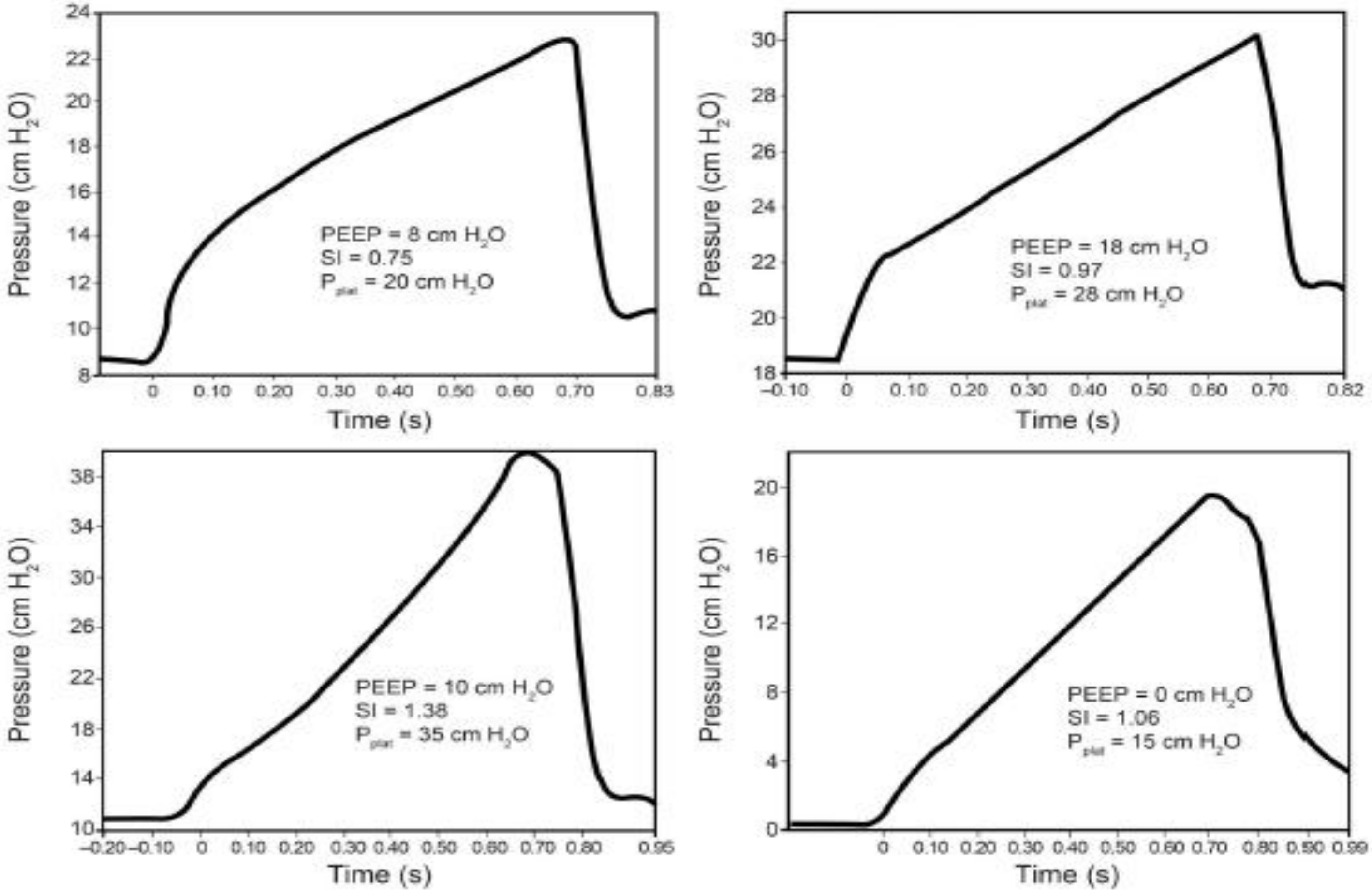
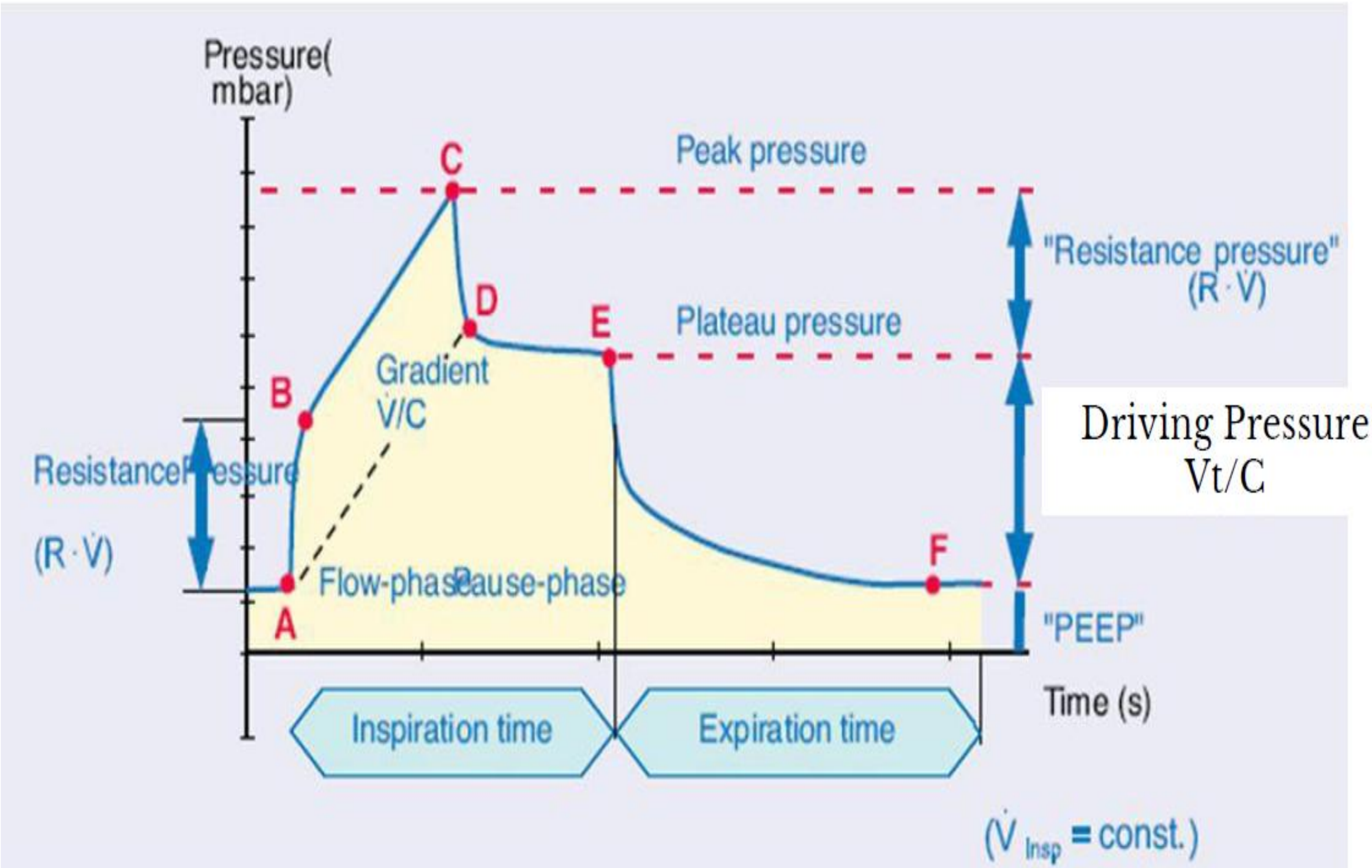
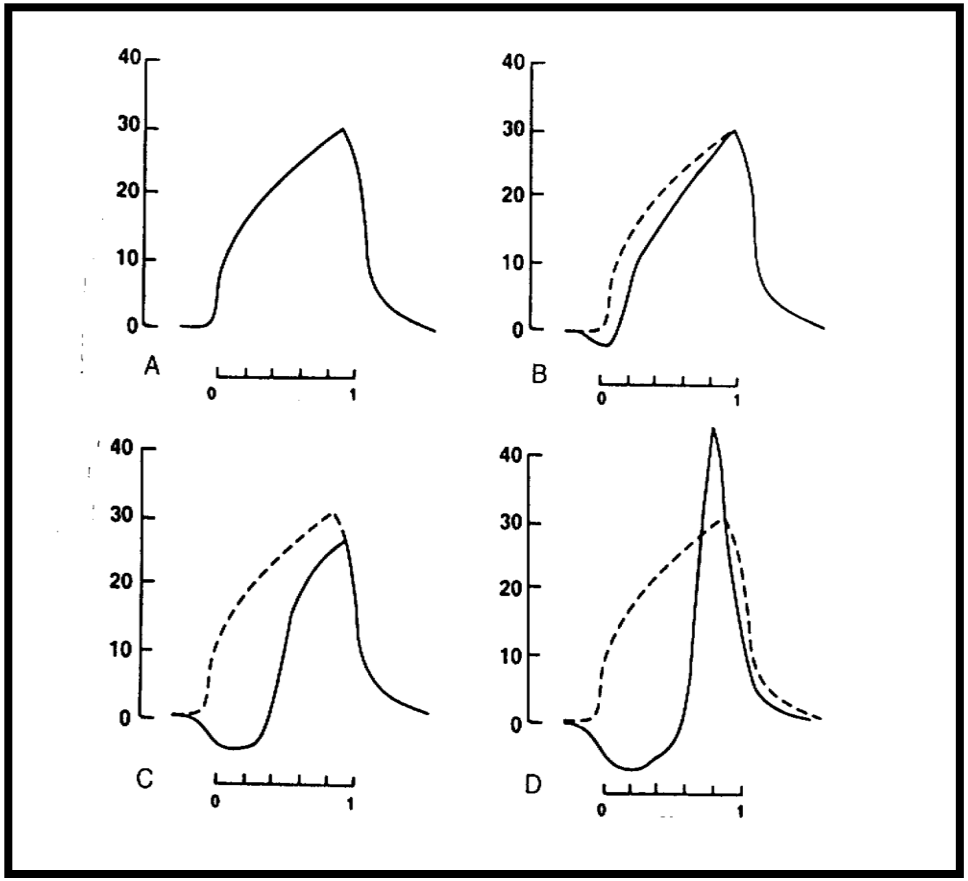


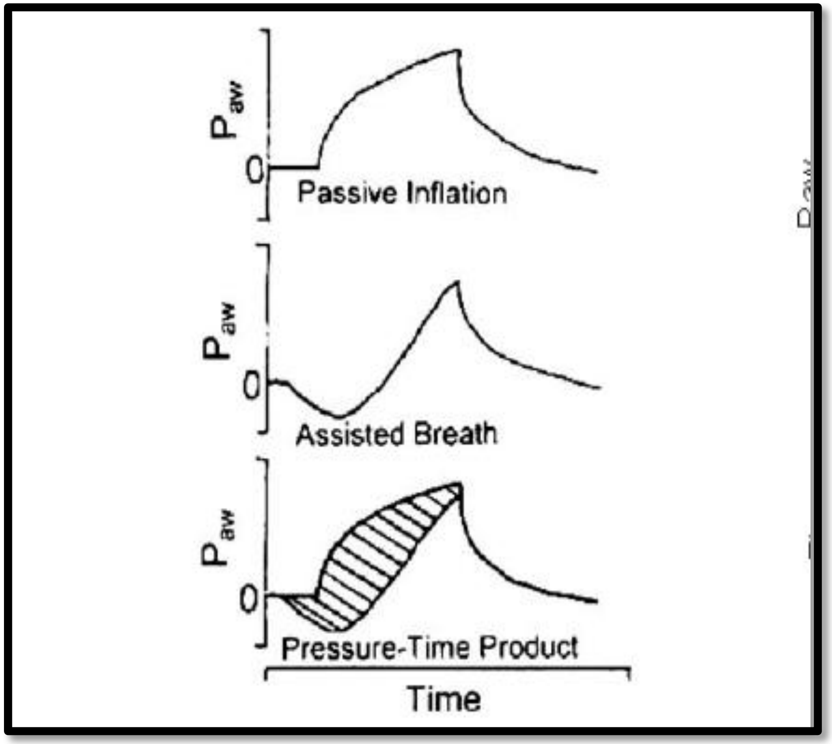
Fig. 11. Top: Stress index (SI) in a patient early in the course of ARDS. In this case, the stress index improved as PEEP was increased. Bottom: Stress index in a patient late in the course of ARDS. In this case, the stress index improved as PEEP was decreased. P_{plat} = plateau pressure. From Reference 31.

Pressure – time curve (volume – oriented mode)



AKIM HIZI YETERLİ Mİ?





Kaynak: *Pilbeam SP. Basic terms and concepts of mechanical ventilation.,in Mechanical Ventilation:Physiological and Clinical Applications ed 4, St Louis 2006, Mosby*

Solunum Mekaniklerinin Yatak Başında Değerlendirilmesi-Expiratory Hold

Restrepo et al

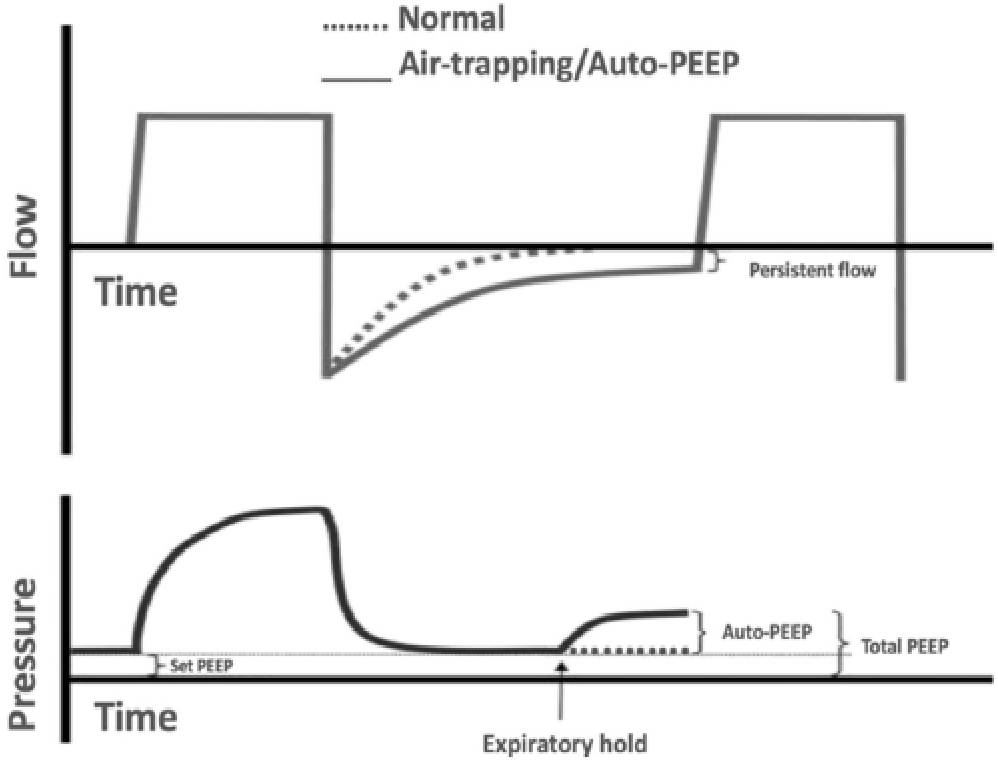
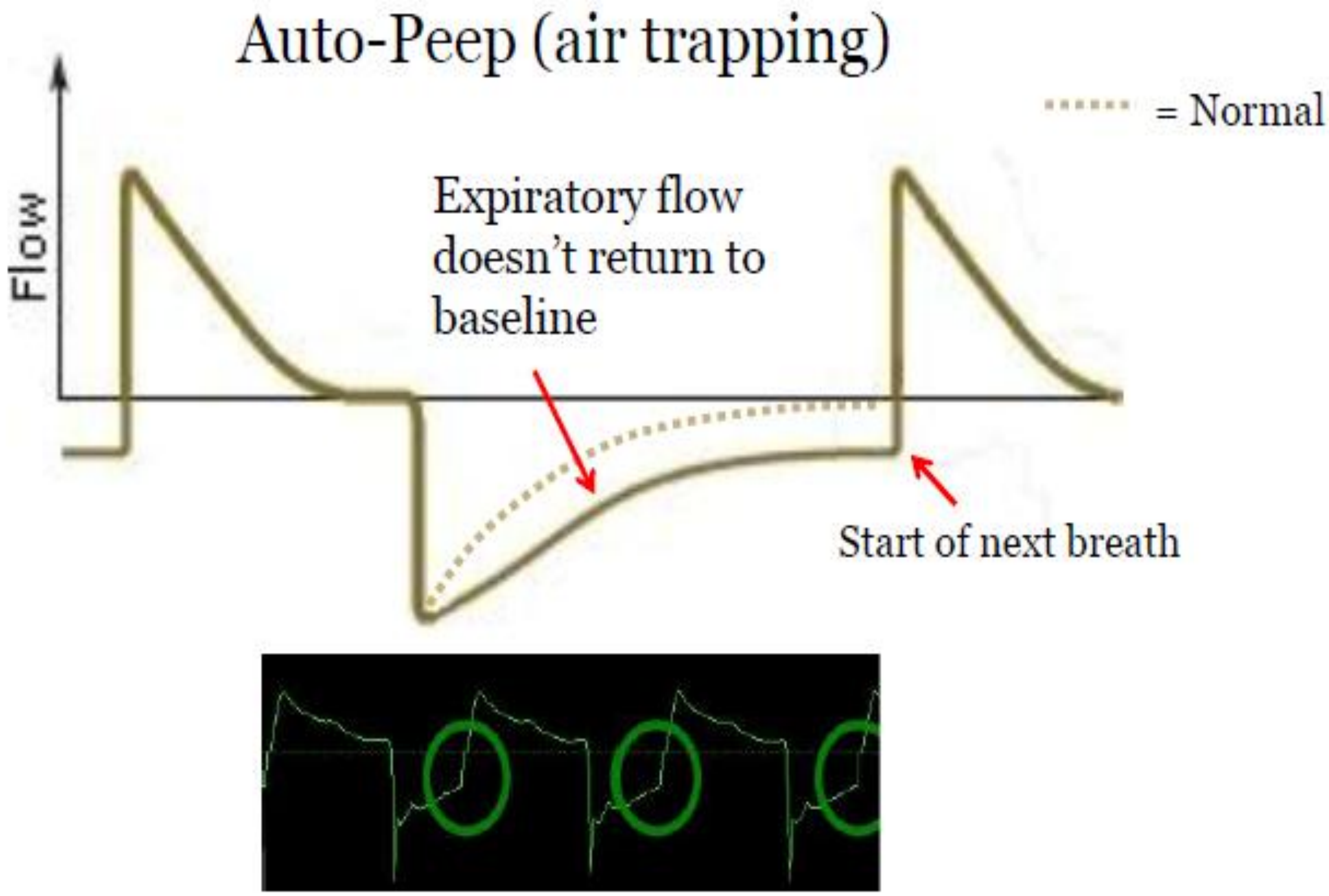
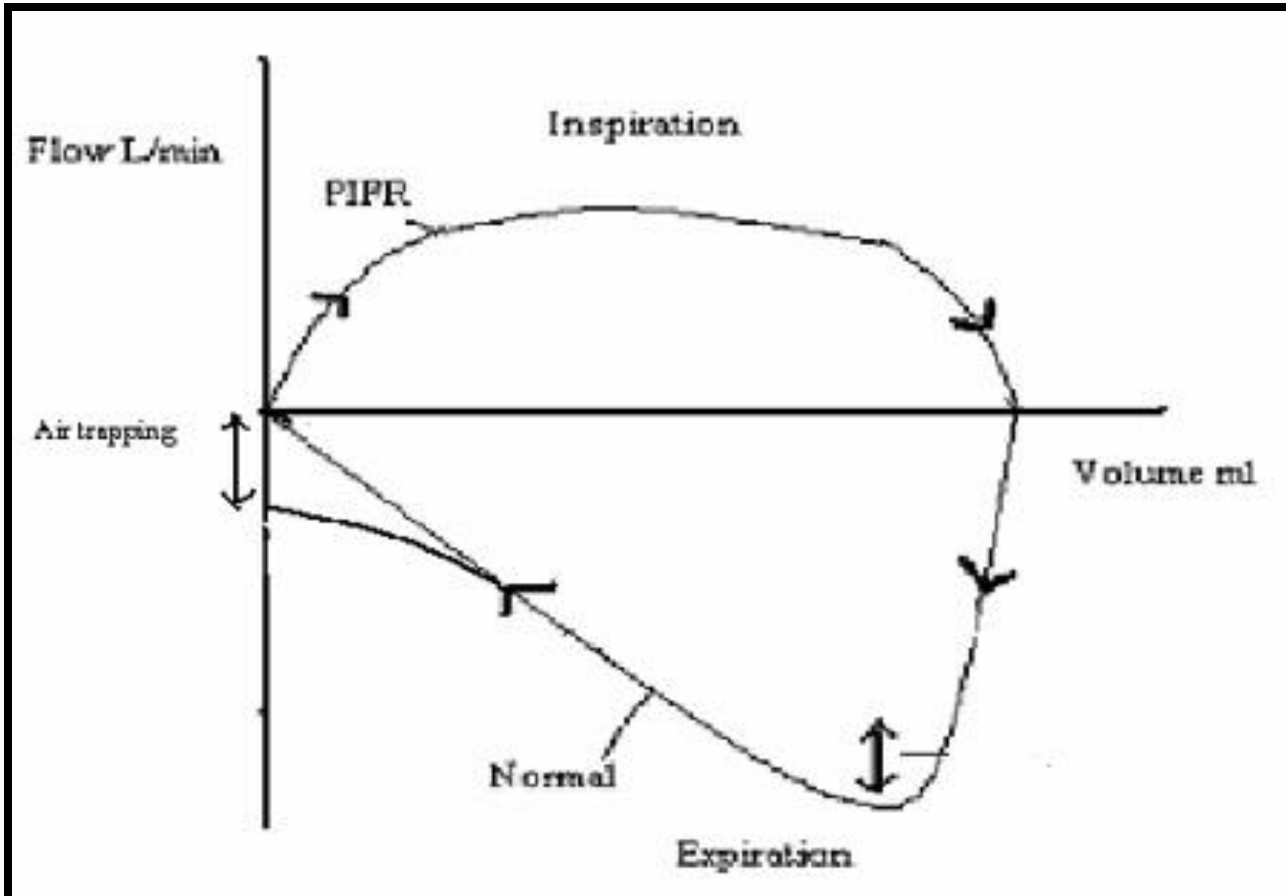


Fig. 4. Flow-time scalar (*top*) indicating persistency of expiratory flow at the end of the breath, indicating air trapping. The end-expiratory alveolar pressure is obtained after applying an end-expiratory pause. The difference between the pressure measured during this maneuver (total PEEP) and the level of PEEP selected by the operator is the amount of auto-PEEP. The pressure-time scalar (*bottom*) displays the end-expiratory alveolar pressure obtained after applying an end-expiratory pause.

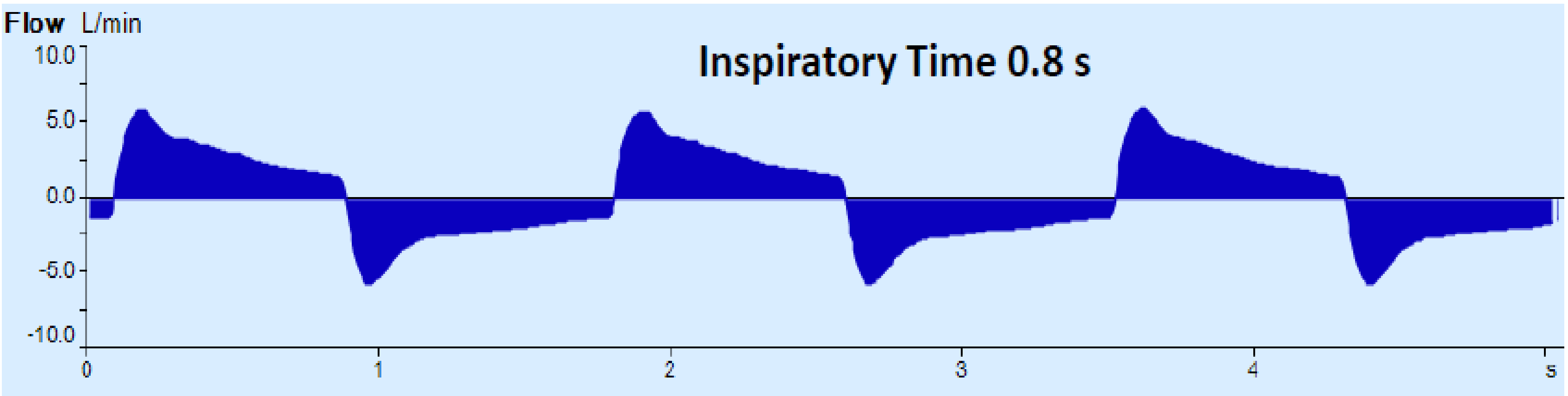
HAVA HAPSİ-OTO PEEP

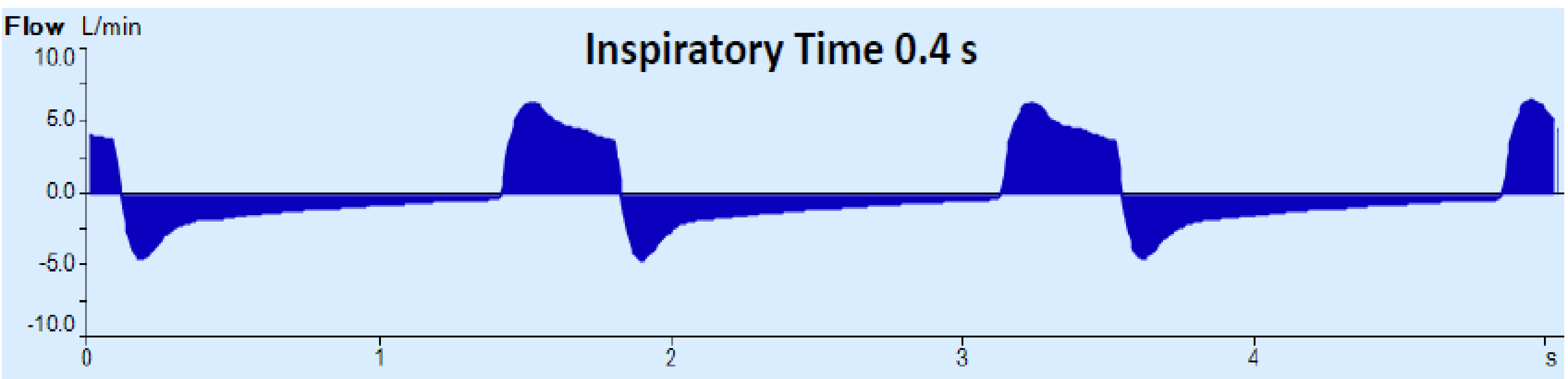


HAVA HAPSİ-OTO PEEP

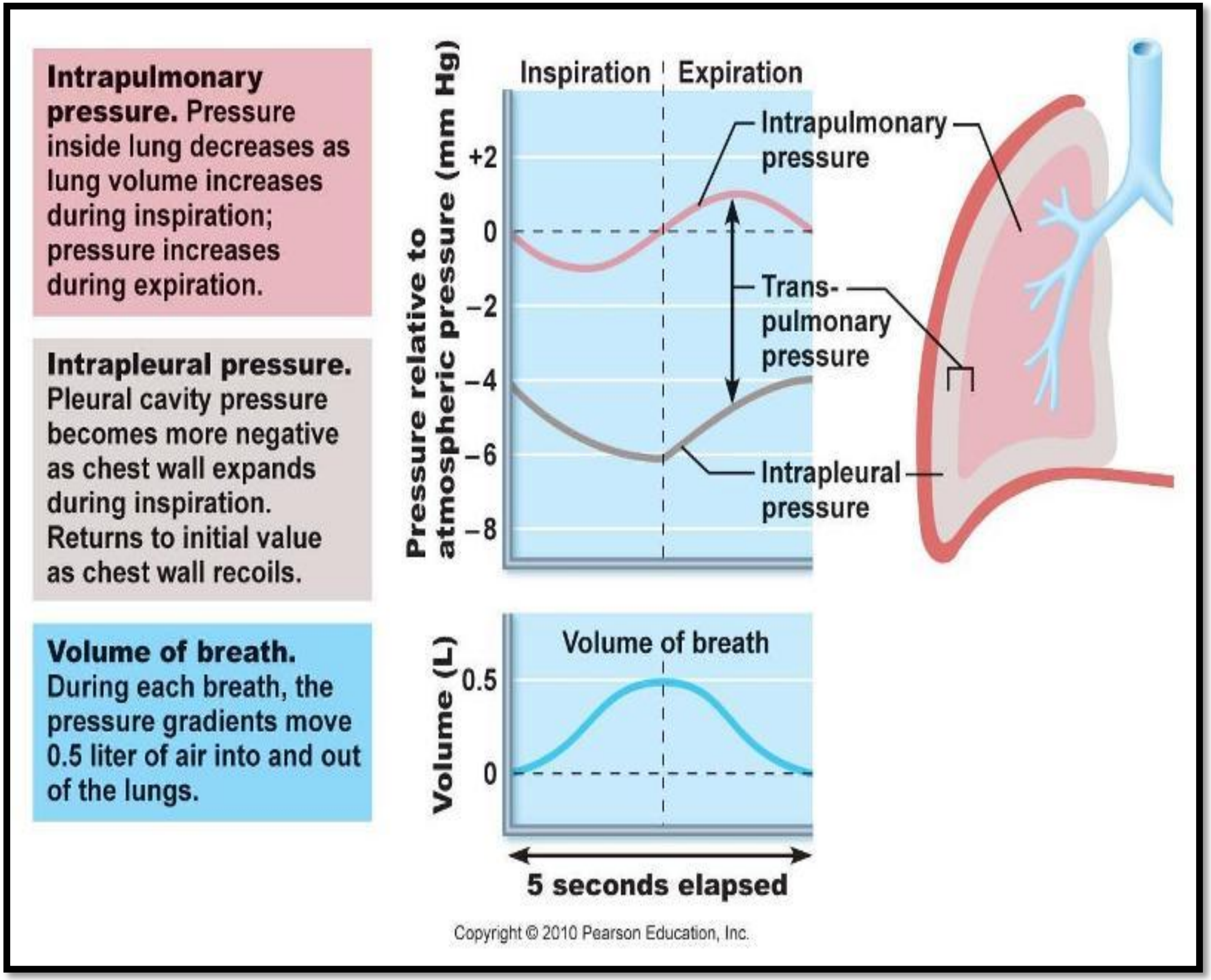


HAVA HAPSİ-OTO PEEP



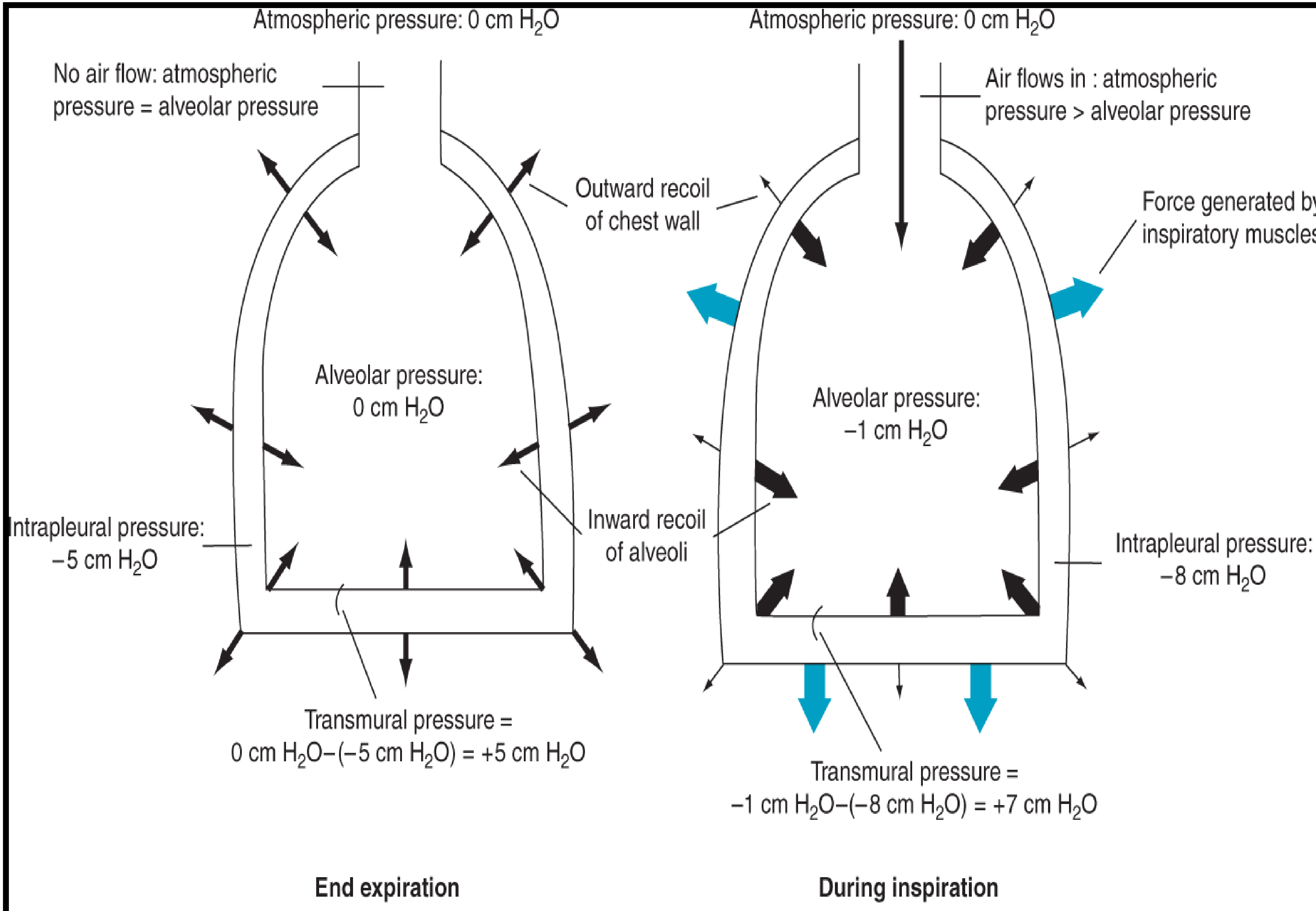


ÖZAFAGEAL (PLEVRAL) VE GASTRİK (ABDOMİNAL) BASINÇLAR



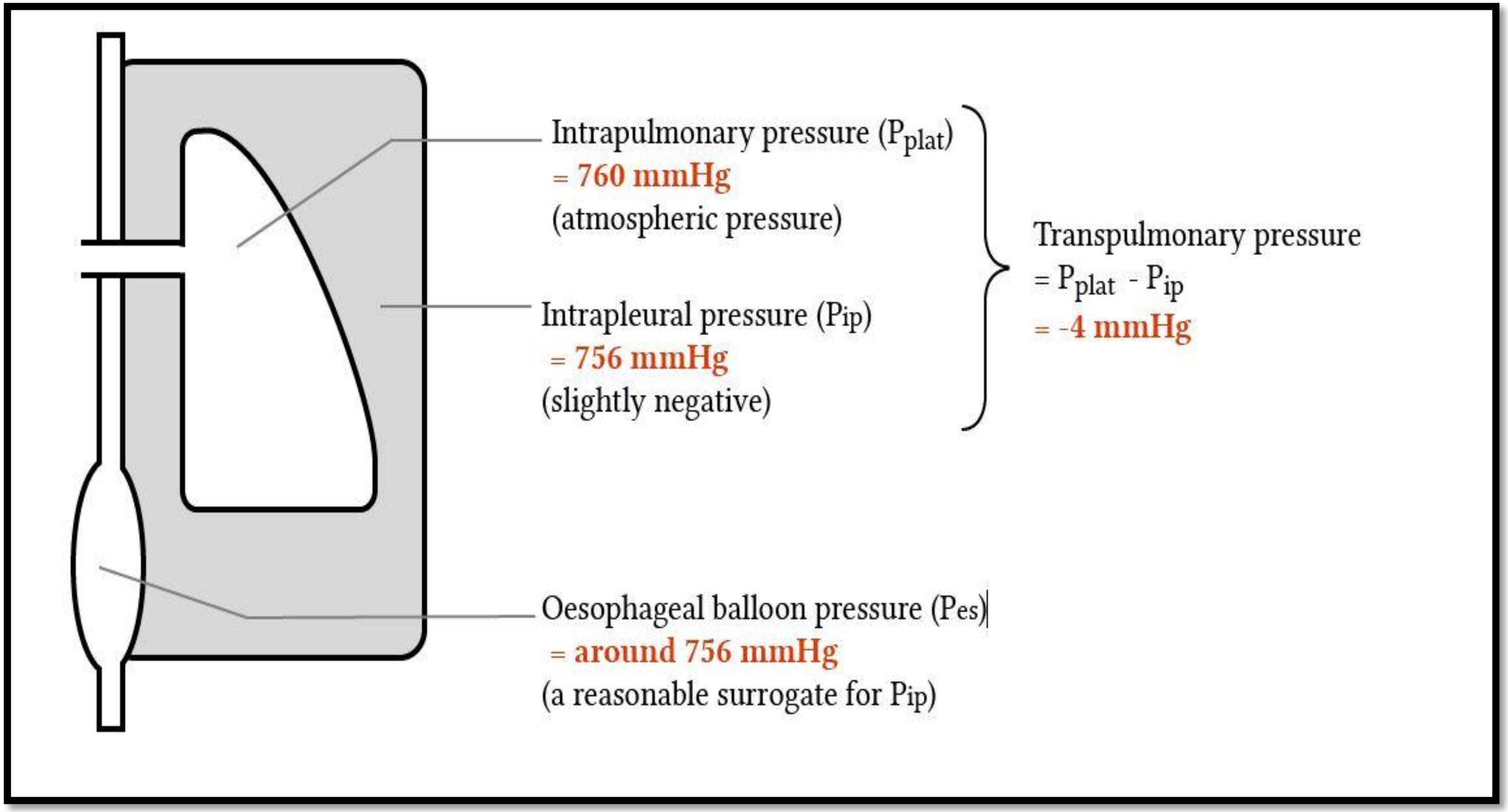
Transpulmoner P(P_L): P_A-P_{pl}

alveolar havalanmadan sorumludur.



Source: Levitzky MG: *Pulmonary Physiology, Eighth Edition*: www.accessmedicine.com

TRANSPULMONER BASINÇ



ÖZAFAGEAL (PLEVRAL) VE GASTRİK (ABDOMİNAL) BASINÇLAR

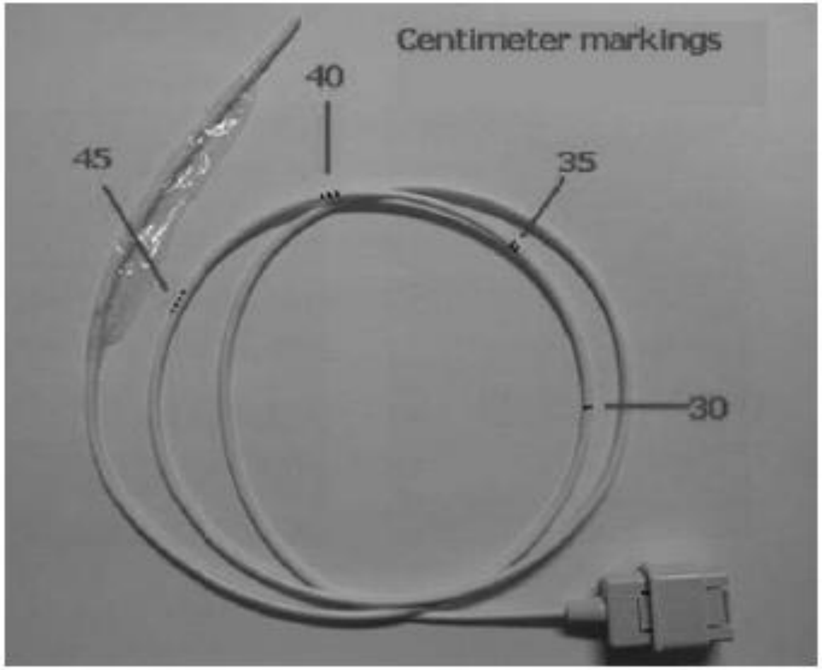


Fig. 1. Picture of an esophageal manometer demonstrating the size and position of the balloon, as well as the depth markings in centimeters.

W.R. Henderson, A.W. Sheel / Respiratory Physiology & Neurobiology 180 (2012) 162–172

ÖZAFAGEAL (PLEVRAL)
VE GASTRİK (ABDOMİNAL) BASINÇLAR

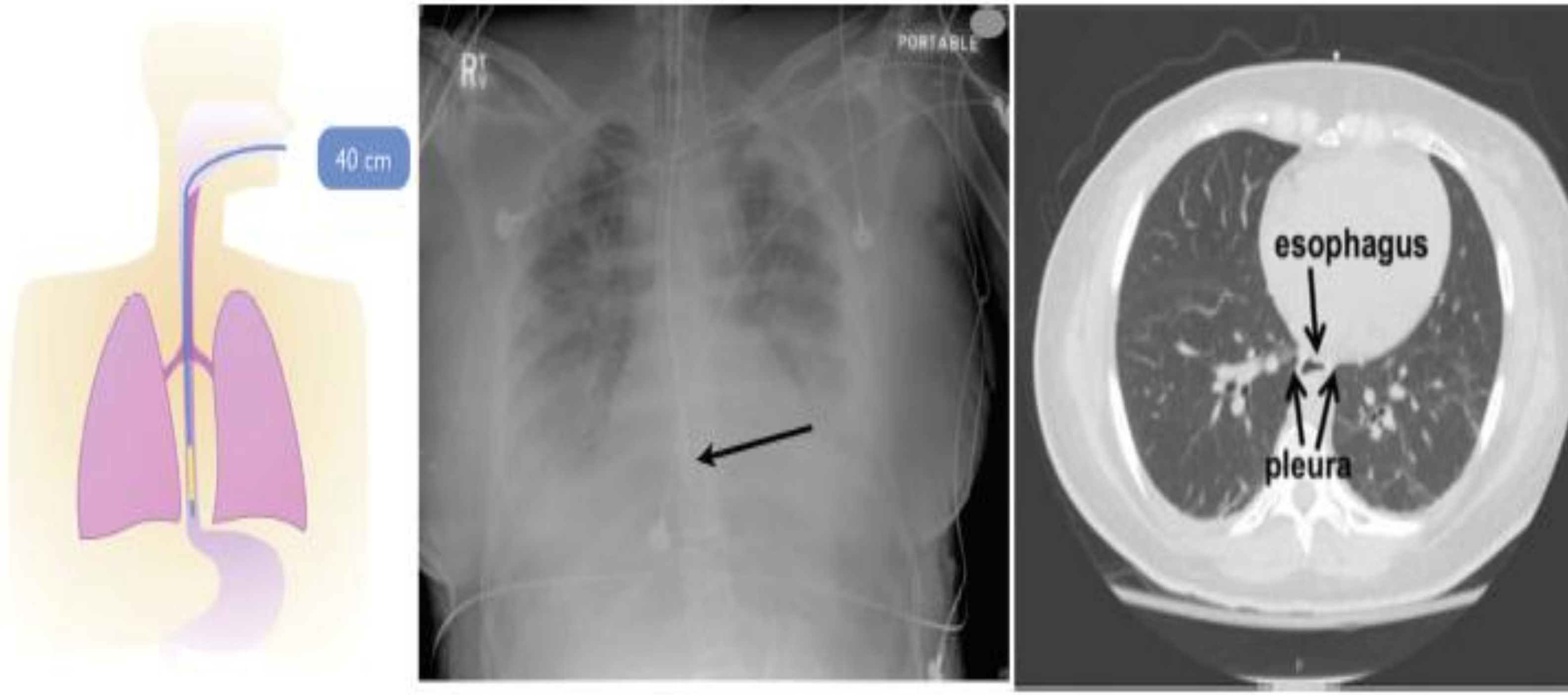


Fig. 6. Left: Correct positioning of the esophageal balloon, ~40 cm from the lips. Center: Chest radiograph showing correct balloon placement (arrow). Right: Note that the esophagus borders the pleural space in the mid-thorax (arrows). Left and center images from Reference 19.

ÖZAFAGEAL (PLEVRAL)
VE GASTRİK (ABDOMİNAL) BASINÇLAR

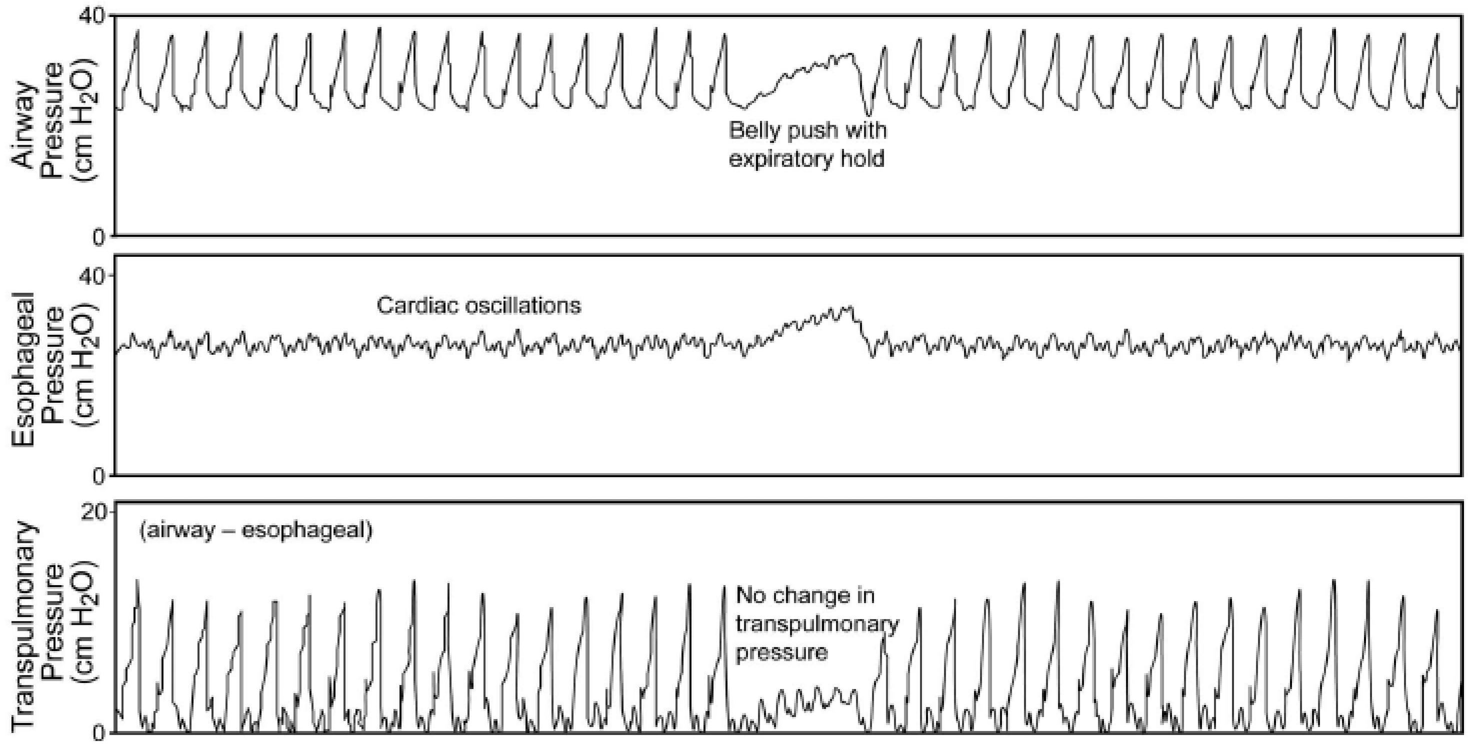


Fig. 5. Illustrated here are several features used to determine that the esophageal balloon is correctly placed in the esophagus. Notice the presence of cardiac oscillations on the esophageal pressure waveform. Also note that there is no change in transpulmonary pressure when pressure is applied to the abdomen.

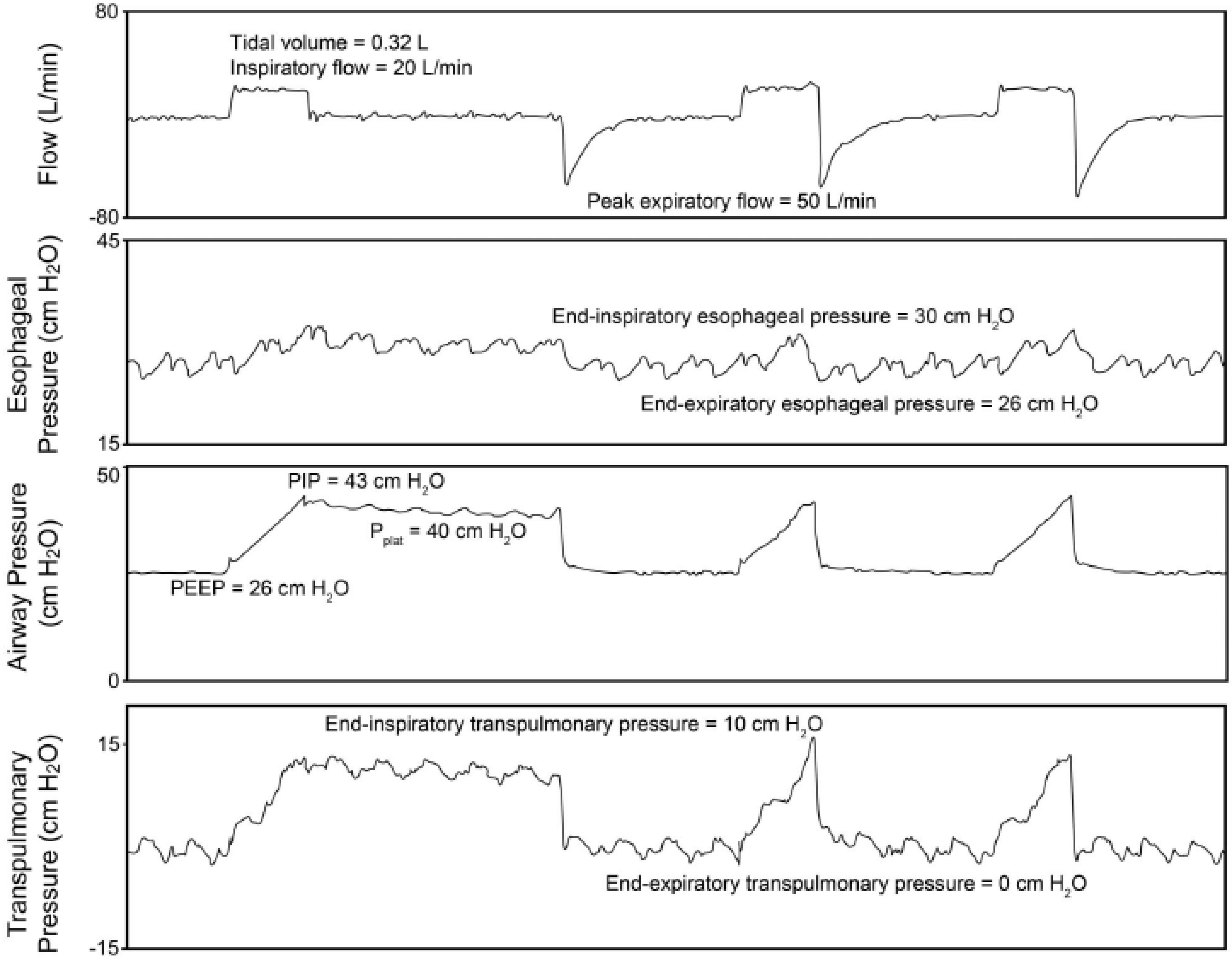


Fig. 17. Flow, esophageal pressure, airway pressure, and transpulmonary pressure can be used to calculate respiratory system compliance, chest-wall compliance, lung compliance, inspiratory airway resistance, and expiratory airway resistance. See text for details. PIP = peak inspiratory pressure; P_{plat} = plateau pressure.

Table 1 Case-scenarios in which esophageal and transpulmonary pressure monitoring could be of help at the bedside

Case-scenario	Relevant Pes-derived measure[a]	Clinical significance	Clinical recommendation
Passively ventilated patient	Tidal ΔP_L	Measure of the tidal stress applied to lung parenchyma	Possibly keep below 10–12 cmH_2O in ARDS patients
	End Inspiratory P_L	Measure of the total stress applied to lung parenchyma	Possibly keep below 20–25 cmH_2O in ARDS patients
	End expiratory P_L	Negative value possibly indicating tendency of the alveoli and/or airways to collapse	Possibly keep above 0 cmH_2O in ARDS patients
	Transmural pulmonary vascular pressure	Effective pressure driving blood flow in intrathoracic vascular structures	Consider delta between CVP and end-expiratory Pes rather than CVP per se to better understand volume status of the patient
	Periodically interspersed negative Pes swings after passively delivered ventilator breaths	Detection of reverse triggering	Consider paralysis or modify sedation (reduce sedation to let the patient trigger)
Ventilated patient with active breathing	Transmural pulmonary vascular pressure	Effective pressure across intrathoracic vascular structures	Consider delta between CVP and end-expiratory Pes rather than CVP per se to better understand volume status of the patient
	End inspiratory P_L	Measure of the tidal stress applied to lung parenchyma	Possibly keep below 20–25 cmH_2O in ARDS patients
	Pmus	Measure of the pressure generated by the patient's inspiratory muscles	Normal values are between 5 and 10 cmH_2O
	Work of breathing	Measure of patient's total work during the respiratory cycle	Normal values are around 0.35 or 2.4 $J\ min^{-1}$
	PTPes	Measure of patient's respiratory muscles effort to breathe	Normal values are around 100 $cmH_2O\ s\ min^{-1}$
	Negative Pes swings without ventilator pressurization	Ineffective effort	Titrate PEEP and/or decrease support and/or consider NAVA
	Pes inspiratory time longer than ventilator inspiratory time	Double triggering or premature cycling	Increase ventilator Ti up to 0.8–1.0 s or consider switching to NAVA or PAV. Rule out non-ventilatory causes (metabolic acidosis, encephalopathy, etc.)
	No Pes swing prior to ventilator pressurization	Auto-triggering	Check for leaks, trigger settings, ventilator tubing (water in circuits) and/or decrease sedation
	Increasing PTPes and/or Pes swings along spontaneous breathing trial	High likelihood of failure to wean	Differentiate whether resistive or elastic workload increased and treat consequently. Reconnect to ventilator

ARDS Acute respiratory distress syndrome, *CVP* central venous pressure, *NAVA* neurally adjusted ventilatory assist, *PAV* proportional assist ventilation, *PEEP* positive end-expiratory pressure, *Pes* esophageal pressure, P_L transpulmonary pressure, ΔP_L change in transpulmonary pressure, *Pmus* inspiratory muscle pressure, *PTPes* esophageal pressure–time product, *Ti* inspiratory time.

[a] The end expiratory P_L is the absolute value. The end inspiratory P_L can be measured with the elastance method or the absolute value. They do not give the same results, the absolute value being generally lower

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SOLUNUM MEKANİKLERİ

- **Work of breathing**
  - WOB= P X V (ventilasyonu gerçekleştirecek akımın başlaması için gereken enerji)

Table 2. – Determinants of work of breathing in ventilator-dependent patients

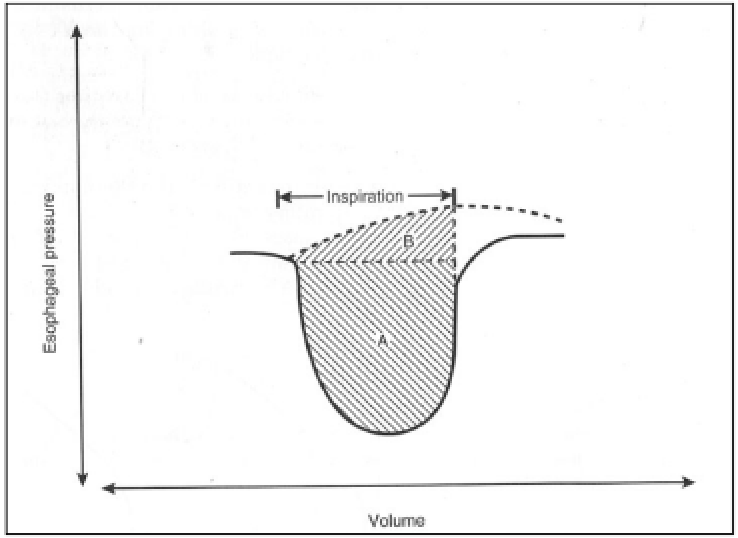
Patient's abnormal mechanics
Low compliance
High flow resistance
PEEPi
Diameter of the endotracheal tube
Ventilator circuit, valves and devices
Ventilatory pattern
V_T and V'_E
Inspiratory flow rate and waveform.

PEEPi: intrinsic positive end expiratory pressure; V_T: tidal volume; V'_E: minute ventilation.

Eur Respir Mon, 2005, 31, 195–206. Printed in UK - all rights reserved. Copyright ERS Journals Ltd 2005.

SOLUNUM MEKANİKLERİ-WOB

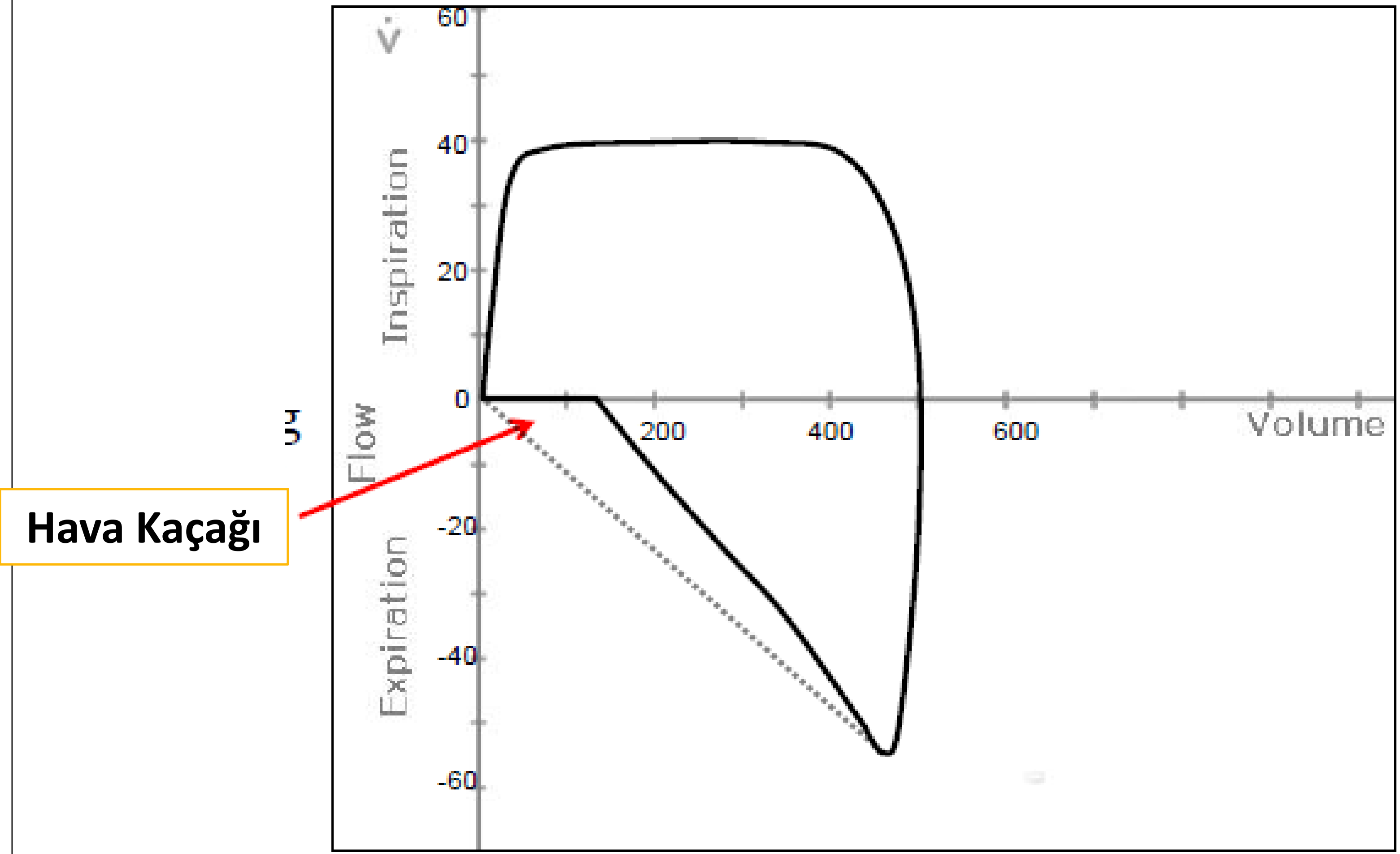
Figure 8



Calculating the work of breathing during spontaneous ventilation using an esophageal balloon. Area A represents the work to move air into and out of the lungs. Area B represents the work to expand the chest wall and is calculated from a pressure–volume curve in a passive patient receiving a mechanically generated breath. The sum of A and B represents the total work of breathing, and it can be determined through integration of the product of esophageal pressure and flow. Reprinted from [1] with permission from Elsevier.

DİĞER ÖZEL BULGULAR

HAVA KAÇAĞI

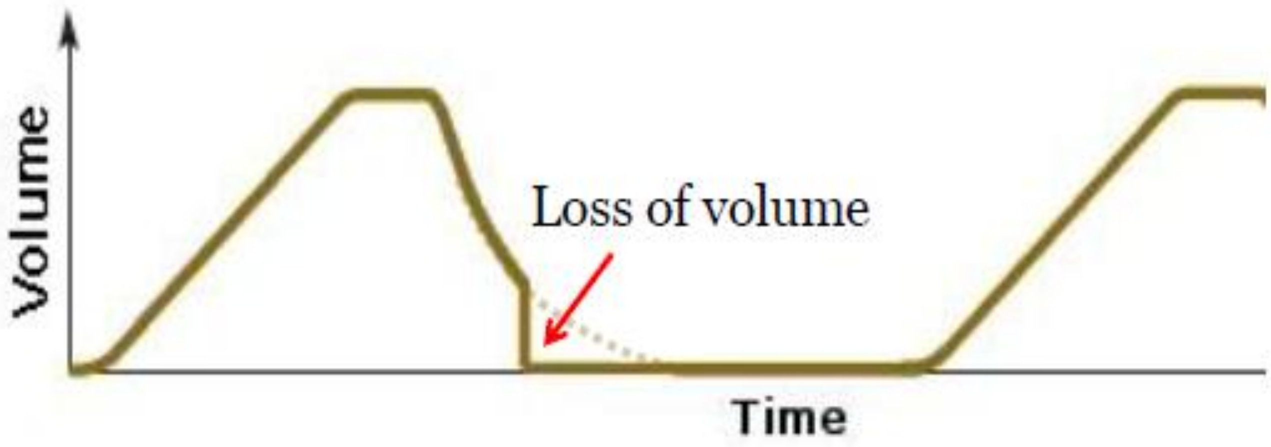


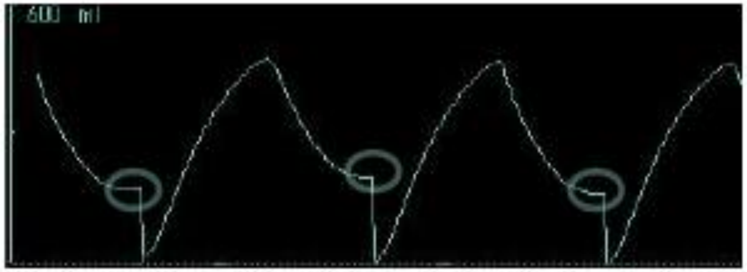
Hava Kaçağı
60
40
20
0
-20
-40
-60
Inspiration
Flow
Expiration
200
400
600
Volume

HAVA KAÇAĞI

PRESSURE A/C
LOOPS
Vt (mL) - Flow (L/min)
Paw (cmH2O) - Vt (mL)
5.1
mL/kg
Vte/kg
14
bpm
Rate
1:3.4
I:E
37.8
mL
Vdel
3
cmH2O
PEEP
17
bpm
Rate
18
cmH2O
Insp Pres
0.80
sec
Insp Time
3
cmH2O
PEEP
0.5
L/min
Flow Trig
21
%
FiO2
0.80 sec
2.73 sec

HAVA KAÇAĞI





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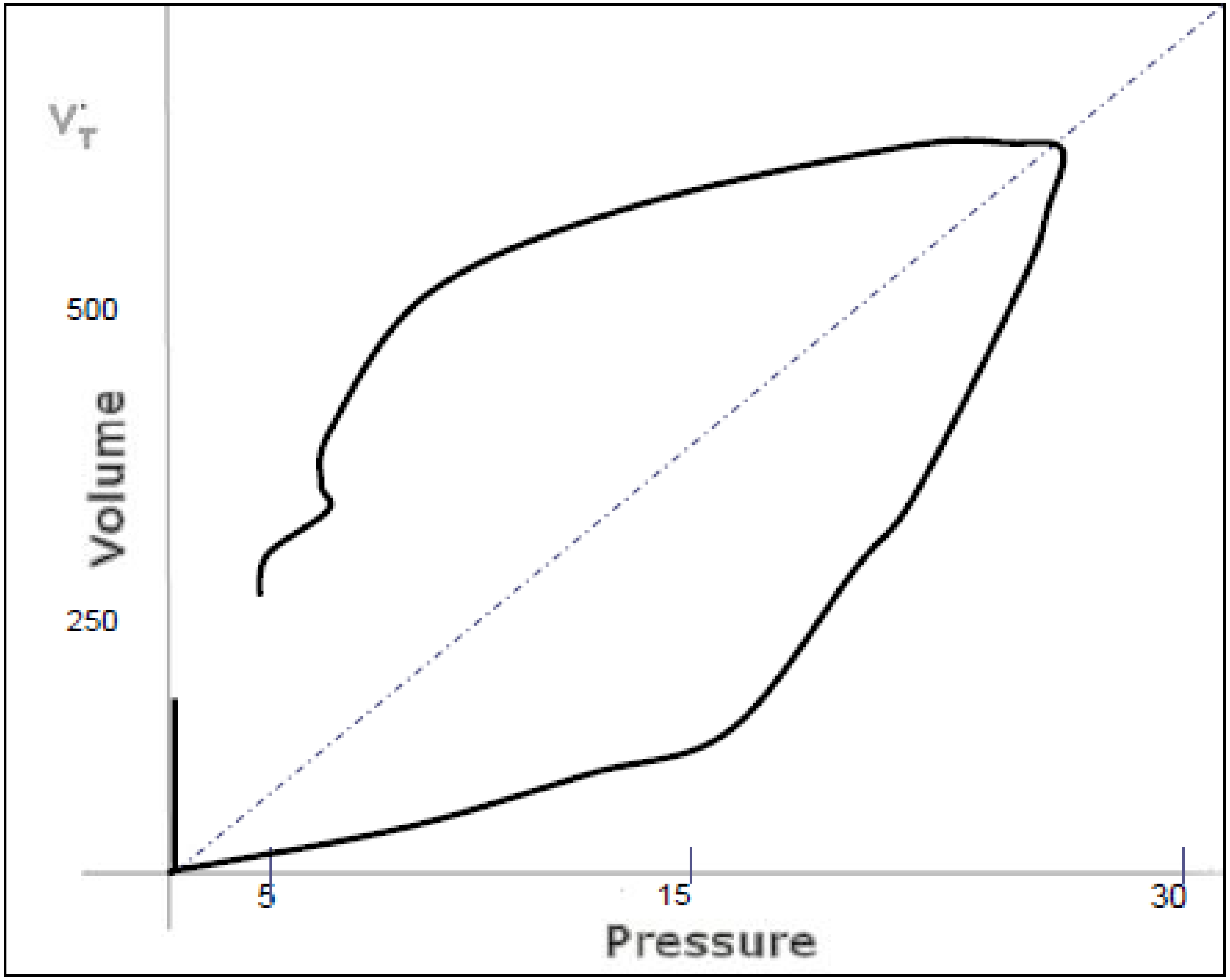

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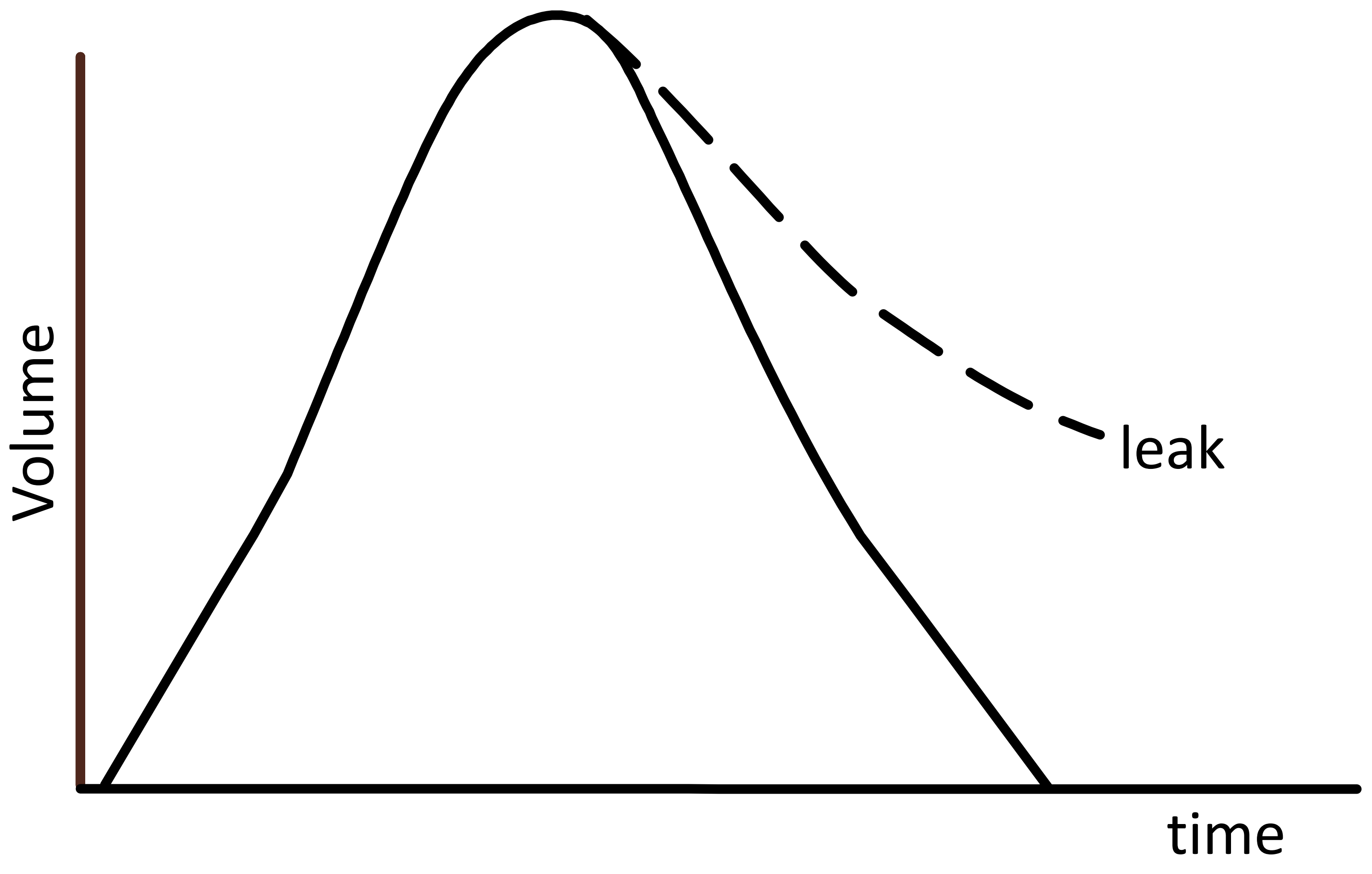


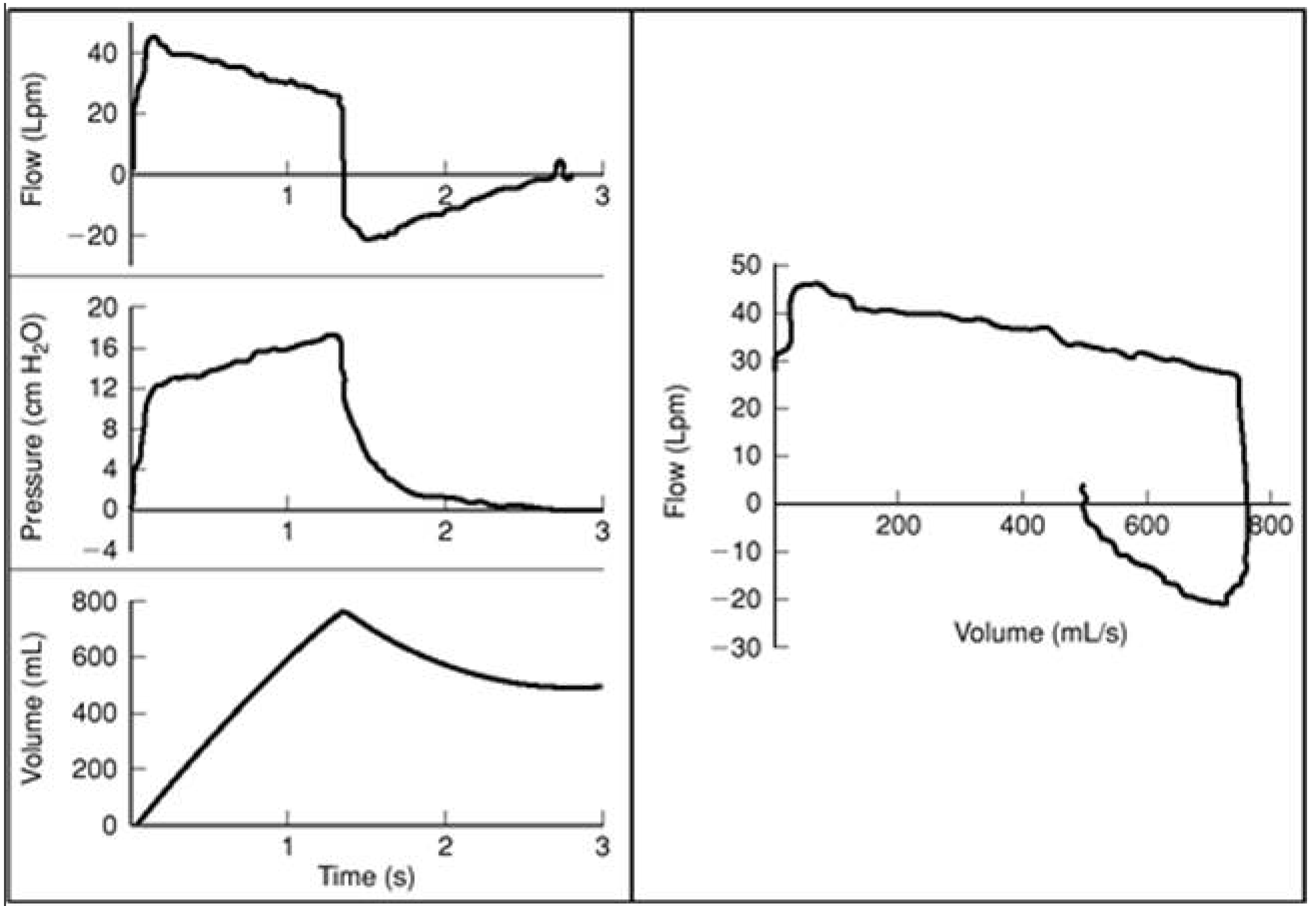
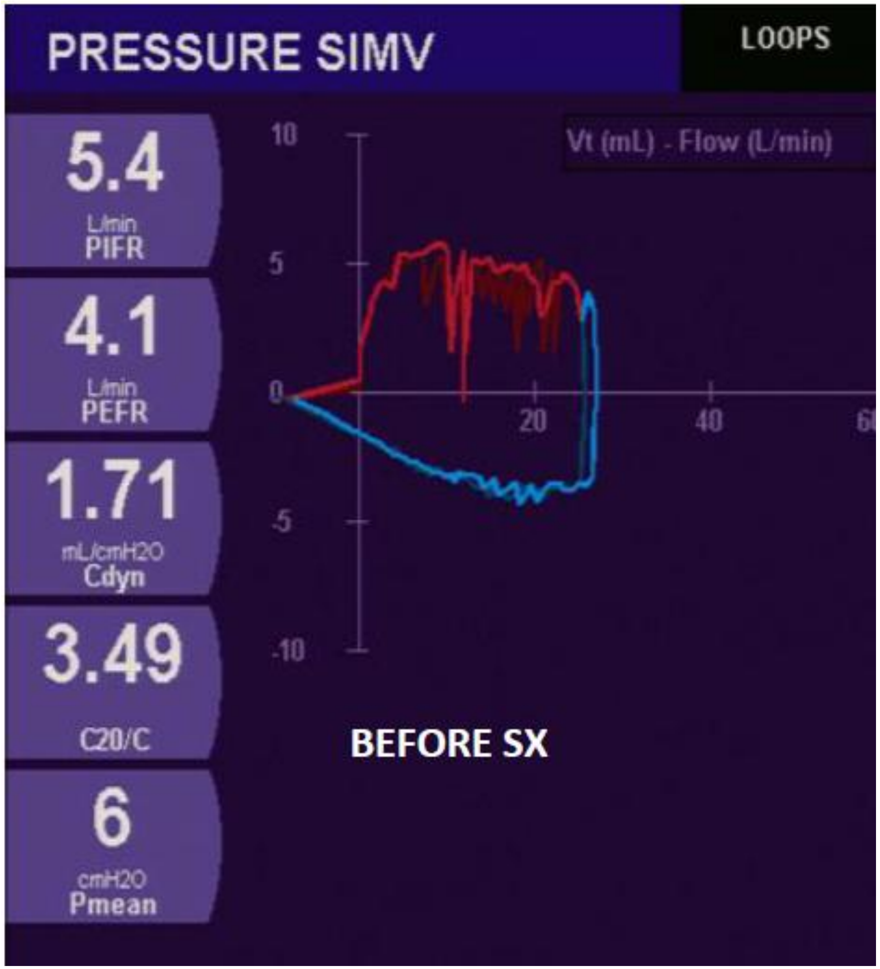
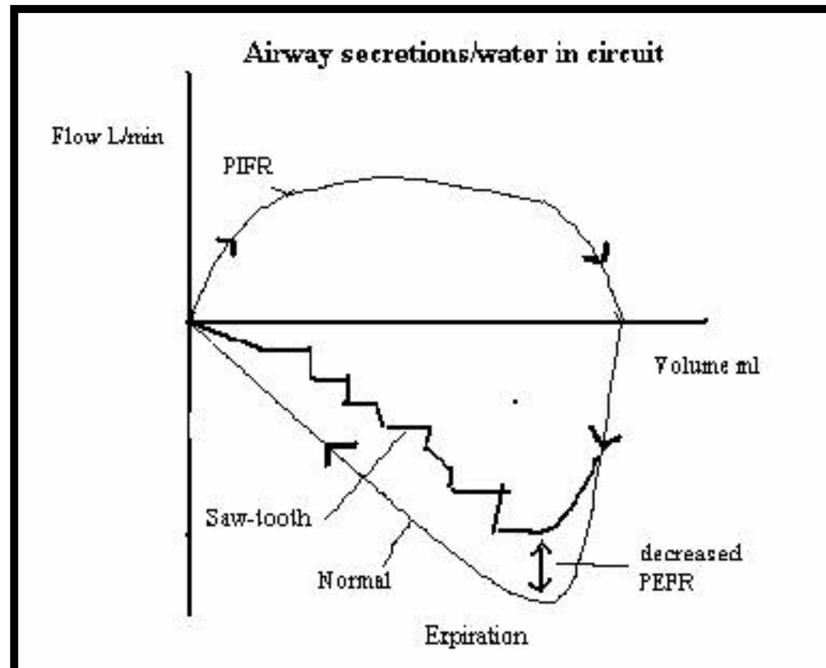


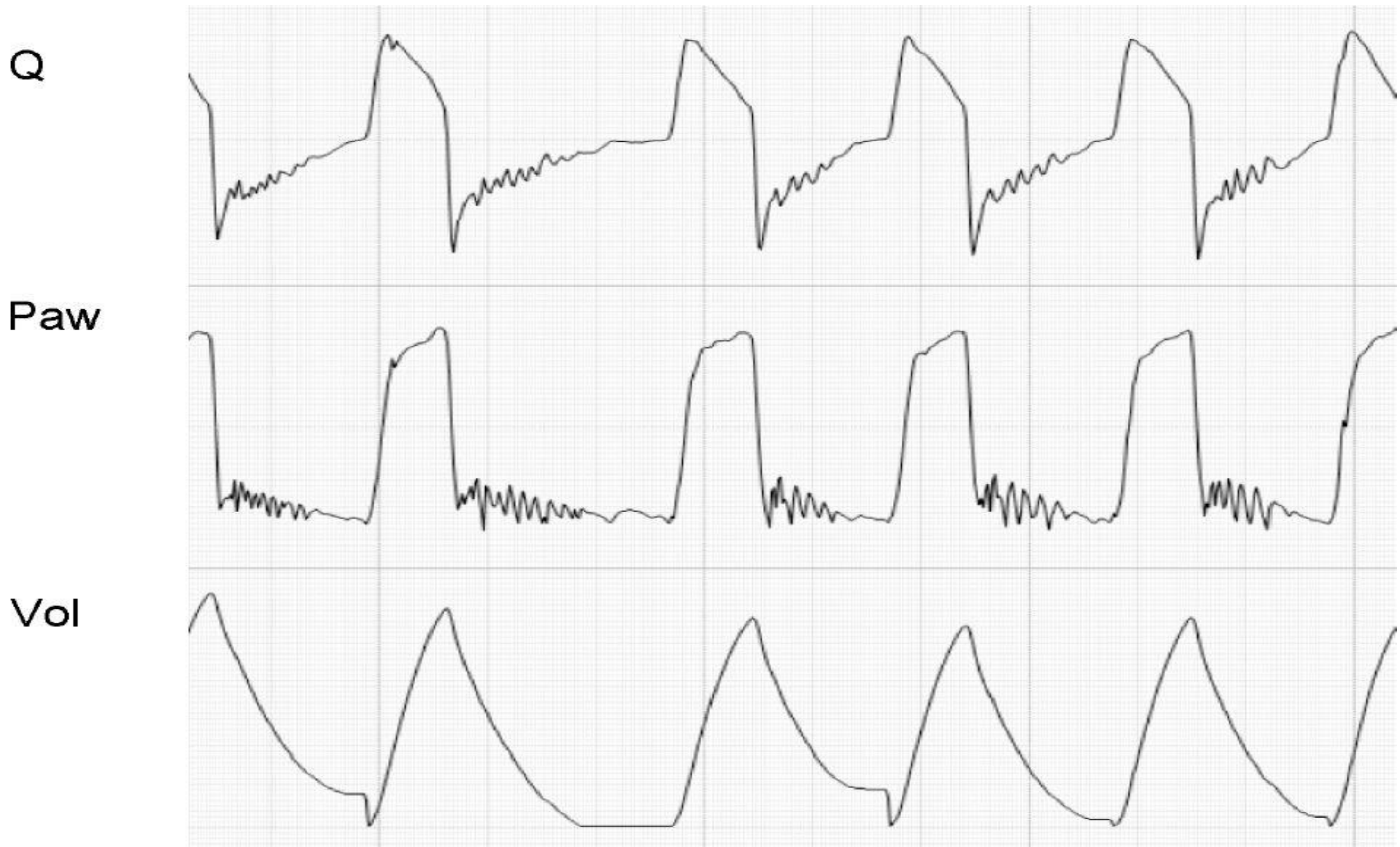
Figure 131.6. Detection of an air leak by ventilator waveform analysis. On the **left**, traces of flow, airway pressure, and volume. Note in the flow trace, the area under the curve (i.e., tidal volume) is smaller during exhalation, indicating a loss of volume. Also note the volume trace that does not reach baseline. On the **right**, the flow–volume loop fails to close at end exhalation. (Modified from Lucangelo U, Bernabe F, Blanch L. Respiratory mechanics derived from signals in the ventilator circuit. *Respir Care.* 2005;50:55–65, with permission.)

SİSTEMDE SU VEYA SEKRESYON

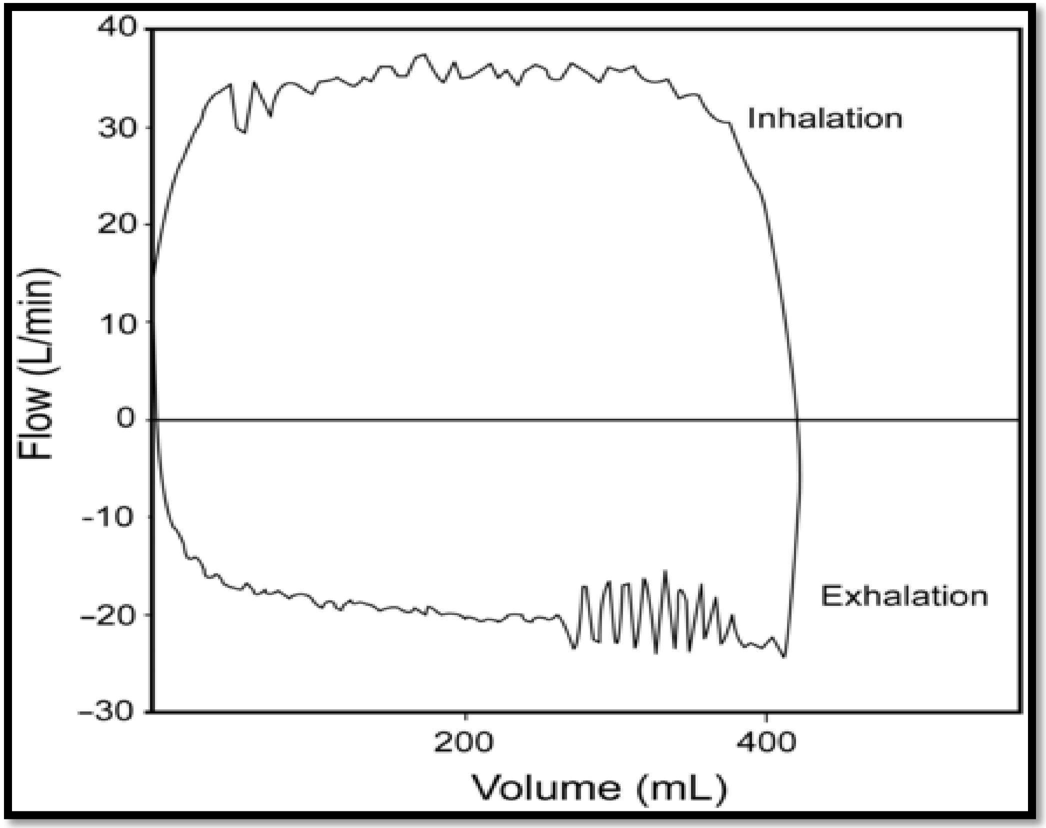




SİSTEMDE SU VEYA SEKRESYON



ENDOTRAKEAL TÜP SEKRESYON İLE TIKANIRSA



FİX-OBSTRÜKSİYON PATERNİ

TEŞEKKÜRLER…..