Ventilator Graphics

Chapter 10

Graphics

- Monitor the function of the ventilator
- Evaluate the patient’s response to the ventilator
- Help the clinician adjust the ventilator settings
- Both scalar and loops
  - Scalar: pressure volume and flow graphed against time
  - Loops: two variable plotted on the X and Y axis, pressure vs volume and flow vs volume

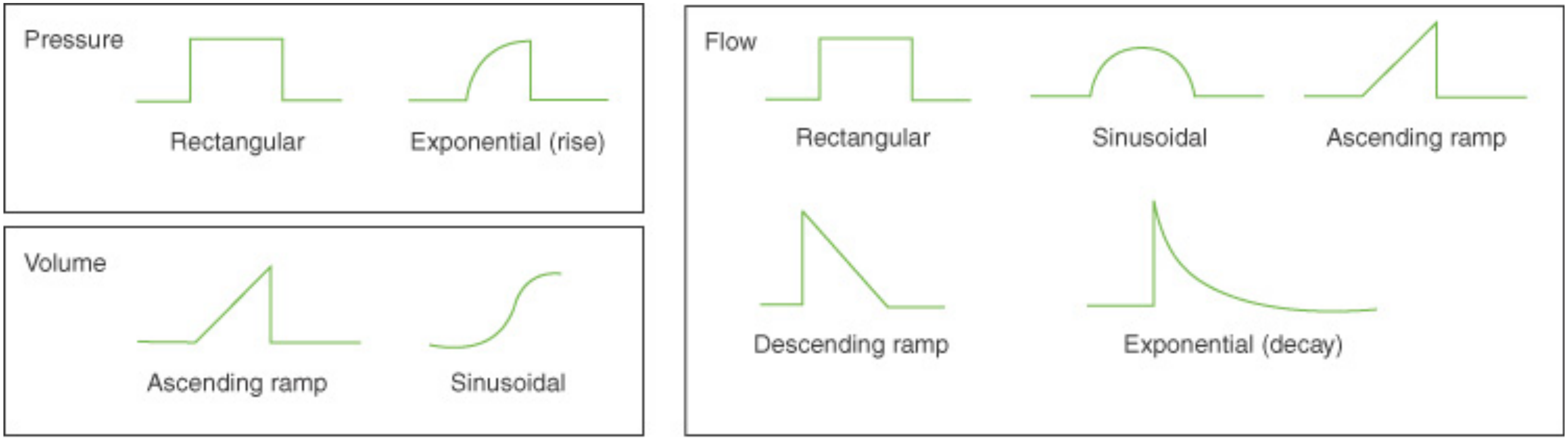

Fig. 10-1 Examples of waveforms for pressure, volume, and flow. Pressure waveforms usually are the rectangular or rising exponential (similar to an ascending ramp) type. Volume waveforms usually are the ascending ramp or sinusoidal (sinelike) type. Flow waveforms can take various forms; the rectangular, ramp (ascending or descending), sinusoidal, and decaying exponential types are seen most often.

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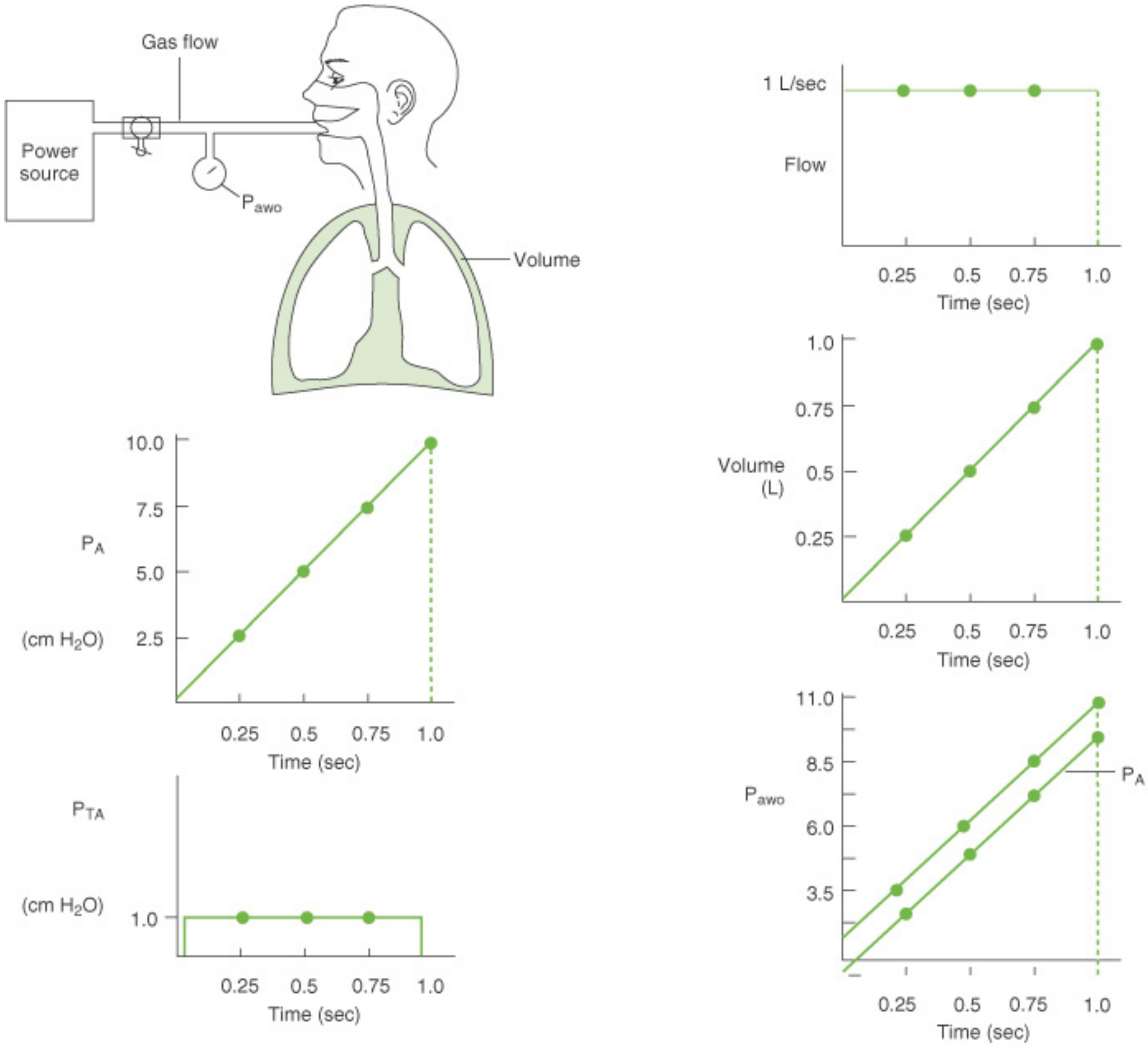

Fig. 10-2 High-pressure source ventilator with high internal resistance. Flow is constant, and volume rises as an ascending ramp during inspiration. Alveolar pressure (P_A) also rises as an ascending ramp. Transairway pressure (P_{TA}) is a rectangular waveform, just like the flow curve. The monitored gauge pressure at the airway opening (P_{awo}) is the sum of P_{TA} and P_A. (See the text for further information.)

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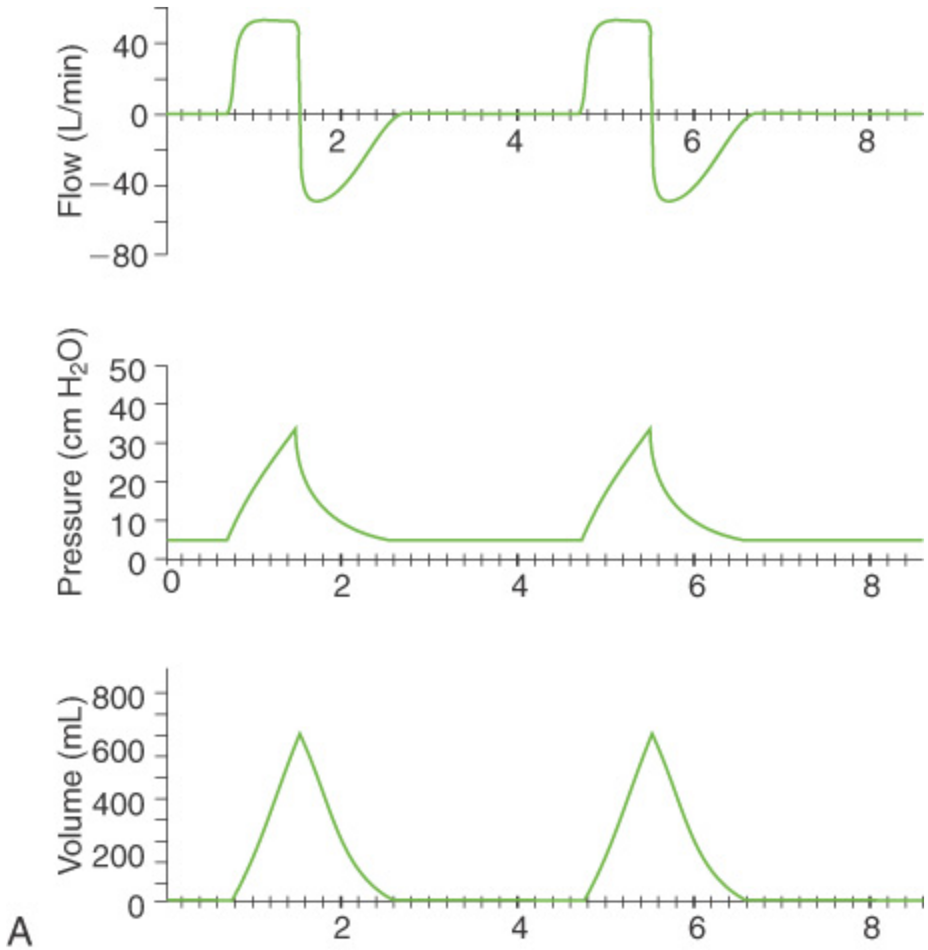

Fig. 10-3A A, Time-triggered, constant flow, volume-targeted ventilation (VC-CMV). **B,** Time-triggered, descending-flow, volume-targeted ventilation.

(Modified from Hess DR, MacIntyre NR, Mishoe SC, et al: *Respiratory care principles and practice,* Philadelphia 2002, WB Saunders.)

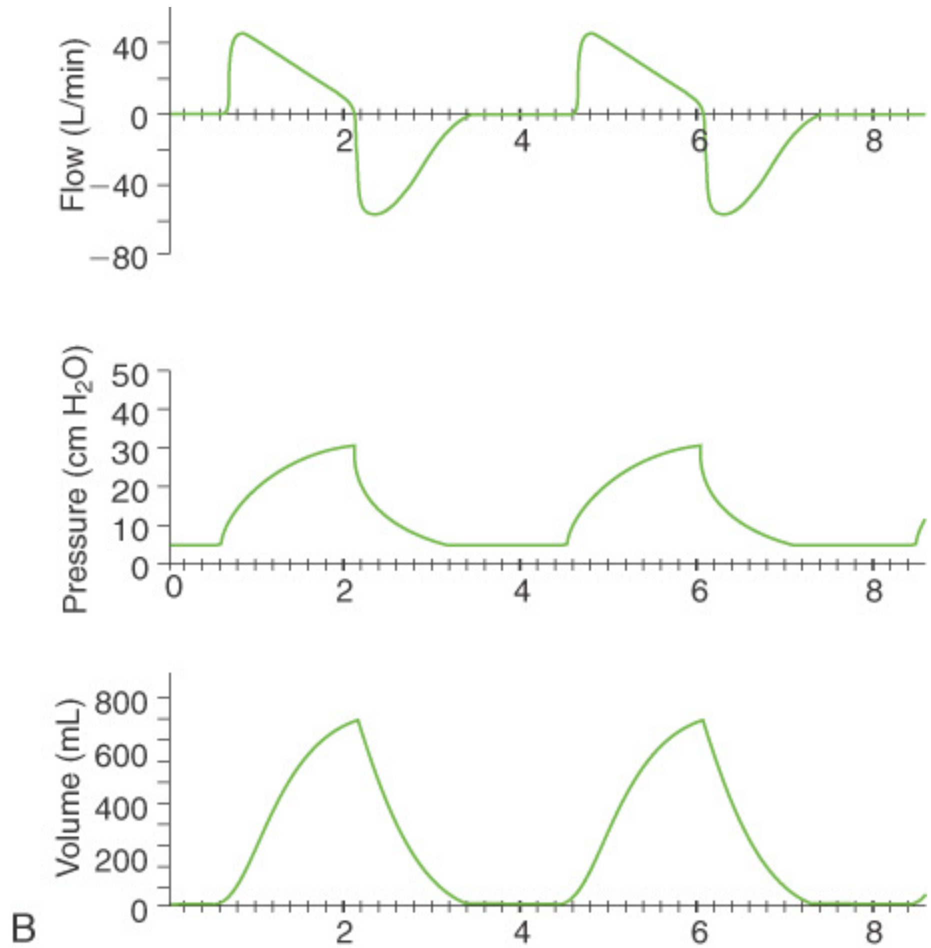

Fig. 10-3B A, Time-triggered, constant flow, volume-targeted ventilation (VC-CMV). **B,** Time-triggered, descending-flow, volume-targeted ventilation.

(Modified from Hess DR, MacIntyre NR, Mishoe SC, et al: *Respiratory care principles and practice,* Philadelphia 2002, WB Saunders.)

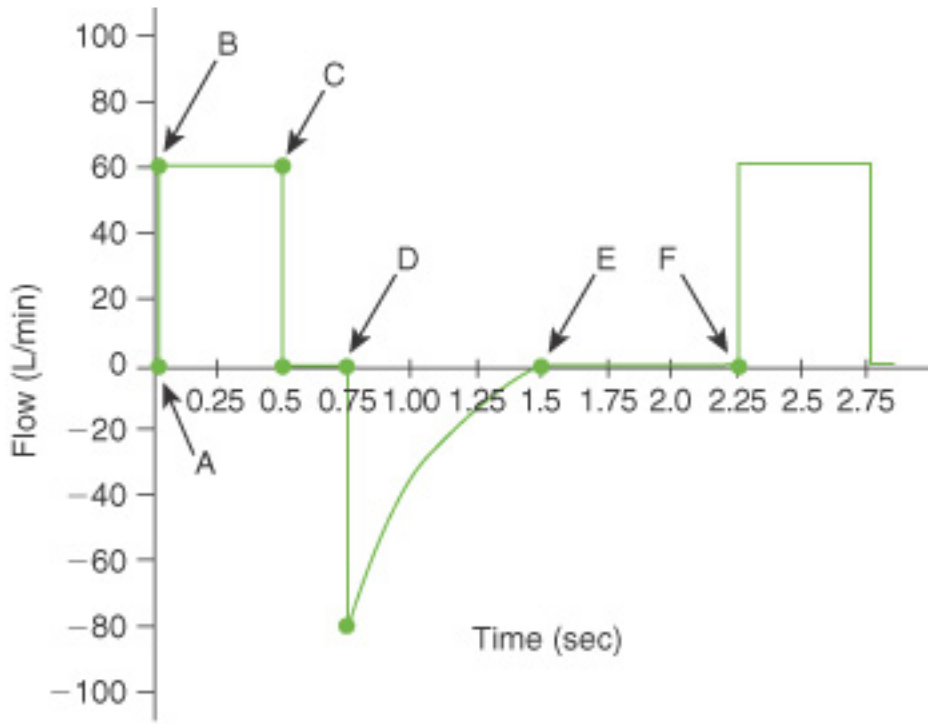

Fig. 10-4 Flow-time graph showing inspiration and expiration during volume ventilation with a constant flow. (See text for explanation.)

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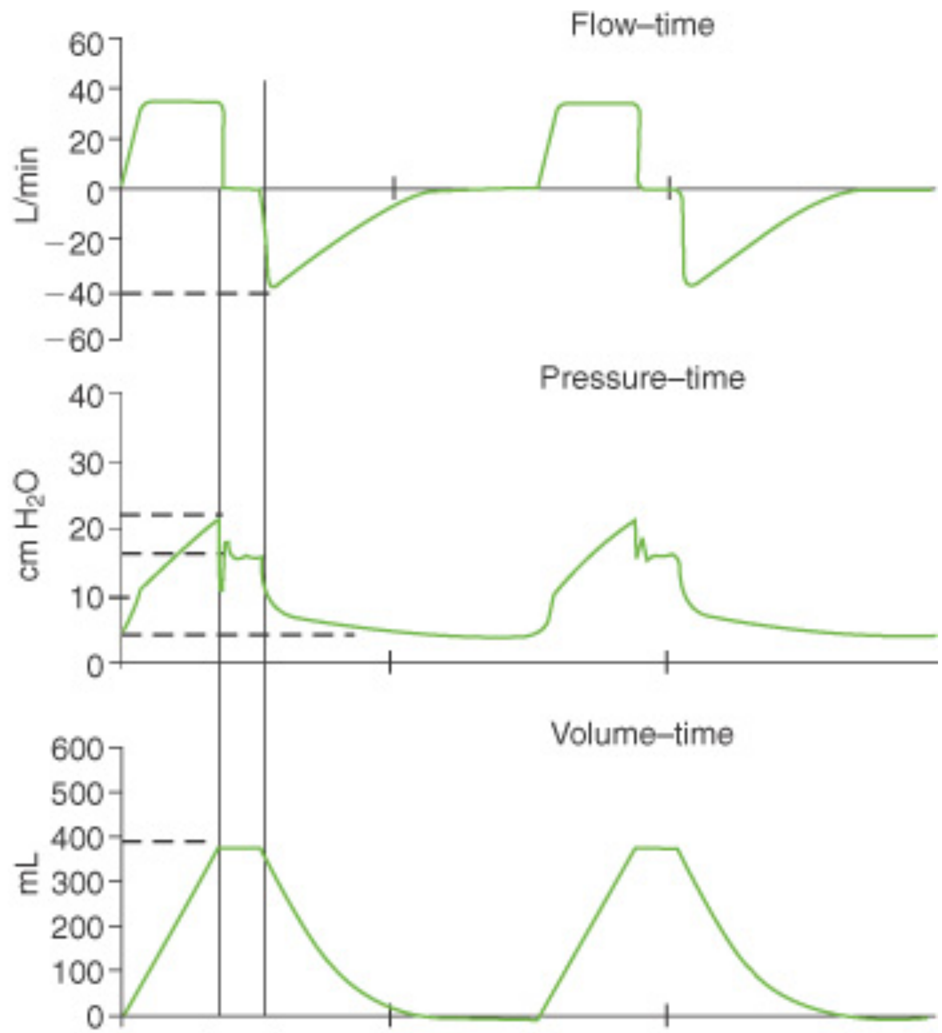

Fig. 10-5 Flow, pressure, and volume scalars during volume ventilation with constant flow and an inspiratory pause. (See text for explanation.)

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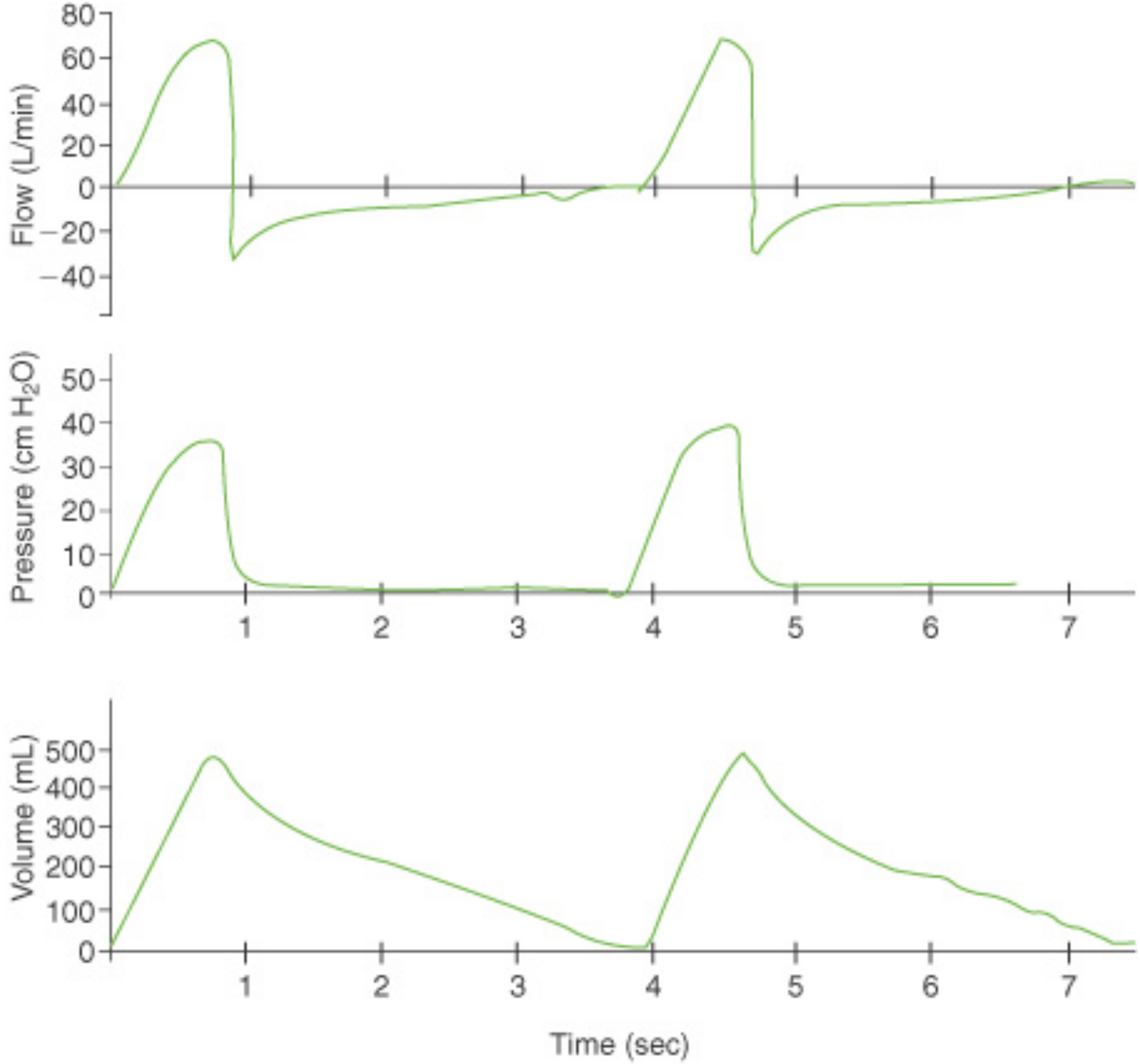

Fig. 10-6 Flow, pressure, and volume scalars during volume ventilation with modified sine flow waveform. (See text for explanation.)

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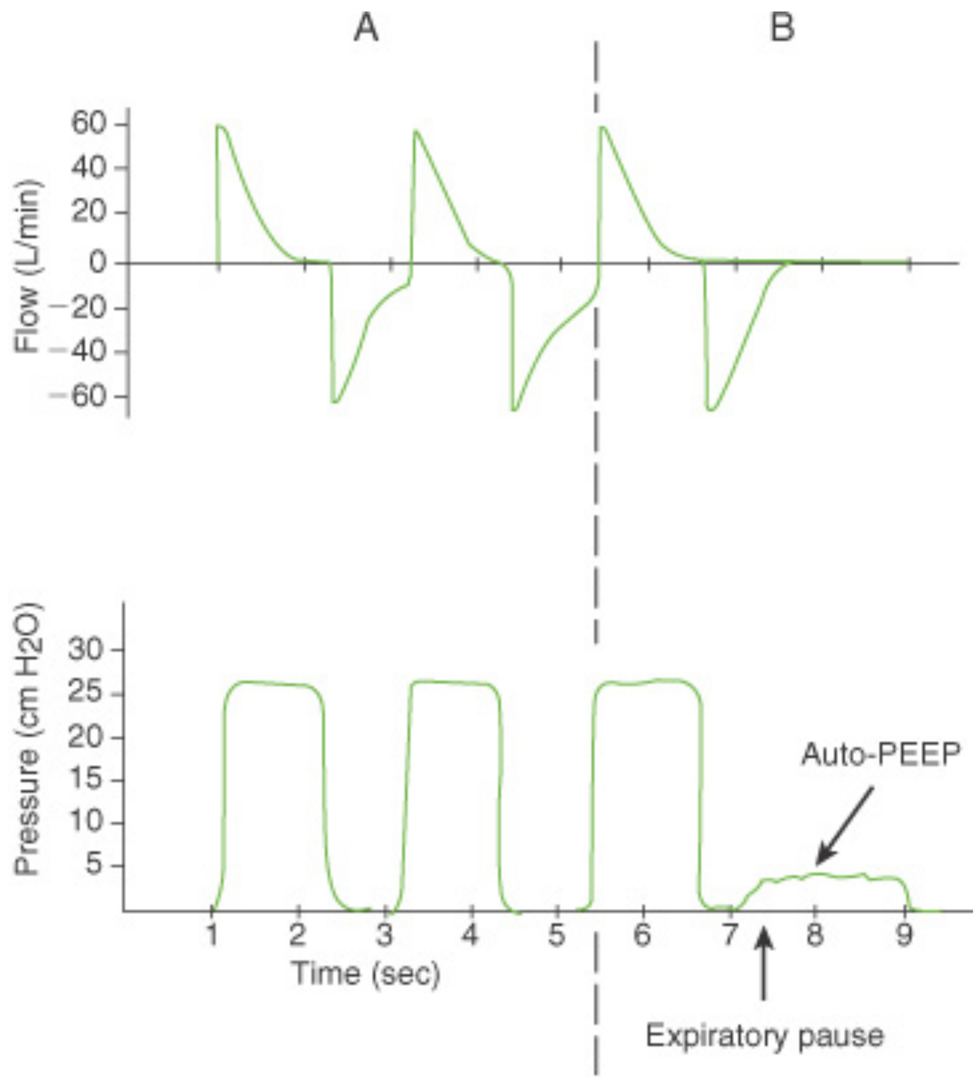

Fig. 10-7 A, Flow and pressure scalars during pressure ventilation. Note the expiratory portion of the flow scalar. **B,** Flow and pressure scalars for the same patient with an expiratory pause *(arrow)* and an auto-PEEP level *(arrow)*. (See text for further explanation.)

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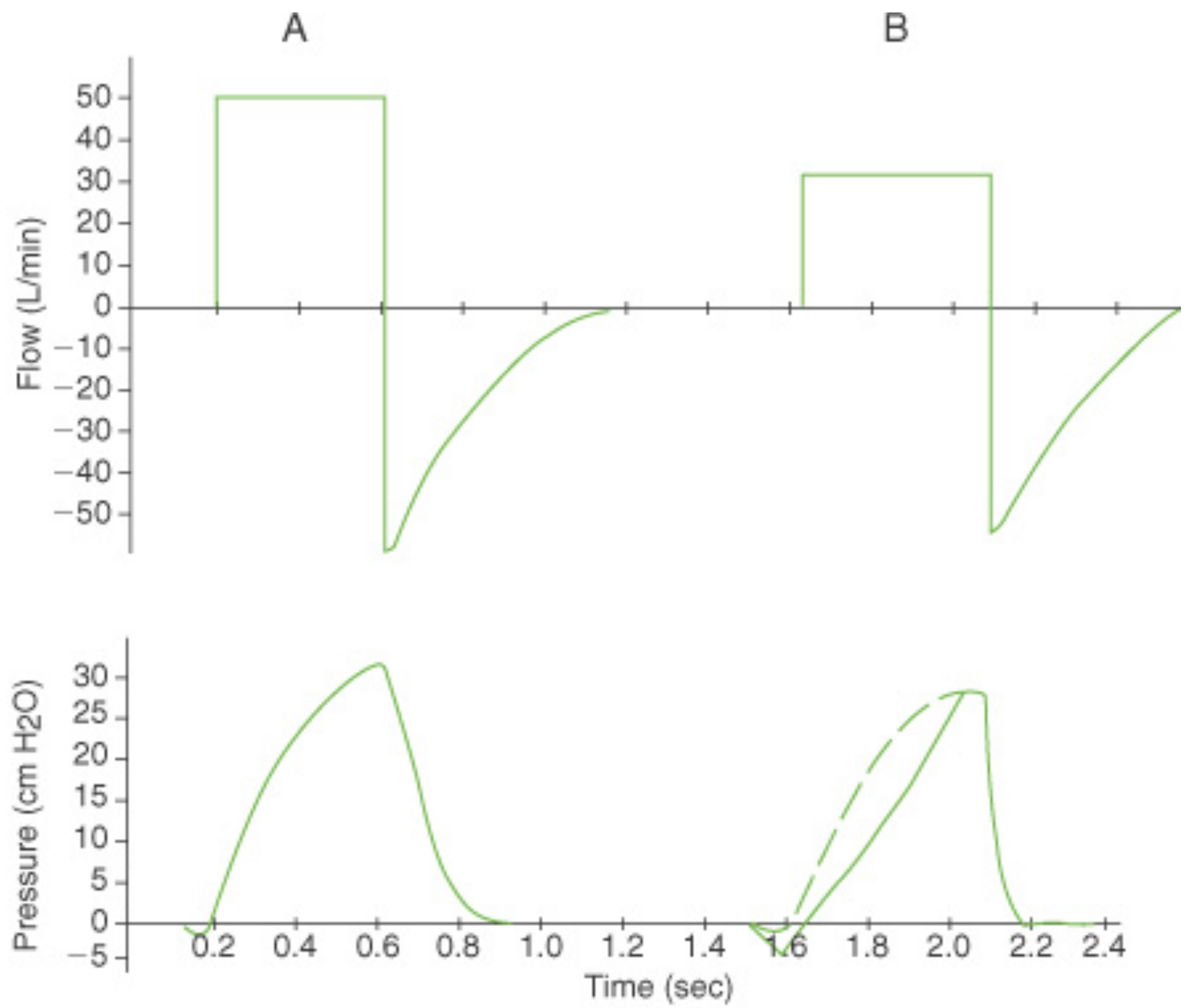

Fig. 10-9 Pressure and flow scalars during volume ventilation. **A,** Patient-triggered breath with an appropriately set sensitivity and adequate flow during inspiration. **B,** Inadequate sensitivity and inadequate flow (flow starvation) with a pressure-time curve showing a concave or downward scoop during inspiration. (Dashed line represents normal pressure curve.) (See text for further explanation.)

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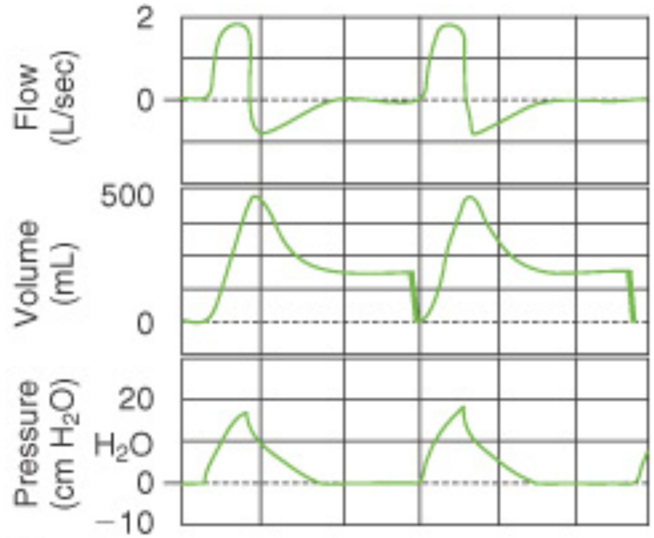
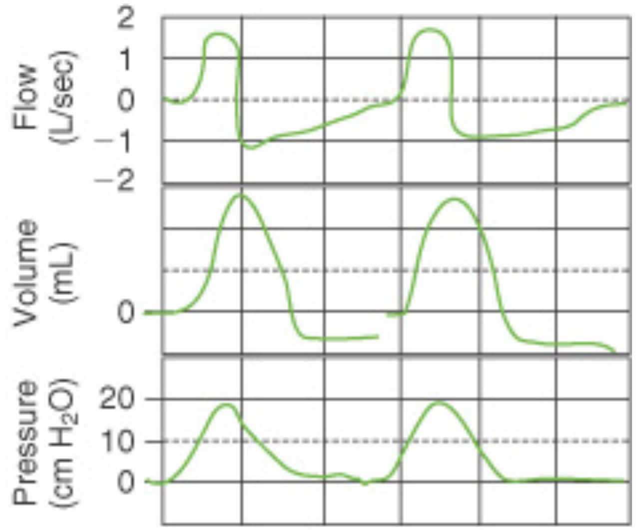


A

Fig 10-10A A, Scalars during volume ventilation: flow *(top),* volume *(middle),* and pressure *(bottom).* Volume-time curve during exhalation is above the baseline and resembles an igloo; this indicates a leak. **B,** Volume-time curve drops below baseline during exhalation, indicating active exhalation or a technical error. (See text for explanation.)

(Modified from Kacmarek RM, Hess D, Stoller JK: *Monitoring in respiratory care, St Louis, 1993, Mosby.*)



B

Fig 10-10B A, Scalars during volume ventilation: flow *(top),* volume *(middle),* and pressure *(bottom).* Volume-time curve during exhalation is above the baseline and resembles an igloo; this indicates a leak. **B,** Volume-time curve drops below baseline during exhalation, indicating active exhalation or a technical error. (See text for explanation.)

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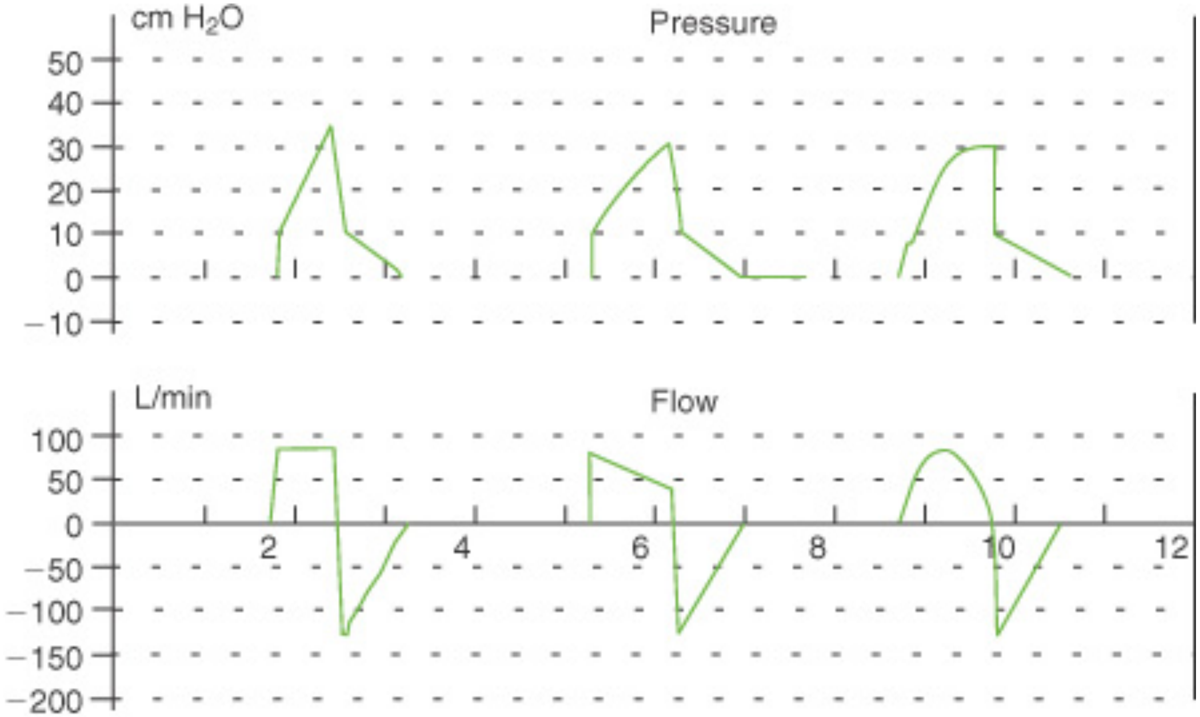

Fig. 10-11 Standard mechanical ventilator flow patterns: rectangular, descending, and sinusoidal. The effect of the flow pattern on the development of pressure is also shown.

(Redrawn from Nilsestuen JO, Hargett K: *Respir Care* 41:1105, 1996.)

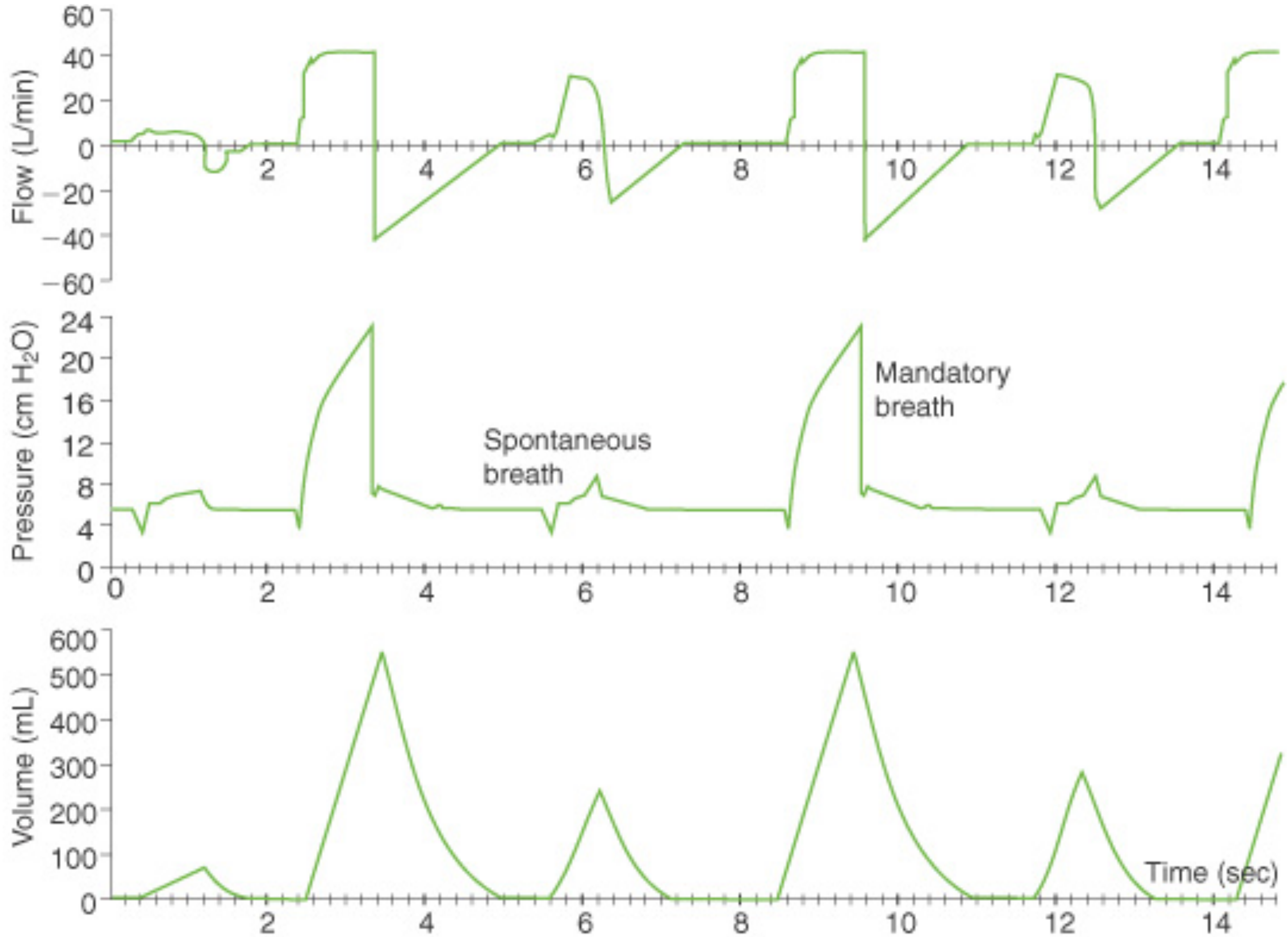

Fig. 10-12 VC-SIMV plus CPAP/PEEP (see text for explanation).

(From Hess DR, MacIntyre NR, Mishoe SC, et al: *Respiratory care principles and practice,* Philadelphia 2002, WB Saunders.)

Clinical Rounds 10-1, p. 182

A patient is volume ventilated at the following settings: PIP 24cmH2O; Pplat 17cmH2O; Vt 400ml; PEEP 5 cmH2O

1. What is the Pta?
2. What is the Cstat?
3. Flow is about 35L/min, what is the Raw?
4. Is this Raw normal?

1. Pta=PIP-Pplat: 24-17=7cmH2O
2. Cstat=Vt/Pplat-PEEP: 400/17-5= 33.3ml/cmH2O
3. Raw=Pta/flow: 7/(35/60)=12cmH2O/L/s
4. The patient has increased Raw

Key Points for Volume Ventilation Graphics

- Observing PIP, Pplat, Pta, PEEP on the pressure-time scalar
- On flow-time scalars locating the beginning of inspiration, the set flow, the beginning of exhalation, PEFR, end-expiratory flow, and the end of exhalation
- Calculating compliance from pressure and flow curves
- Observing inspiratory flow of zero during inspiratory pause
- Checking for Raw using Pta and the expiratory flow curve
- Inadequate sensitivity and inadequate flow and resulting changes in the pressure-time curve
- Checking for auto-PEEP using the expiratory flow curve
- Measuring and observing auto-PEEP levels on the pressure-time curve
- Checking for leaks and for active exhaltion or transducer error in volume-time curves
- Different flow patterns during volume ventilation

Pressure Ventilation

- The pressure waveform is rectangular – constant
- The pressure waveform is not affected by changes in lung characteristics or patient flow demand
- The rate of flow delivery varies according to the lung characteristics, set pressure and inspiratory effort
- The flow waveform rises rapidly at the beginning of inspiration and decreases during inspiration (continuously variable decelerating pattern)

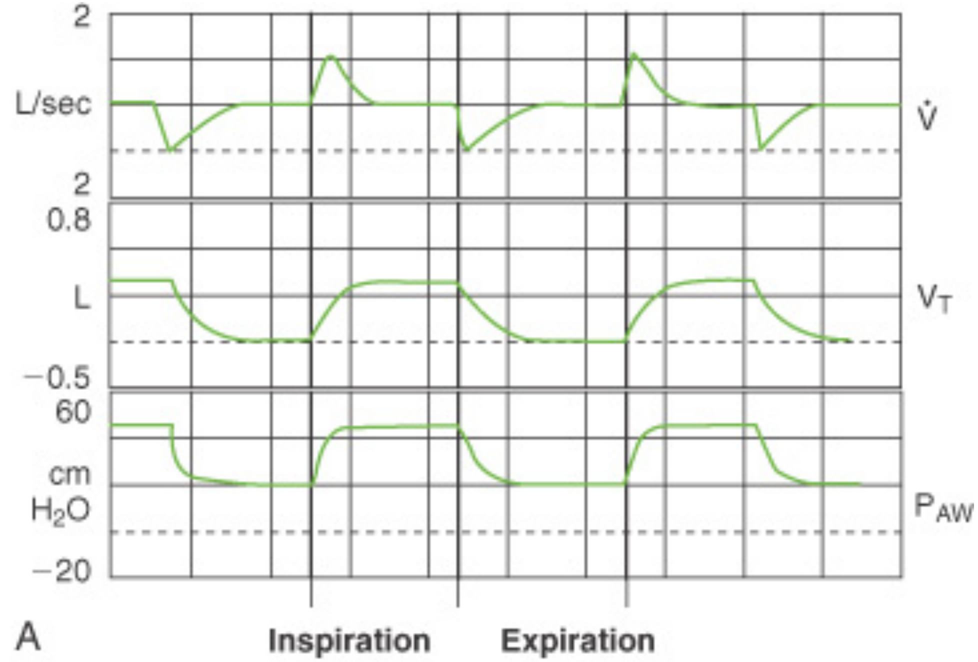

Fig. 10-13A A, PC-CMV scalars for pressure *(bottom),* volume *(middle),* and flow *(top)* during PC-CMV with a long T_I. Alveolar pressure becomes equal to the peak (set) pressure because flow returns to zero before the end of inspiration. **B,** T_I is shorter. Flow does not return to zero nor is an inflation hold (no flow) observed during inspiration. (See text for explanation.)

(From Kacmarek RM, Hess D, Stoller JK: *Monitoring in respiratory care,* St Louis, 1993, Mosby.)

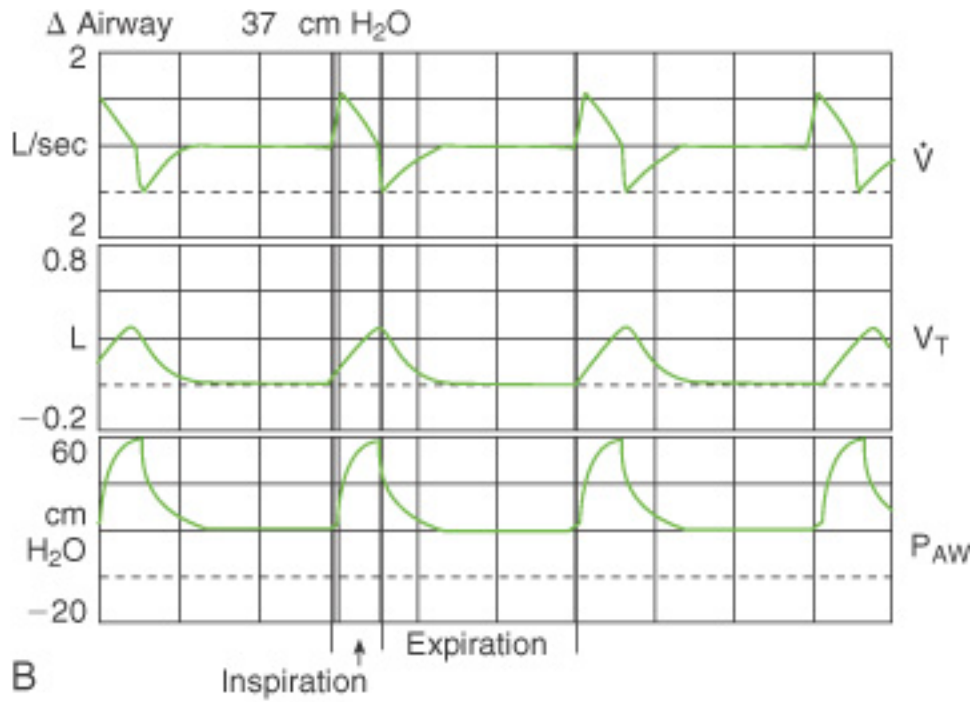

Fig. 10-13B A, PC-CMV scalars for pressure *(bottom)*, volume *(middle)*, and flow *(top)* during PC-CMV with a long T_I. Alveolar pressure becomes equal to the peak (set) pressure because flow returns to zero before the end of inspiration. **B,** T_I is shorter. Flow does not return to zero nor is an inflation hold (no flow) observed during inspiration. (See text for explanation.)

(From Kacmarek RM, Hess D, Stoller JK: *Monitoring in respiratory care,* St Louis, 1993, Mosby.)

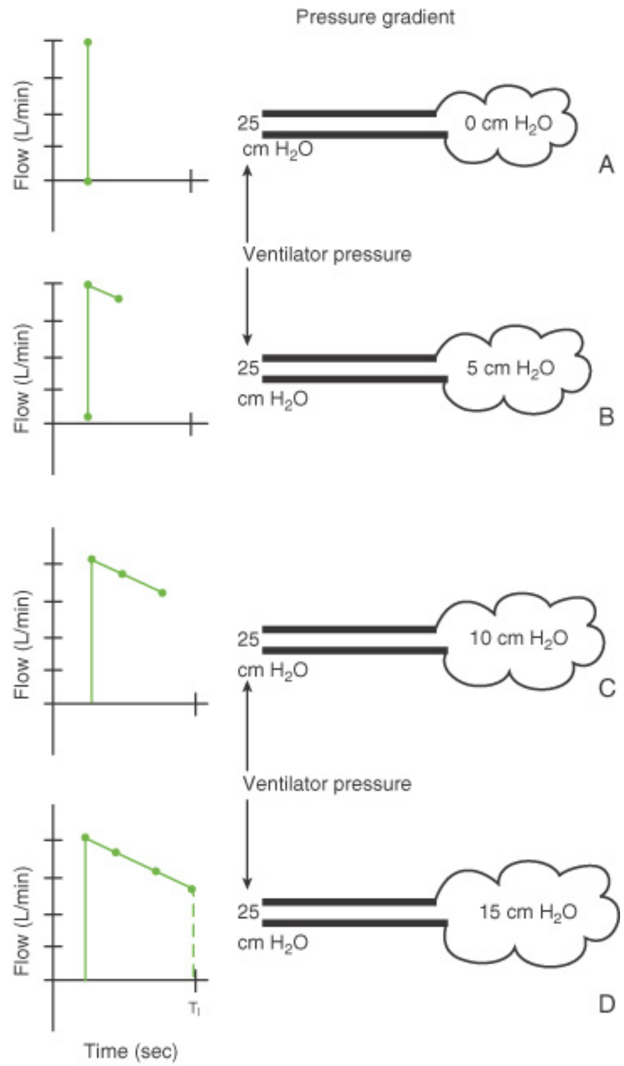

Fig. 10-14 Patient with increased Raw ventilated with PCV. The set pressure is 25 cm H_2O. **A,** At the beginning of the breath, the pressure gradient (ΔP) is 25 cm H_2O (set P – P_A). **B,** P_A is 5 cm H_2O; ΔP is 20 cm H_2O. **C,** P_A is 10 cm H_2O; ΔP is 15 cm H_2O. **D,** P_A is 15 cm H_2O; ΔP is 10 cm H_2O. The flow drop during inspiration is not as rapid as with normal Raw. Flow does not reach zero by end inspiration. Volume delivery is lower than with normal Raw.

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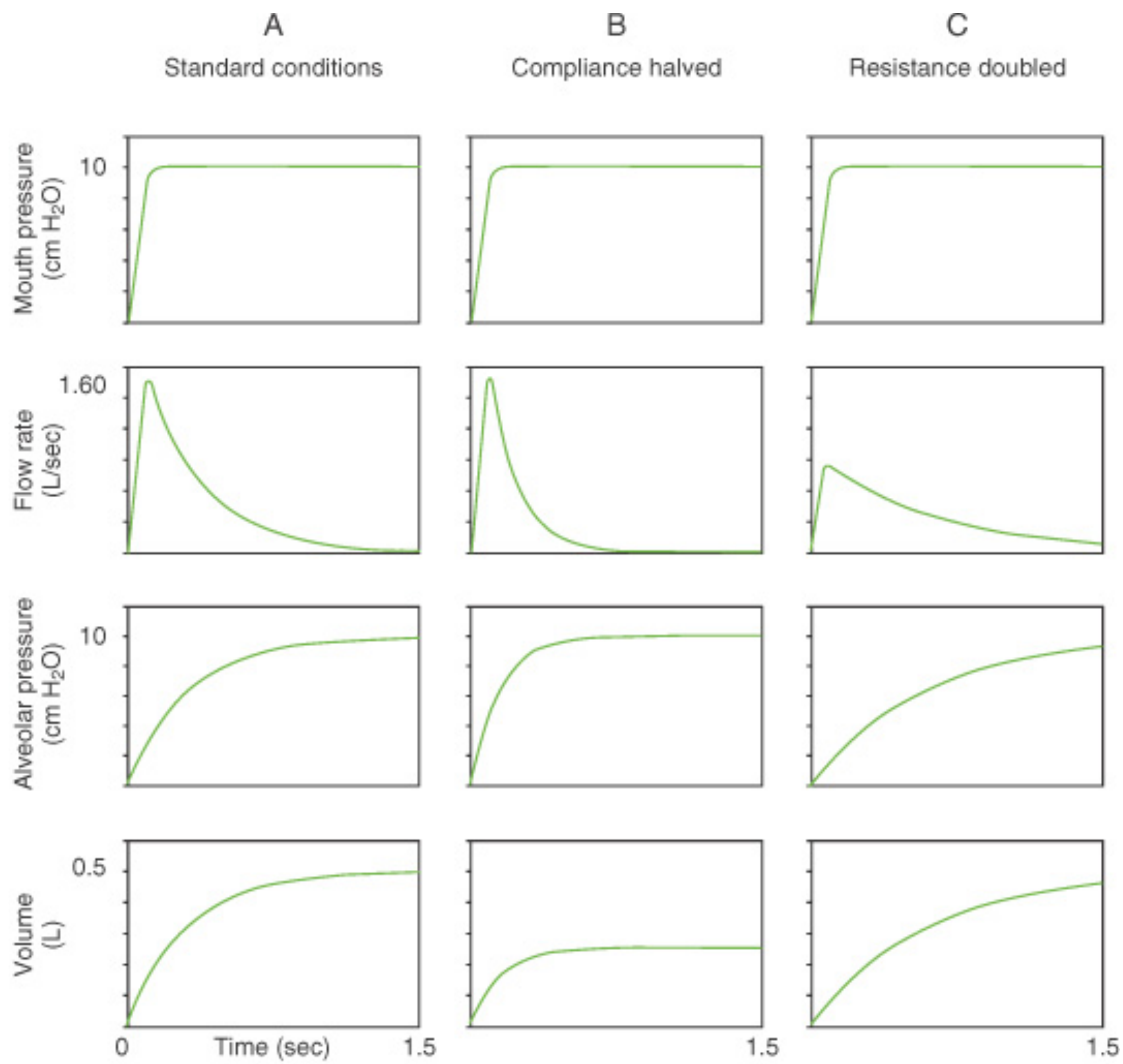

Fig. 10-15 Theoretical waveforms generated by a microprocessor-controlled ventilator operating in the pressure control mode (pressure ventilation). The pressure setting is 10 cm H_2O, inspiratory time is 1.5 seconds, compliance is 50 mL/cm H_2O, and airway resistance is 6 cm H_2O/L/sec. **A,** Standard conditions described. **B,** Compliance has been halved (25 mL/cm H_2O). **C,** Airway resistance has doubled (12 cm H_2O/L/sec).

(From Dupuis Y: *Ventilators: theory and clinical application,* ed 2, St Louis, 1992, Mosby.)

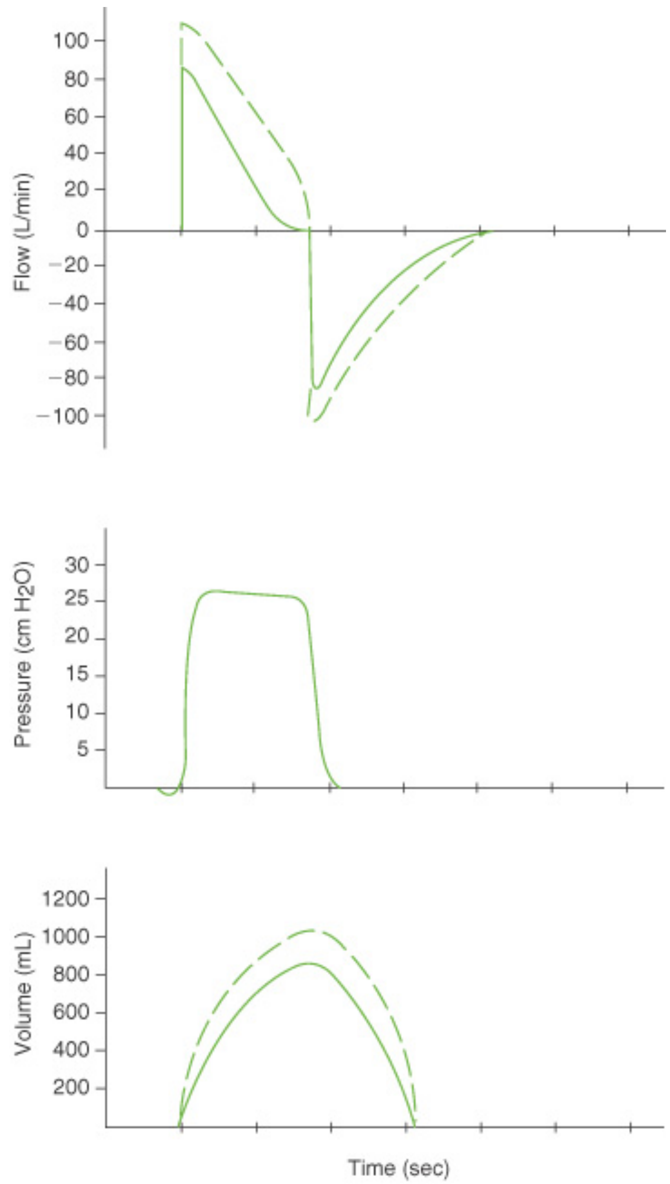

Fig. 10-16 The solid line represents the flow, pressure, and volume scalars for PCV. The dashed line represents active inspiration by the patient. Note the increase in volume and flow delivery. Pressure and T_I remain unchanged.

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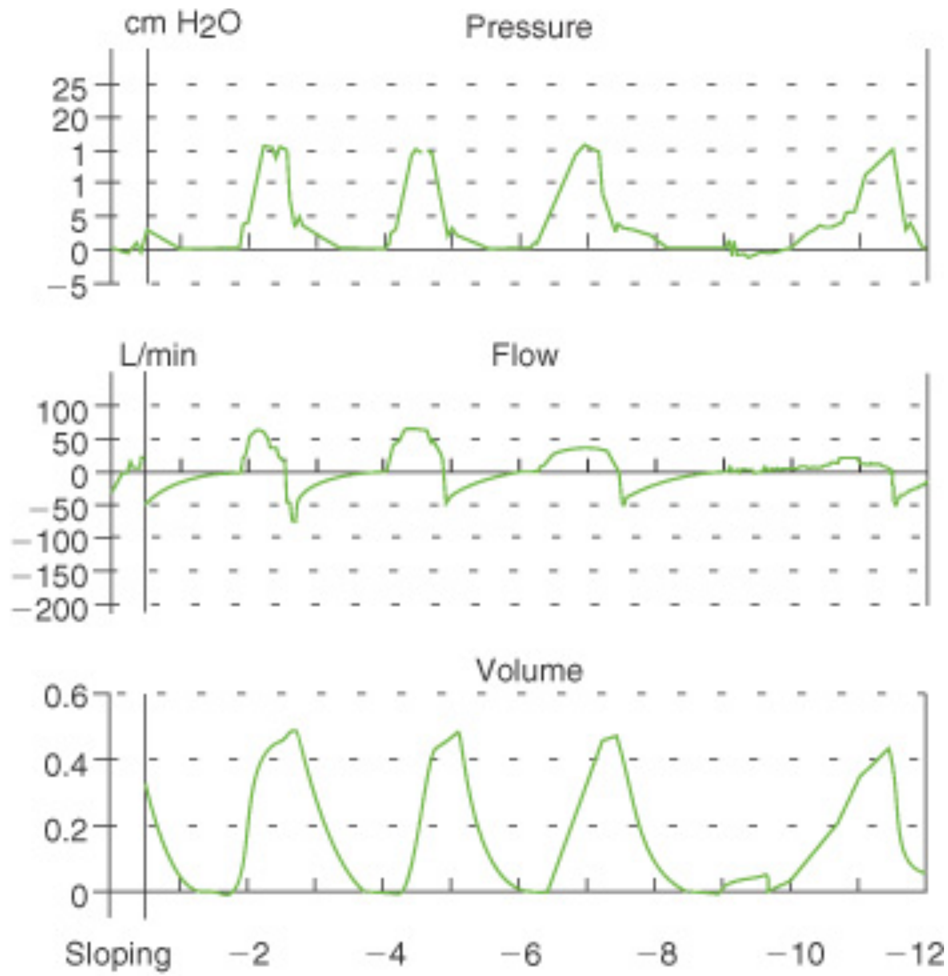

Fig. 10-17 Changes in the gas delivery system produced by adjusting the pressure slope, or rise time function, during pressure-targeted ventilation. (See text for additional information.)

(Redrawn from Nilsestuen JO, Hargett K: *Respir Care* 41:1105, 1996.)

Clinical Rounds 10-2 p. 191

A patient with ARDS is on PCV with the following settings PEEP=10; FiO2=.8; IP=18; PIP=28; Vt=350 (down from 450ml) slope set at the slowest possible flow delivery. ABG's on these settings are 7.28/49/53 (↓O2 ↑CO2 from previous). The RT notices that PIP reaches only 23cmH2O. No leaks are found in the system. What recommendations might be made to improve this patient's ABG's?

Initially it was considered to increase IP to improve ventilation and the FiO2 to improve oxygenation; but better ventilation is actually accomplished by adjusting the slope to achieve a faster pressure delivery and increase the Vt, the PIP will return to 28 cmH2O and the patient's ABG values will improve without further adjustments

Evidence in the waveform with a tapered inspiratory pressure waveform

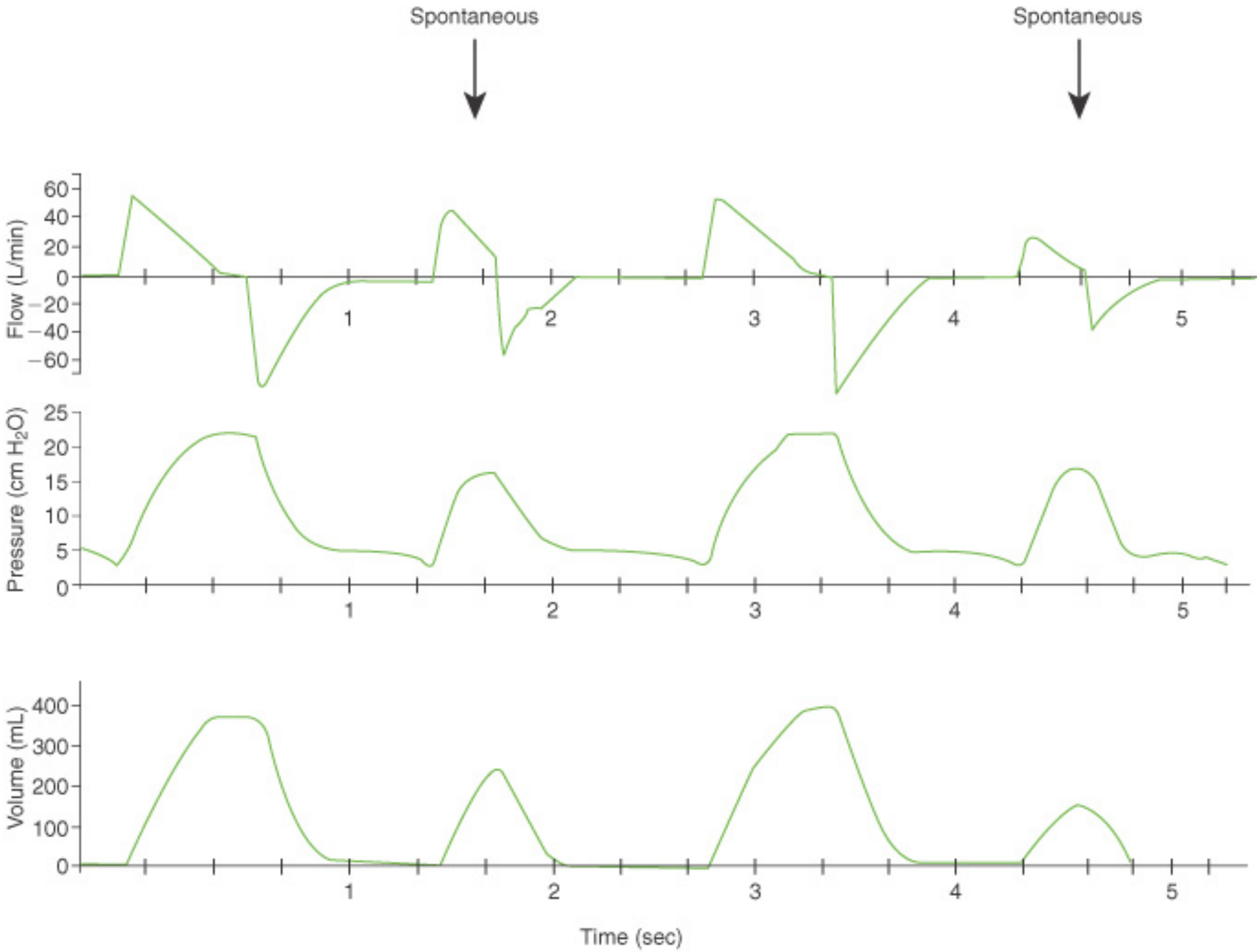

Fig. 10-18 Pressure, flow, and volume scalars for PC-SIMV plus pressure support and CPAP. Arrows indicate spontaneous breaths. (See text for further information.)

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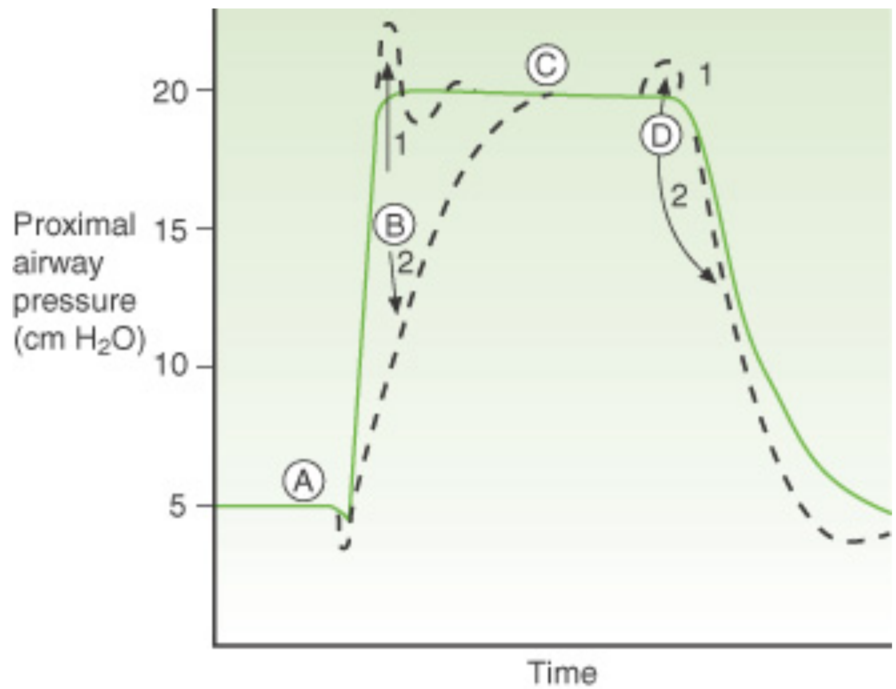

Fig. 10-19 Characteristics of the pressure-time waveform during PSV. (See text for explanation.)

(Modified from MacIntyre N, Nishimura M, Usada Y, et al: *Chest* 97:1463, 1990.)

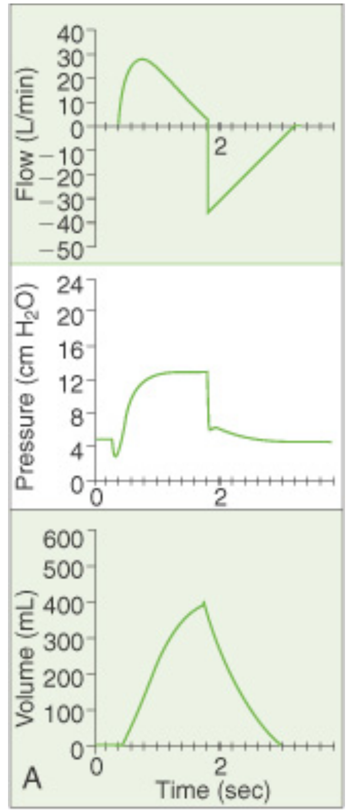

Fig. 10-20A Effect of changes in termination flow during PSV. **A,** A low percentage flow cycle is set so that T_I is longer. **B,** A higher percentage flow cycle is set so that T_I is shorter. (See text for additional explanation.)

(From Hess DR, MacIntyre NR, Mishoe SC, et al: *Respiratory care principles and practice,* Philadelphia, 2002, WB Saunders.)

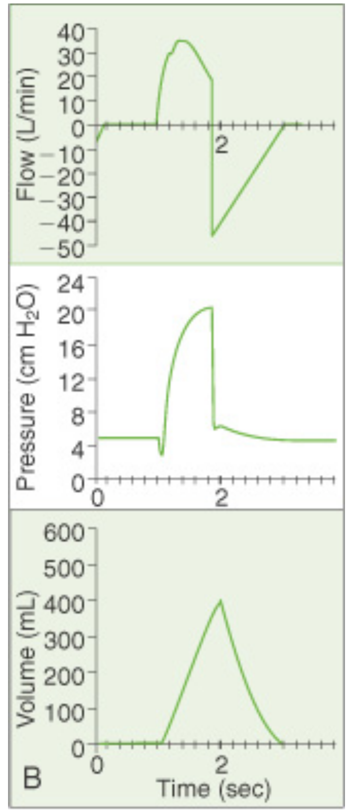

Fig. 10-20B Effect of changes in termination flow during PSV. **A,** A low percentage flow cycle is set so that T_I is longer. **B,** A higher percentage flow cycle is set so that T_I is shorter. (See text for additional explanation.)

(From Hess DR, MacIntyre NR, Mishoe SC, et al: *Respiratory care principles and practice,* Philadelphia, 2002, WB Saunders.)

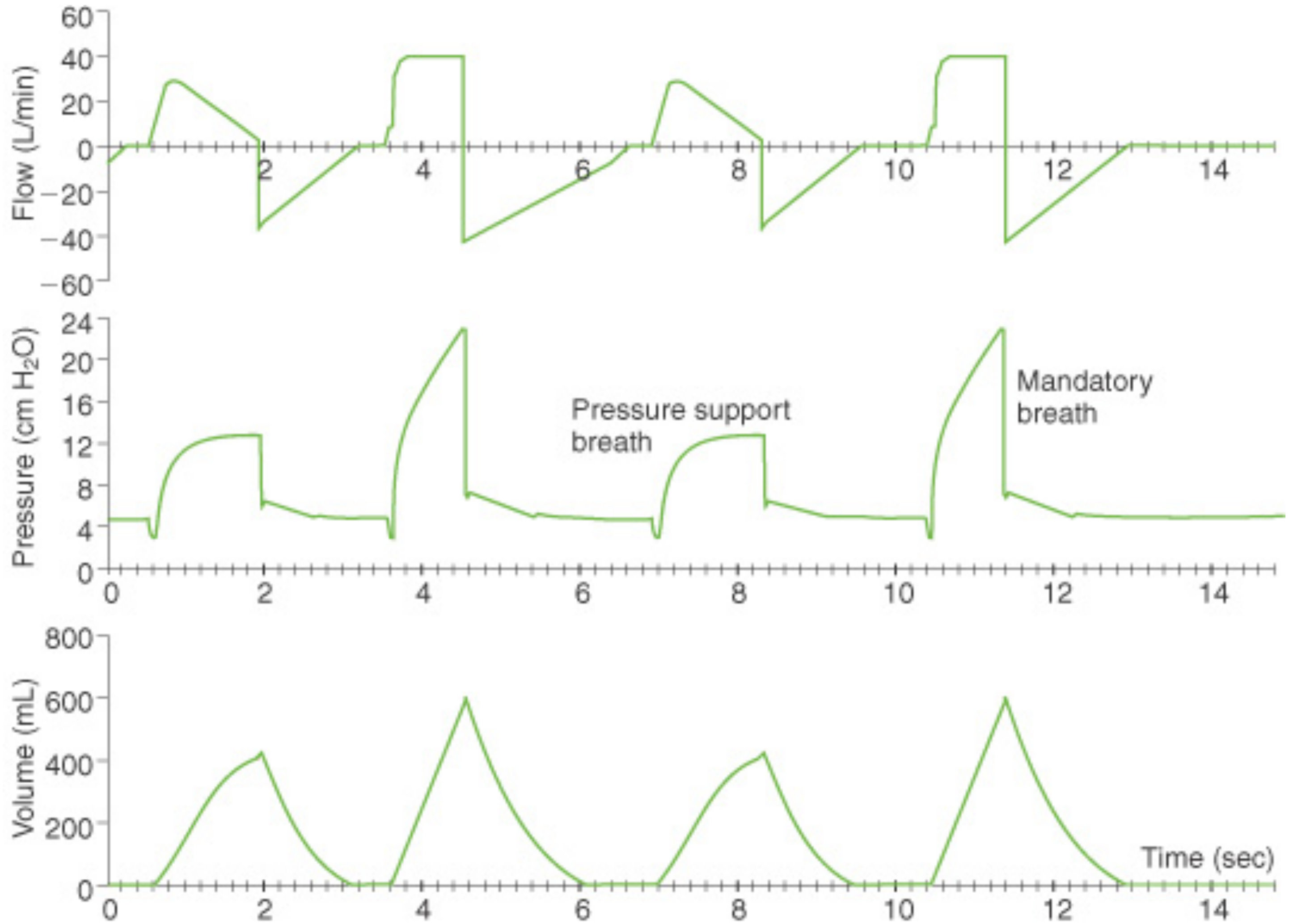

Fig. 10-21 Waveforms for flow *(top),* pressure *(middle),* and volume *(bottom)* during VC-SIMV with PSV and CPAP.

(From Hess DR, MacIntyre NR, Mishoe SC, et al: *Respiratory care principles and practice,* Philadelphia, 2002, WB Saunders.)

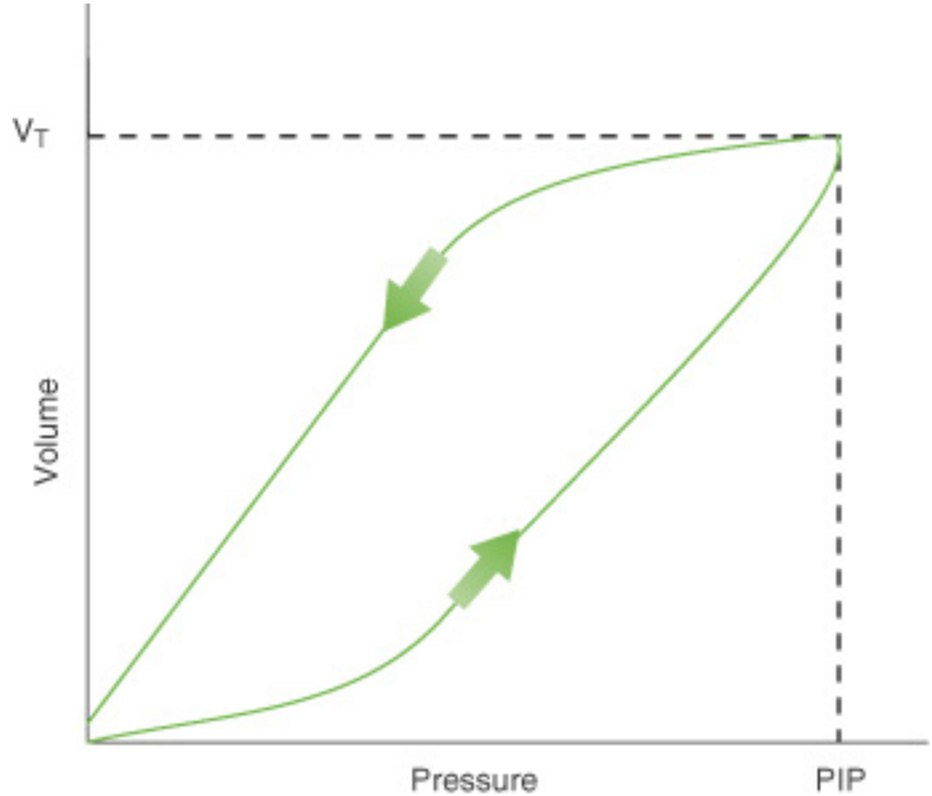

Fig. 10-22 Typical pressure-volume curve for a positive pressure breath. The loop represents the pressure and volume measured at the upper airway (P_{awo}). The highest point for tidal volume (V_T [vertical axis]) and peak inspiratory pressure (PIP [horizontal axis]) represents the dynamic compliance for that pressure-volume relationship.

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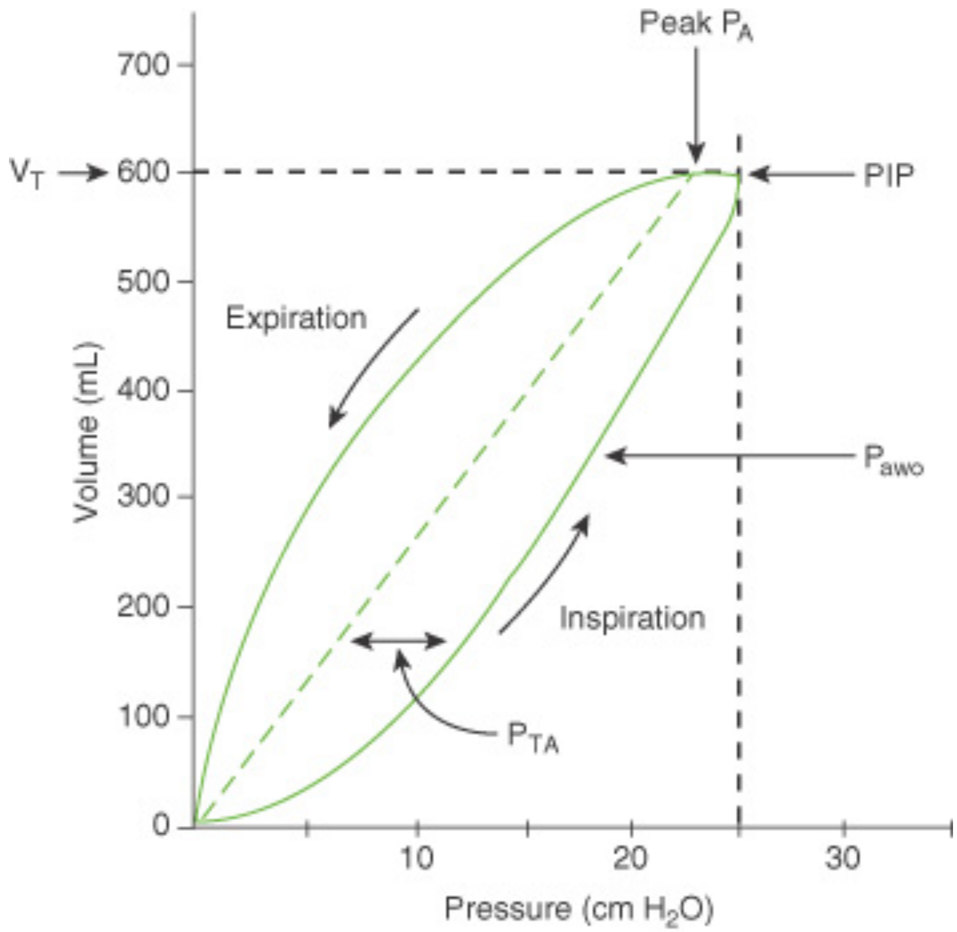

Fig. 10-23 P-V loop showing the peak inspiratory pressure (PIP), pressure at the airway opening (P_{awo}), alveolar pressure (P_{A},), and transairway pressure (P_{TA}). (See text for additional information.)

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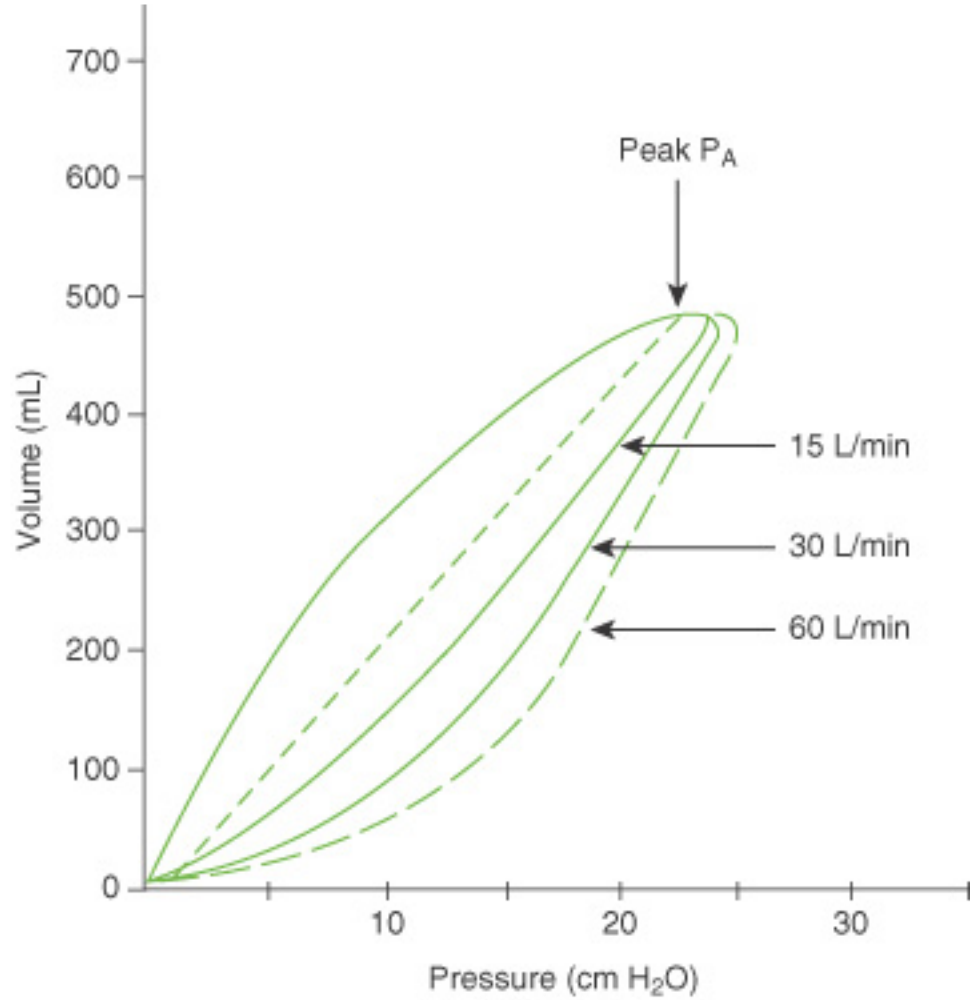

Fig. 10-24 P-V loops with the flow set at 60, 30, and 15 L/min. As flow decreases, less pressure is required to overcome Raw. P_{TA} is reduced, which is reflected in movement of the loop to the left and toward the static P-V line. P_A, Alveolar pressure.

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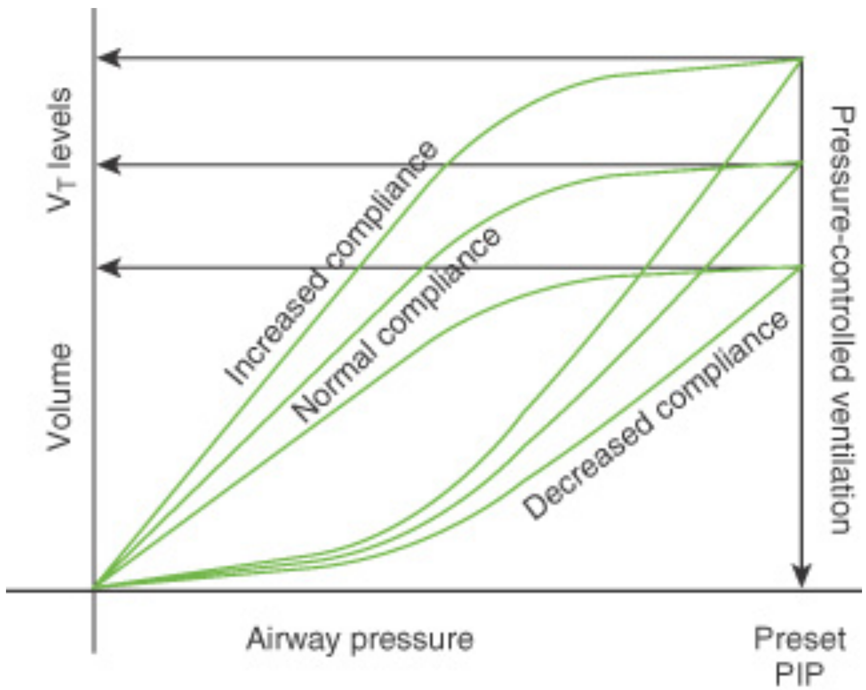

Fig. 10-25 P-V loops during pressure ventilation. As compliance changes, volume delivery changes, but pressure delivery remains constant.

(From Dhand R: *Respir Care* 50:246, 2005.)

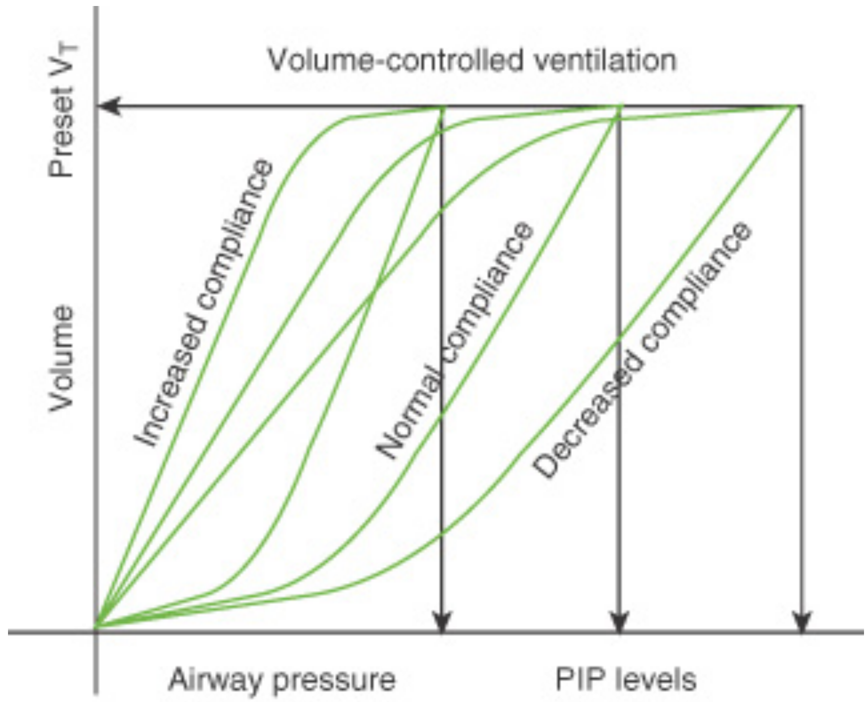

Fig. 10-27 Changes in the P-V loop during volume-targeted ventilation as lung compliances changes. Volume delivery remains constant, but PIP changes.

(From Dhand R: *Respir Care* 50:246, 2005.)

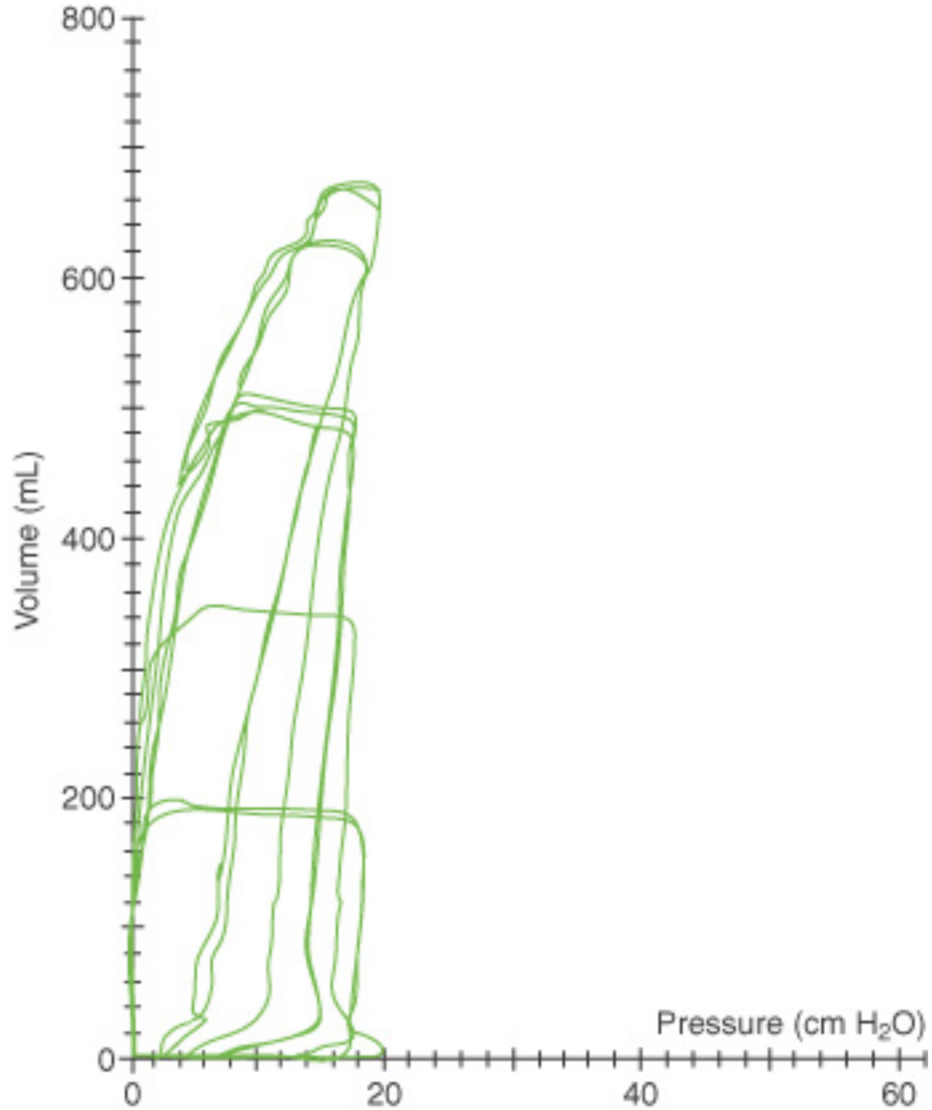

Fig. 10-28 P-V loops during pressure ventilation demonstrating changes in airway resistance. As resistance increases, less volume is delivered, and the loop shortens and widens.

(From Lucangelo U, Bernabé F, Blanch L: *Respir Care* 50:55, 2005.)

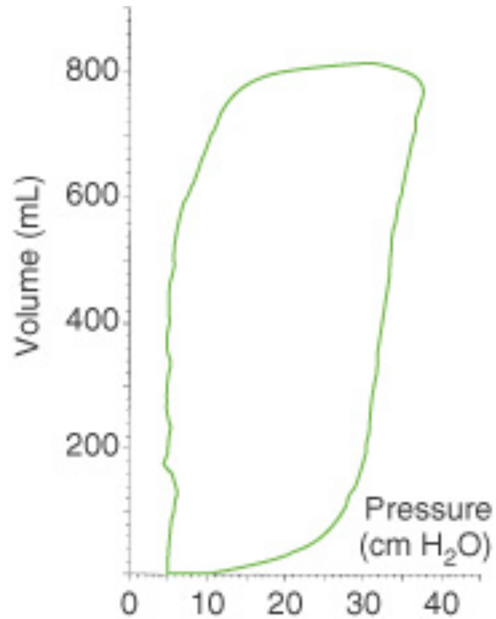

Fig. 10-29 Airway P-V loop recorded in a patient with COPD during controlled ventilation. Note the increased nonelastic inspiratory and expiratory work (widening of the loop) and the shift of the dynamic compliance curve (P-V loop) upward and to the left.

(From Kacmarek RM, Hess D, Stoller JK: *Monitoring in respiratory care, St Louis,* 1993, Mosby.)

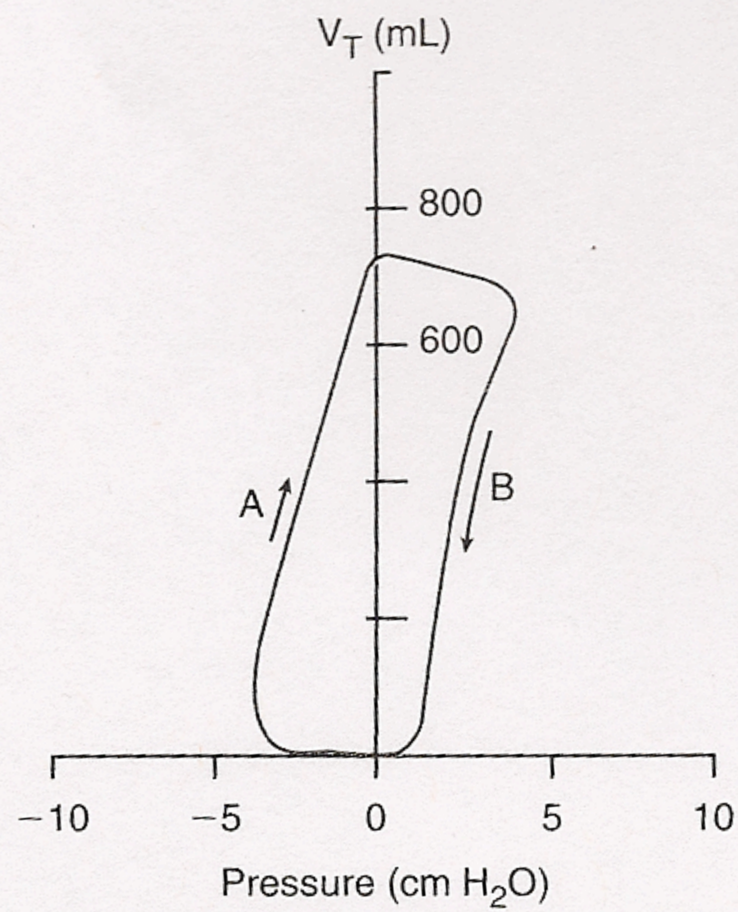

Fig. 10-30 P-V loop for a spontaneous, unsupported breath (see text). No CPAP or PSV is delivered. Arrow *A* indicates inspiration, and arrow *B* indicates expiration. (Modified from Puritan Bennett: *Waveforms: the graphical presentation of ventilator data,* Form AA-1594 [2/91], Pleasanton, Calif, 1991, Puritan Bennett Tyco.)

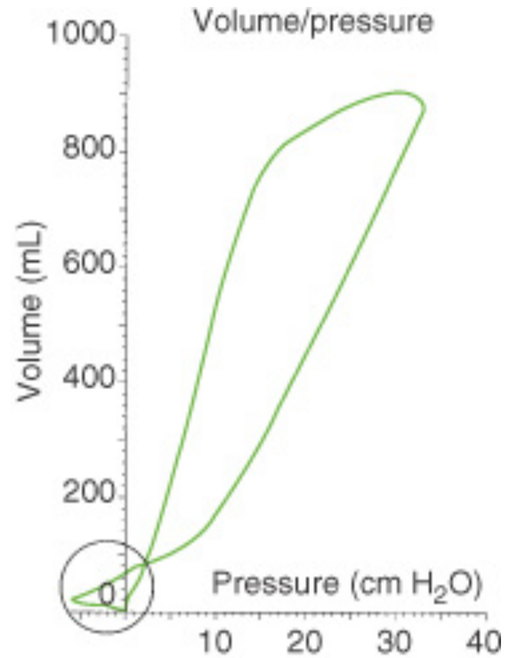

Fig. 10-31 Airway P-V loop from a patient-triggered breath during volume ventilation. Note the large area in the circle, which indicates patient effort to trigger the ventilator to inspiration. The machine is not sensitive enough to the patient's effort.

(From Kacmarek RM, Hess D, Stoller JK: *Monitoring in respiratory care,* St Louis, 1993, Mosby.)

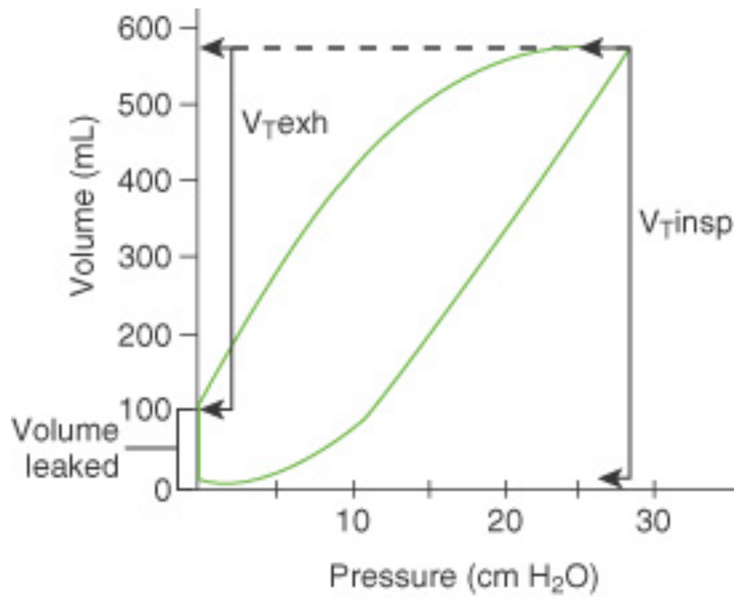

Fig. 10-33 P-V loop with an abnormal finding. (See text for explanation.) *$V_T$insp*, Inspired tidal volume; *$V_T$exh*, exhaled tidal volume.

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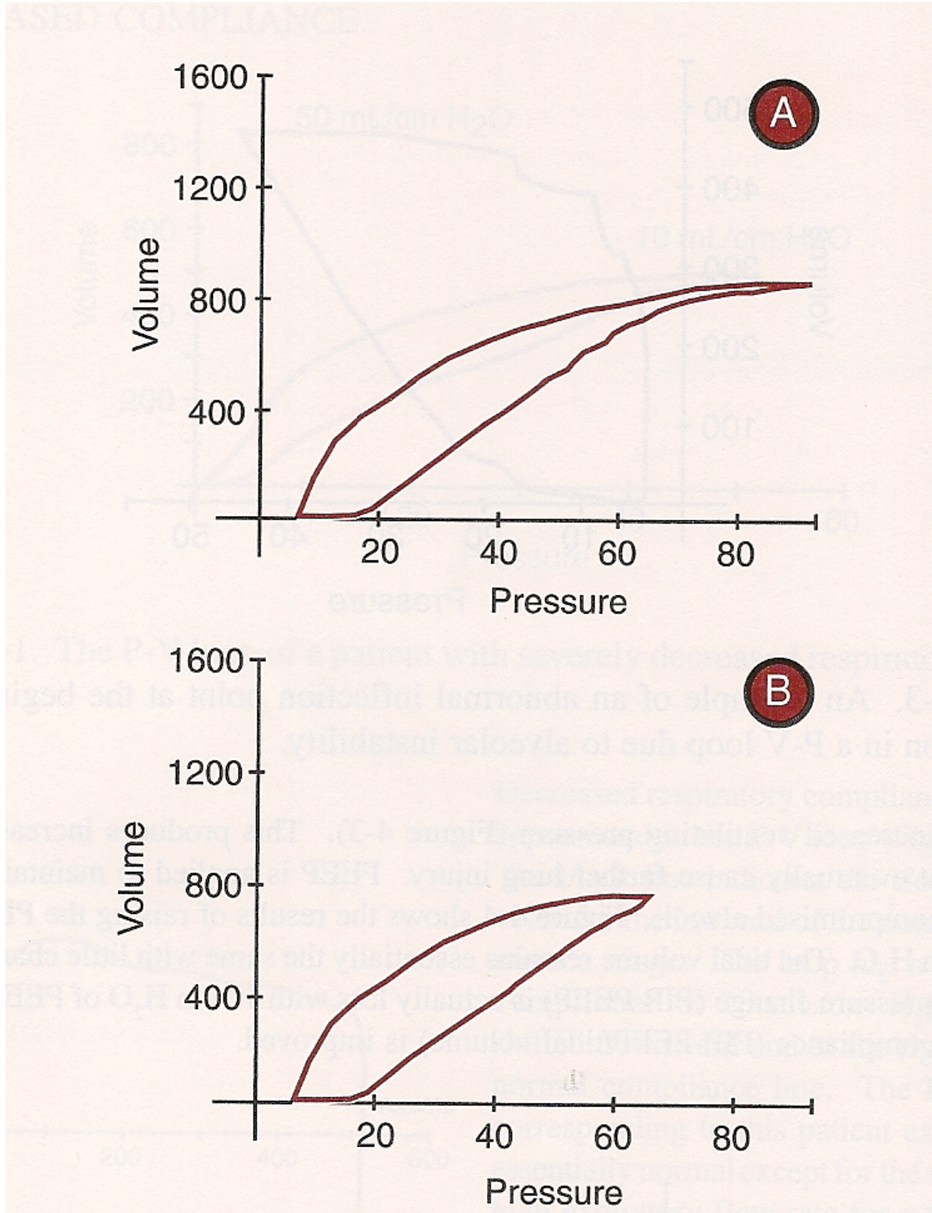

Figure 4-5 Identification and correction of overdistention as seen in P-V loops
Rapid Interpretation of Ventilator Waveforms by Waugh, Deshpande, Harwood

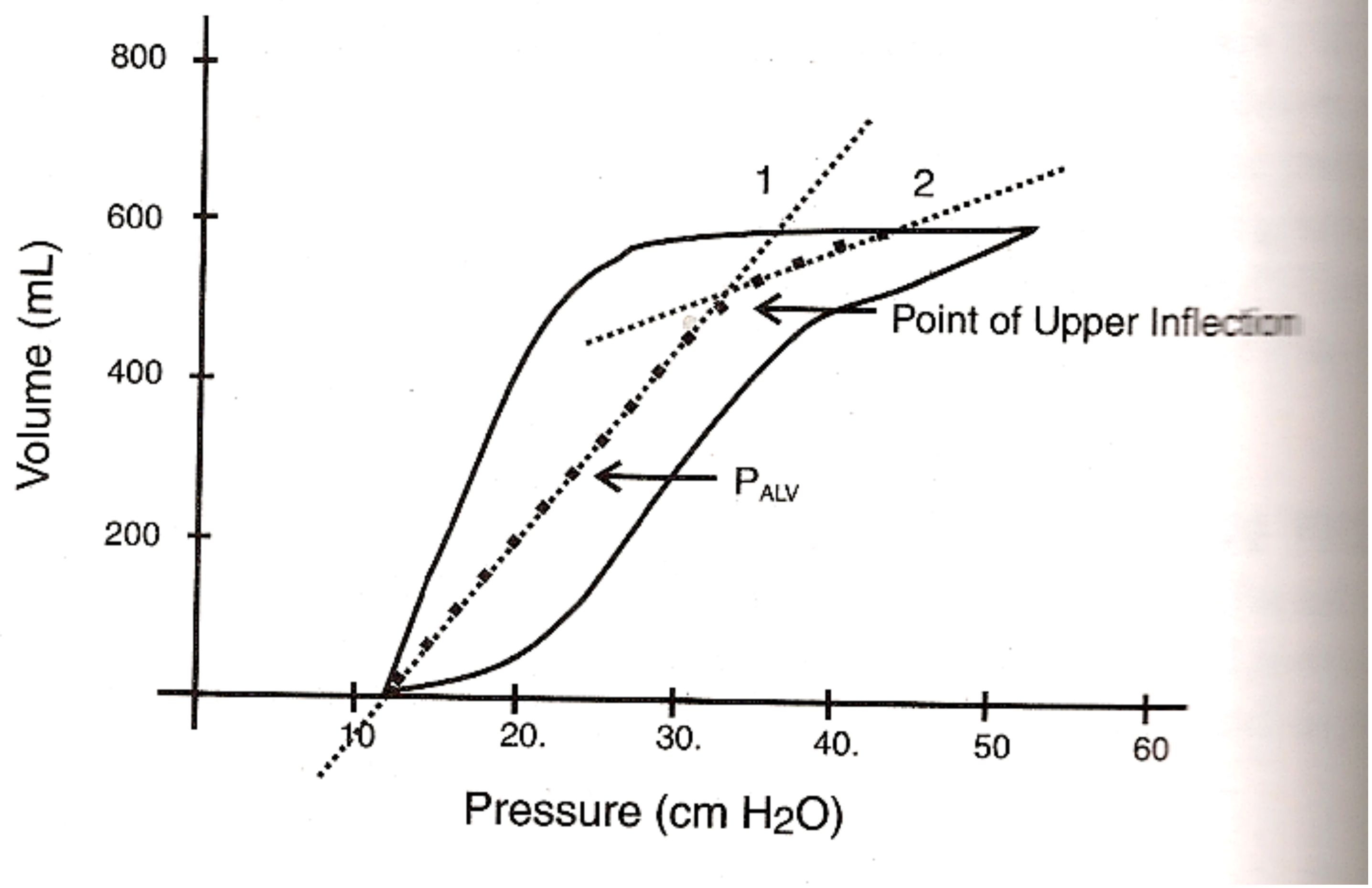

Figure 11-42 Alveolar pressure plotted (manually) at various volumes to Determine the point of alveolar overdistention (upper inflection point) Clinical Application of Mechanical Ventilation by Chang © Delamar 2001

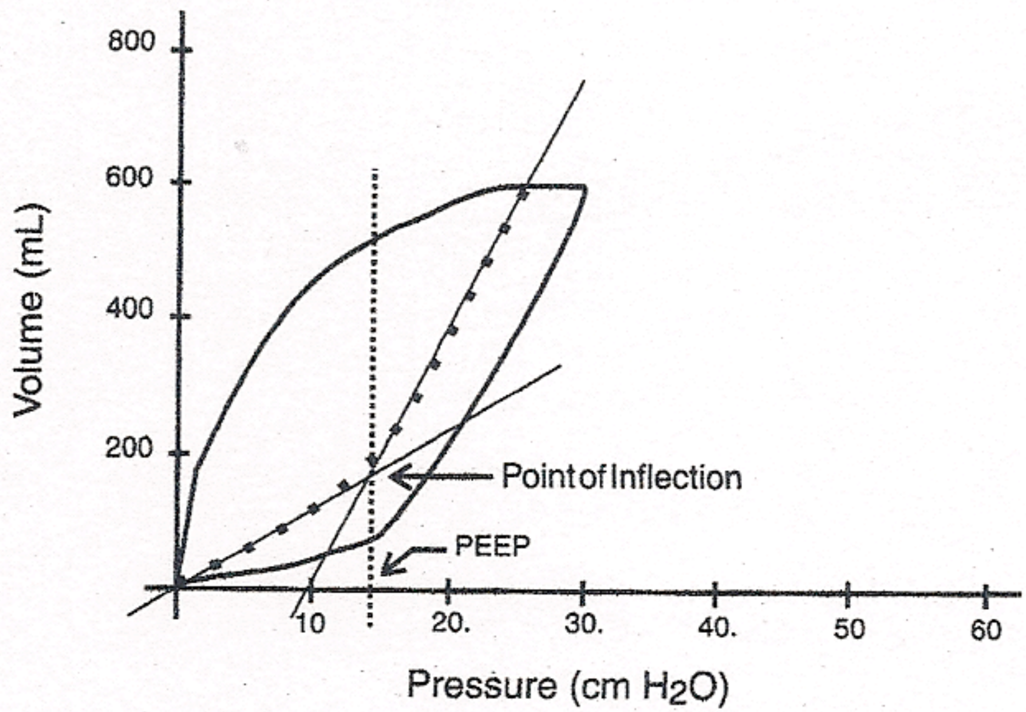

Figure 11-41 Alveolar pressure plotted (manually) at various volumes to determine the initial inflection point on a PVC created by alveolar recruitment.

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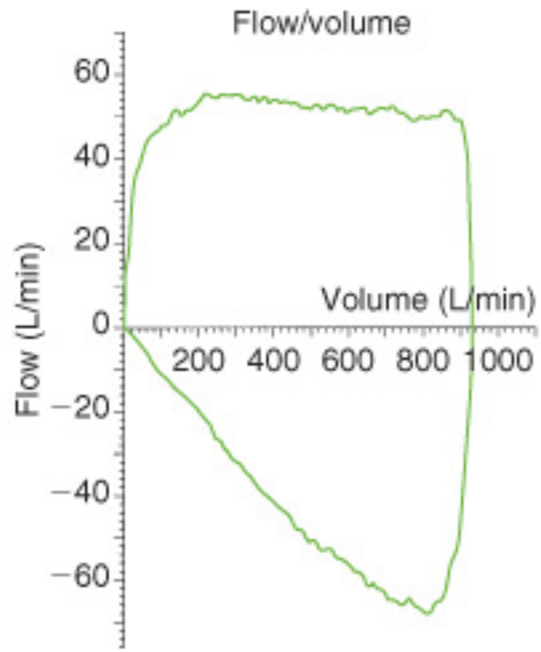

Fig. 10-34 Normal F-V loop during volume ventilation. The inspiratory curve is on the top, and the expiratory curve is on the bottom. Note the linear change in expiratory flow from peak to end-expiration. Also, the end-expiratory flow is zero.

(From Kacmarek RM, Hess D, Stoller JK: *Monitoring in respiratory care,* St Louis, 1993, Mosby.)

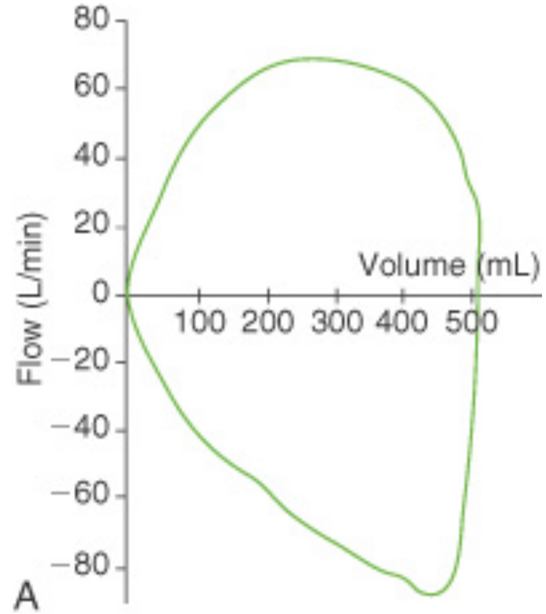

Fig. 10-35A A, F-V loop with a sinelike flow waveform during inspiration with volume ventilation. **B,** F-V loops during volume ventilation at three flow settings. (See text for additional information.)

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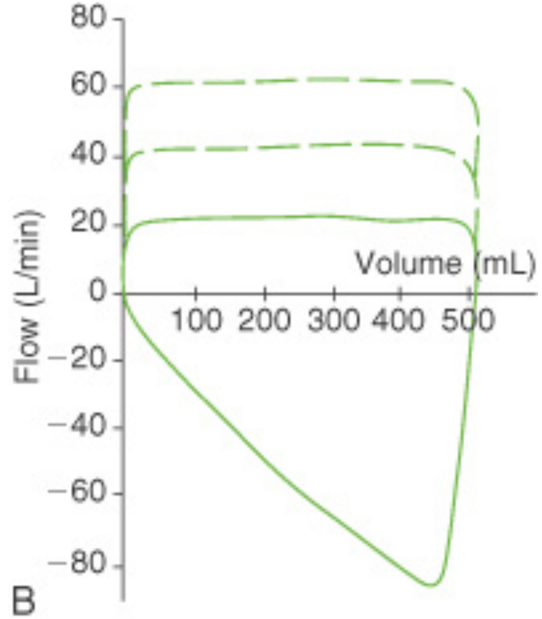

Fig. 10-35B A, F-V loop with a sinelike flow waveform during inspiration with volume ventilation. **B,** F-V loops during volume ventilation at three flow settings. (See text for additional information.)

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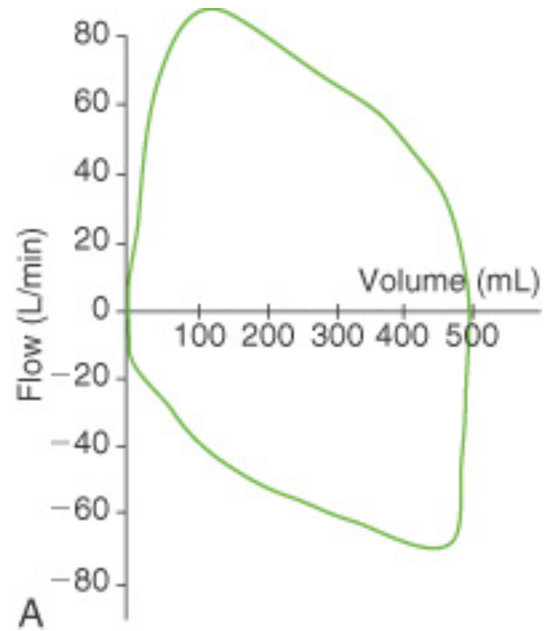

Fig. 10-36A A, F-V loop during PCV. **B,** F-V loops during PCV with different pressure settings. As pressure increases, flow and volume delivery increase. Compliance and Raw are constant in this example.

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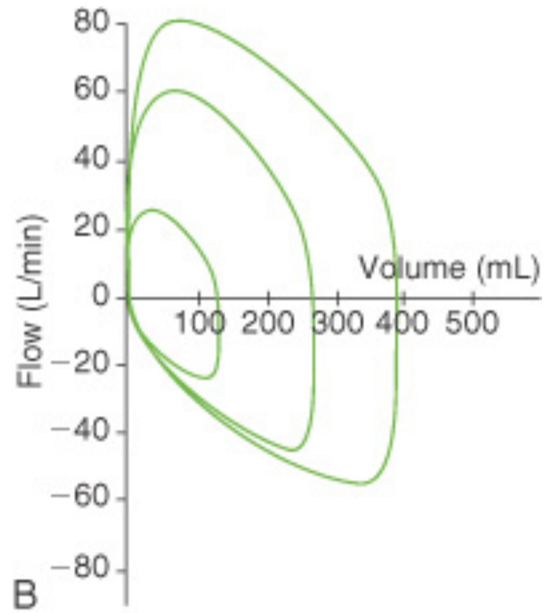

Fig. 10-36B A, F-V loop during PCV. **B,** F-V loops during PCV with different pressure settings. As pressure increases, flow and volume delivery increase. Compliance and Raw are constant in this example.

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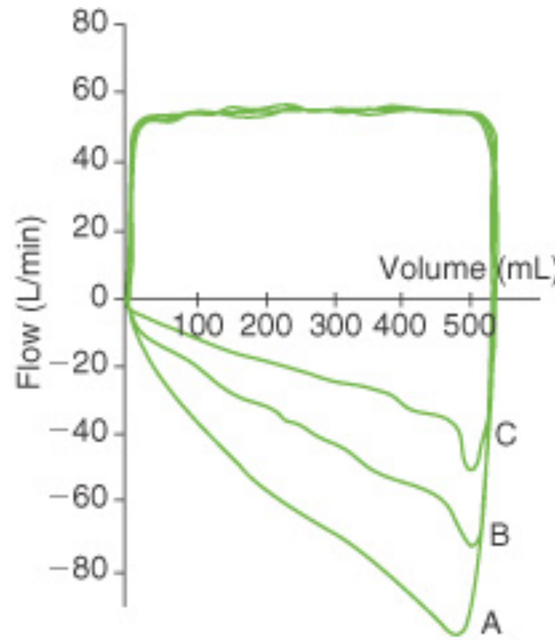

Fig. 10-37 F-V loops showing volume-targeted breaths with a constant flow but changing airway resistance (compliance constant). Loop *A* shows a normal Raw. Loops *B* and *C* represent progressively increasing Raw. Note the drop in expiratory flow and PEFR as resistance increases.

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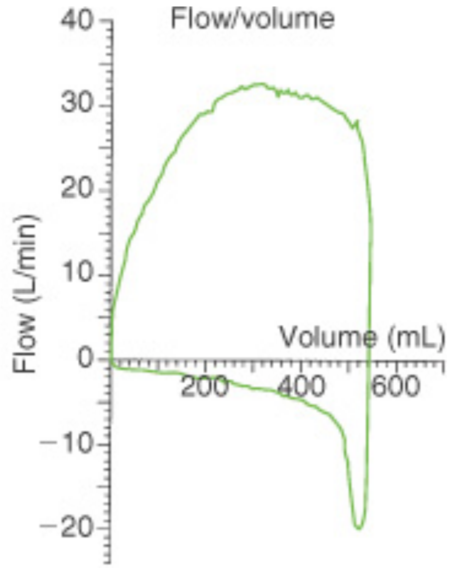

Fig. 10-38 F-V loop during volume ventilation in a patient with COPD. Note the diminished peak expiratory flow and the scooped-out (concave) shape of the expiratory F-V curve. (NOTE: The flow scale is 0 to 30 L/min during inspiration and 0 to –20 L/min during exhalation.) The clinician must make sure to check the scale when reading graphs. Inspiration *(top)* and expiration *(bottom)*.

(From Kacmarek RM, Hess D, Stoller JK: *Monitoring in respiratory care,* St Louis, 1993, Mosby.)

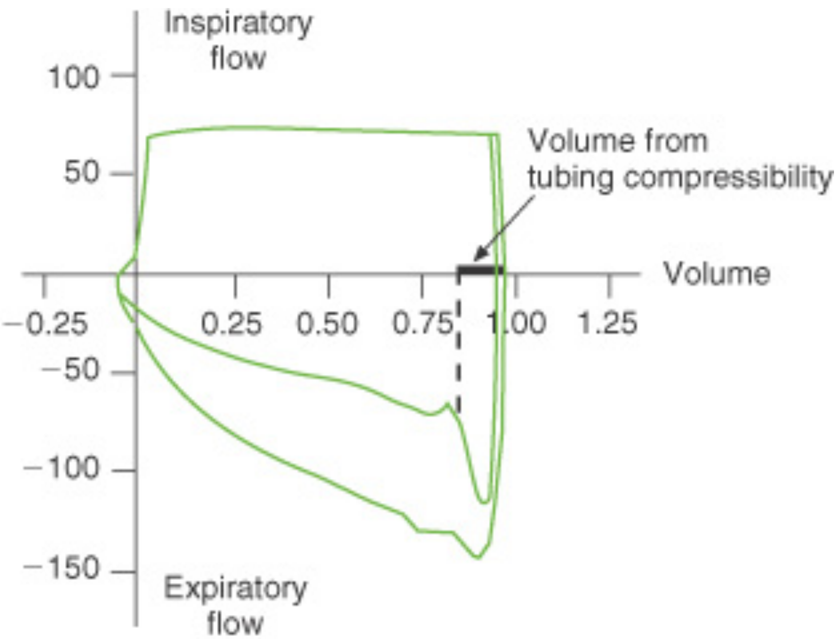

Fig. 10-39 Two F-V loops produced during volume ventilation (constant flow waveform). The inner loop indicates increased airway resistance. The outer loop represents the patient's response to bronchodilator therapy. Note the improvement in expiratory flow. (NOTE: The high expiratory flow spike in the lower right corner of the inner loop results from gas decompression of the patient circuit. The initial expiratory flow spike is an artifact and represents release of the volume of gas trapped in the patient circuit at the beginning of the breath.)

(Redrawn from Nilsestuen JO, Hargett K: *Respir Care* 41:1105, 1996.)

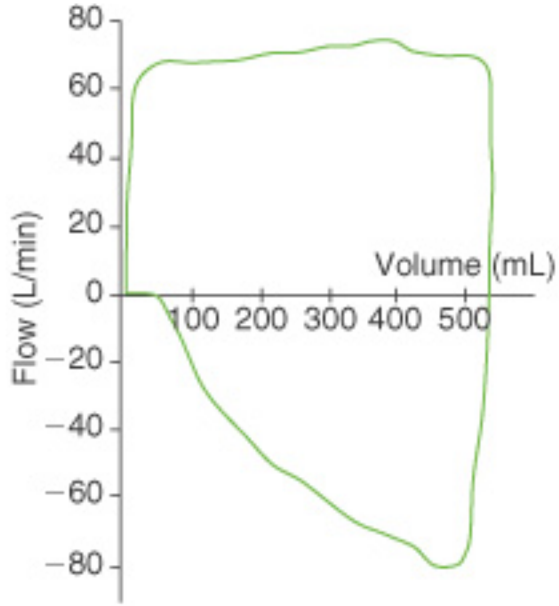

Fig. 10-40 F-V loop indicating a leak. (See text for explanation.)

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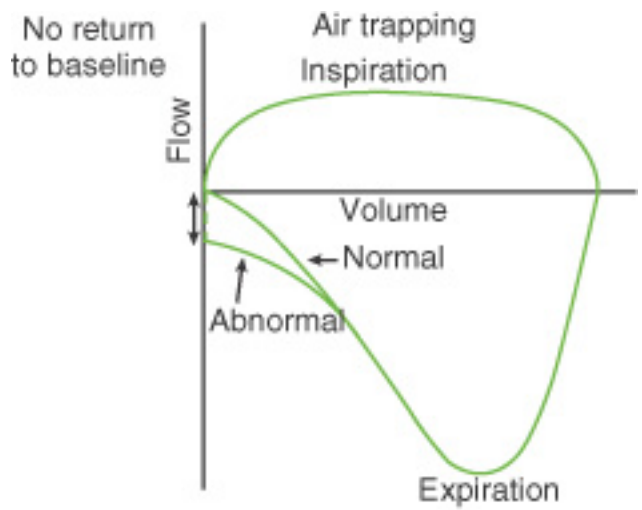

Fig. 10-41 Air trapping (auto-PEEP) identified in a F-V loop in which the expiratory portion of the curve does not return to zero but drops to some value less than zero.

(From Dhand R: *Respir Care* 50:256, 2005.)

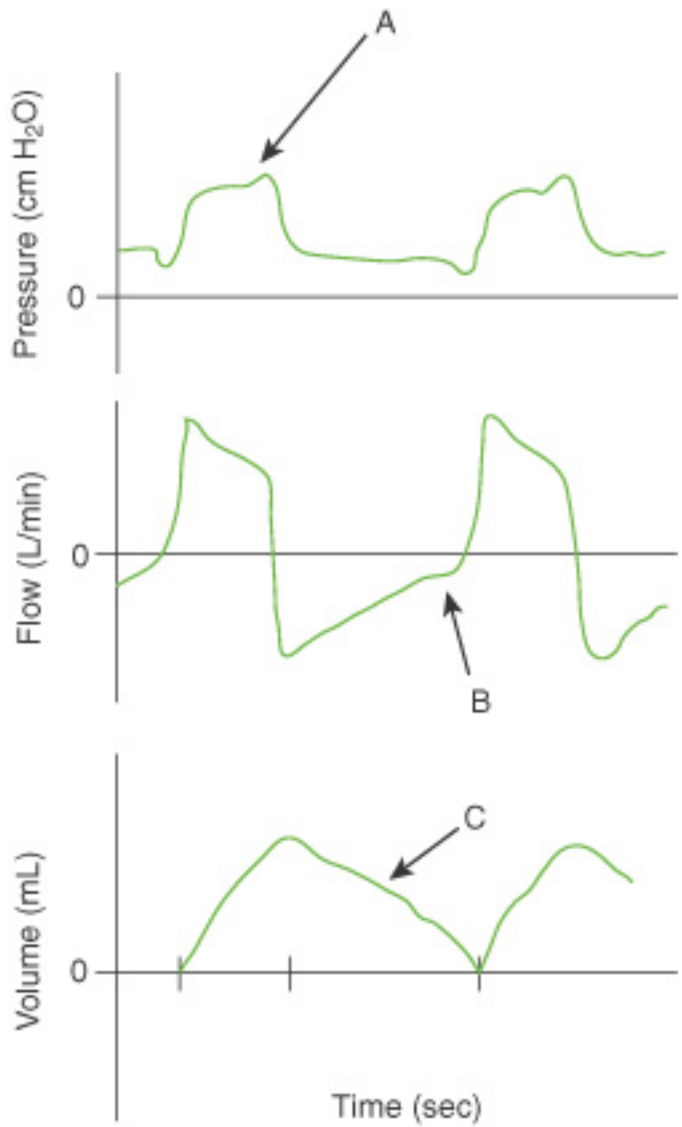

Fig. 10-42 Pressure, flow, and volume scalars for PSV (see Review Question 1).

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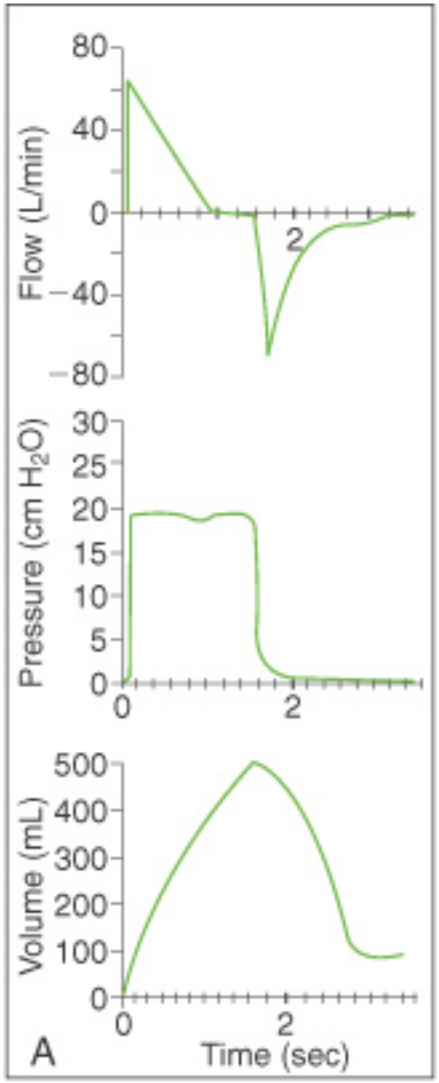

Fig. 10-43A Flow, pressure, and volume scalars for three different ventilation situations (see Review Questions 2 through 4).

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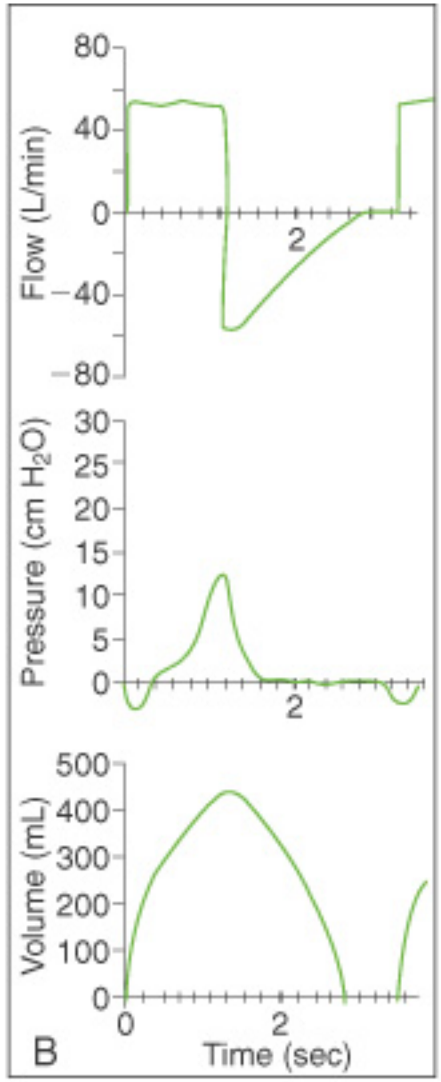

Fig. 10-43B Flow, pressure, and volume scalars for three different ventilation situations (see Review Questions 2 through 4).

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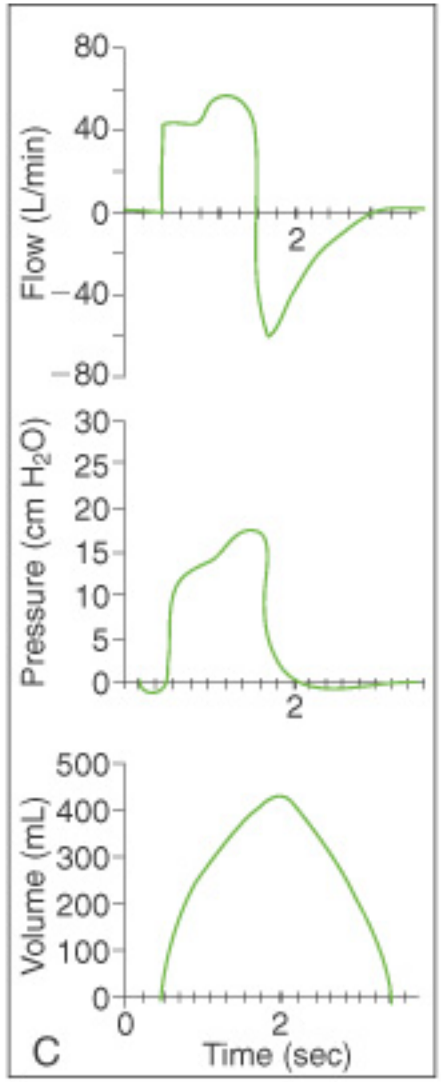

Fig. 10-43C Flow, pressure, and volume scalars for three different ventilation situations (see Review Questions 2 through 4).

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