小兒呼吸器使用的基本原則

台中榮民總醫院 兒童加護中心
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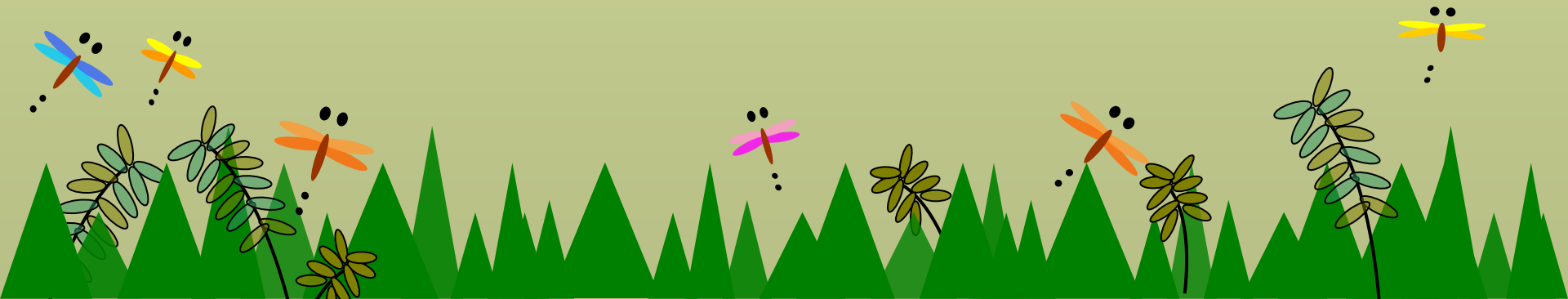


機械呼吸的基本術語

- 陽壓及負壓呼吸
  - 呼吸器可以經由二種方式將氣體輸送到病人肺中，一種是直接作用在氣道的壓力將氣體擠入肺中，另一種是經由胸廓的負壓而改變壓力動力學，以致氣體由相對性陽壓的大氣壓流向相對性負壓的肺中，目前臨床上應用較廣的是陽壓呼吸。

機械呼吸的基本術語

- 呼吸方式（modes）
  - ***Assisted mode***：病人自行決定到底需要多少次呼吸，呼吸器感應到病人的呼吸力量，而將預設的容積或壓力輸送出去，幫病人輕鬆而有效的完成呼吸。
  - ***Control mode***：機器每分鐘給予一定次數的呼吸，但在這些固定的呼吸之間，病人無法自行呼吸，因此並非理想的呼吸方式。目前大多數呼吸器將之合併爲所謂A/C mode。

機械呼吸的基本術語

- ***IMV mode*：機器每分鐘給予一定次數的呼吸，但在這些固定的呼吸之間，病人可以自行呼吸，所以是理想的呼吸方式之一。**
- ***SIMV mode*：和IMV相同，但可和病人的自發性呼吸同步化而不相拮抗。**

機械呼吸的基本術語

- ***CPAP mode*：病人經由呼吸器自行呼吸，呼吸器僅提供氣體的來源及加濕，但在呼氣終了時，機械裝置會使氣道壓力高於大氣壓（PEEP）。**
- ***I/E ratio*：是指呼氣時間和吐氣時間的比值。在正常情形下，I/E比值約爲1：2，臨床上常用到所謂I/E比值倒轉，是指I/E比值大於1：1的特殊情形。**

機械呼吸的基本術語

- ***敏感度(sensitivity)***：是指呼吸器能感應到病人呼吸需求的靈敏度。一般是指病人必須產生多少的負壓，呼吸器才能感應到。現在新式的呼吸器如Servo-300及Servo-i均有所謂的flow sensor，藉由背景氣流的些微改變來偵測病人的呼吸動作，這在小兒科的應用是比傳統的負壓感應式實用。

機械呼吸的基本術語

- ***呼氣末端陽壓(end-expiratory exhalation pressure, PEEP)：***PEEP是一種機械上的技術，以防止呼吸終了時，氣道壓力降至大氣壓相同的程度，以防止肺泡塌陷。

需求式及連續式氣流
（demand flow V.S. continuous flow）

- 大多數的嬰兒呼吸器使用連續性氣流系統，病人可以在任何時間內吸到氣體，如本院目前採用之VIPbird，Newport系統。而所謂需求式氣流，是指機械必須感應到病人的吸氣需求時才供應氣流，如果無法感應到，則病人吸不到氣體，如本院目前採用之Servo系列。

Mechanical ventilator classification

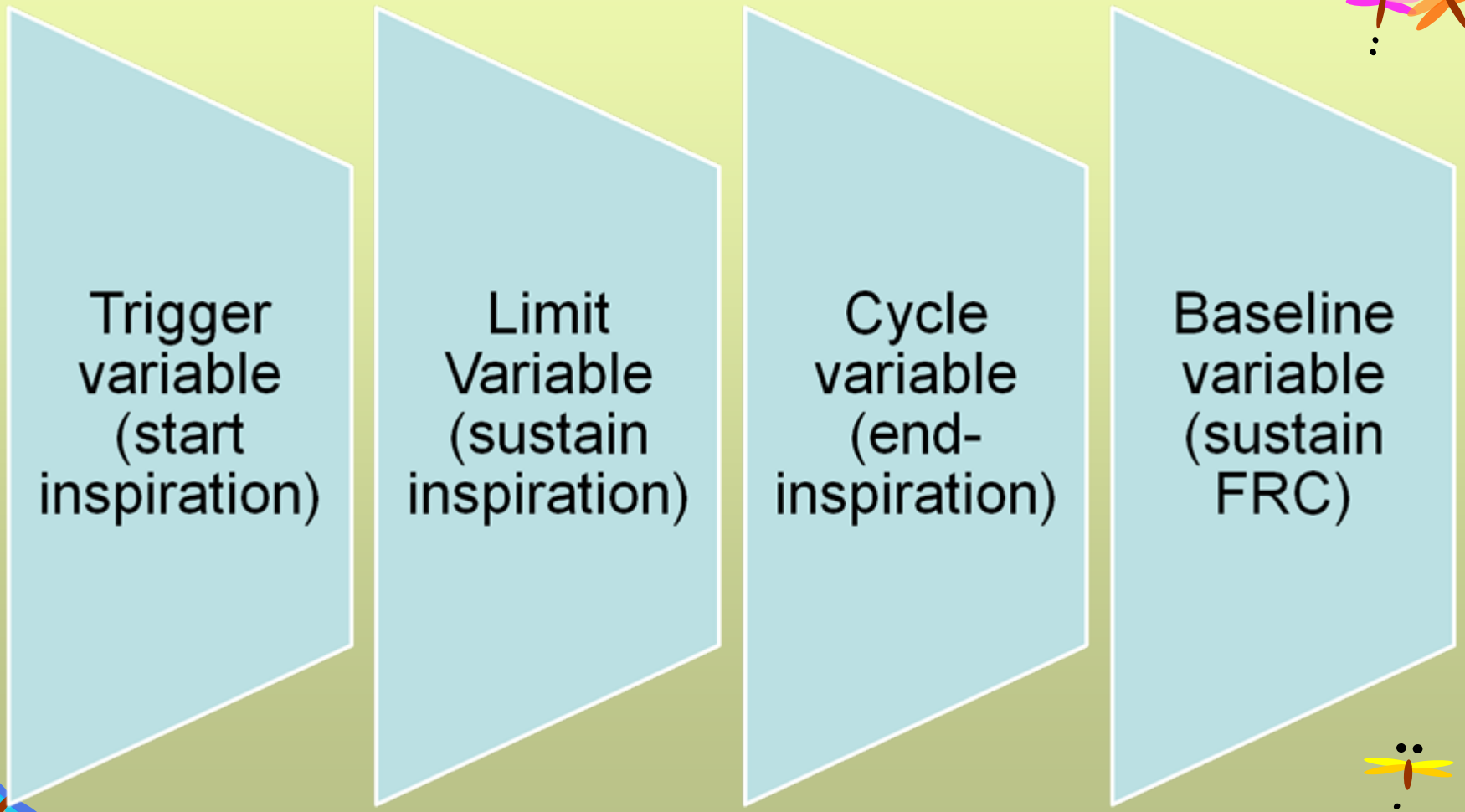
- Control
- Cycling
- Triggering
- Breaths
- Flow Pattern
- Mode or Breath Pattern

Control

- 指呼吸器如何知道送多少氣流進入：
  - Volume controlled (volume limited, volume targeted) and pressure variable
  - Pressure controlled (pressure limited, pressure targeted) and volume variable
  - Dual controlled (volume targeted (guaranteed) pressure limited)

Control

- Trigger – time, pressure, volume, flow
- Limit – time, pressure, volume, flow
- Cycle – time, pressure, volume, flow
- Baseline – pressure


Trigger variable (start inspiration)
Limit Variable (sustain inspiration)
Cycle variable (end-inspiration)
Baseline variable (sustain FRC)

Cycline

- 呼吸器何時由吸氣變吐氣
  - Time cycled: PC
  - Flow cycled: PS
  - Volume cycled: VC

Triggering

- Time
- Pressure
- Flow

Breaths are either...

- Mandatory (controlled): CMV rate
- Assisted (e.g.: A/C, SIMV, PS)
- Spontaneous (CPAP)

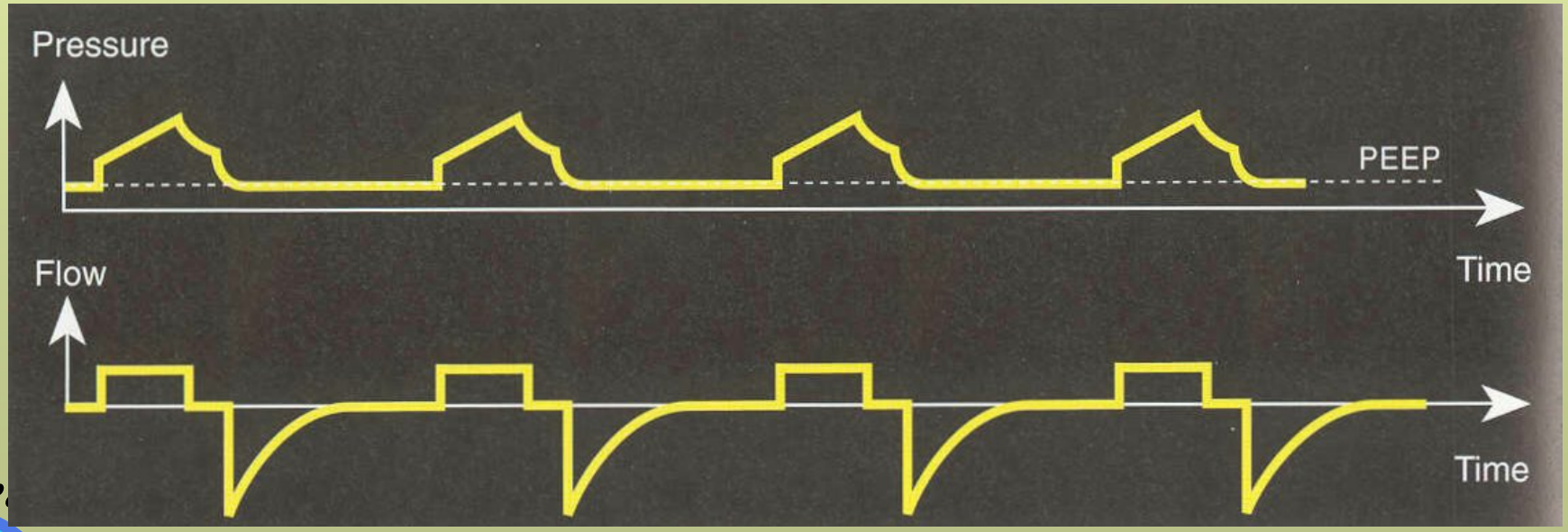
常用呼吸器mode的基本介紹:
Control modes

Volume Control Mode

目的：提供預設的通氣量，以預設的呼吸速率及吸氣時間給予，與病人本身肺的阻力或是compliance無關。

應用：提供肺部正常因其他原因如開刀麻醉的病人使用。

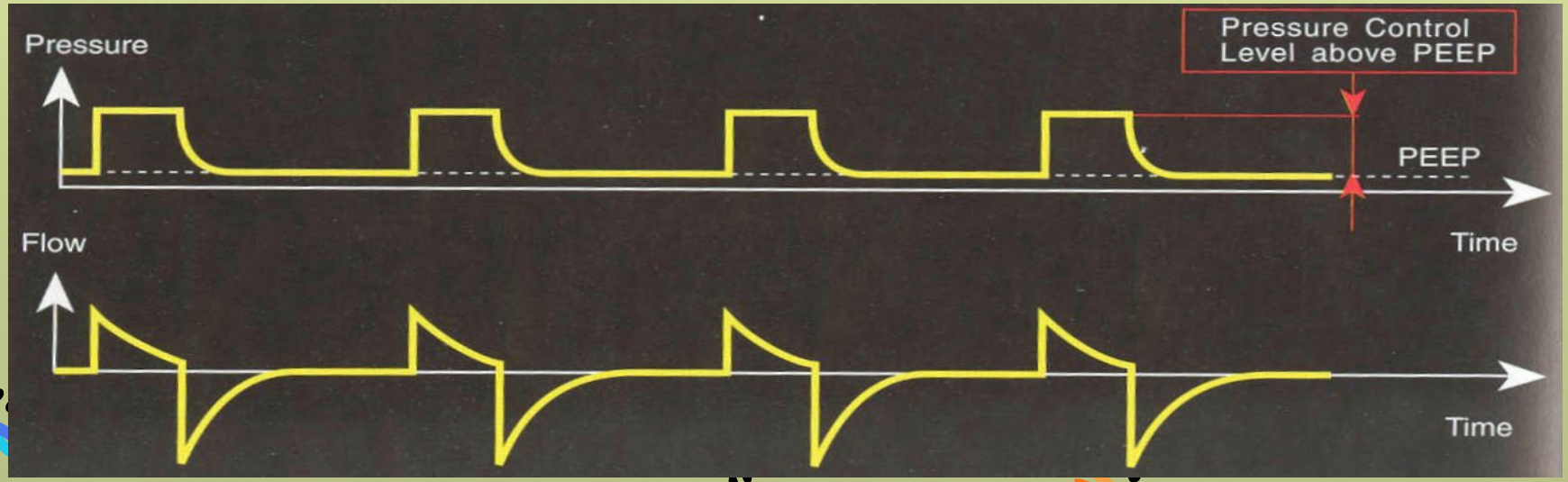
特色：恆定的流速，符合一般生理狀態。



Pressure Control Mode

目的：提供吸氣期恆定的壓力，避免不必要的高氣道壓力，遞減的flow rate，可以控制呼吸速率及I/E ratio。

應用：一般用在無自主呼吸的病人，爲兒童較常用的control mode。應用於使用沒有cuff氣管內管或是氣管內管有漏氣情形的病人。Asthma， lung injury， COPD， bronchospasm的病人。或是某些需要一開始較高flow使肺葉張開的病人，某些需要避免高氣道壓力的病

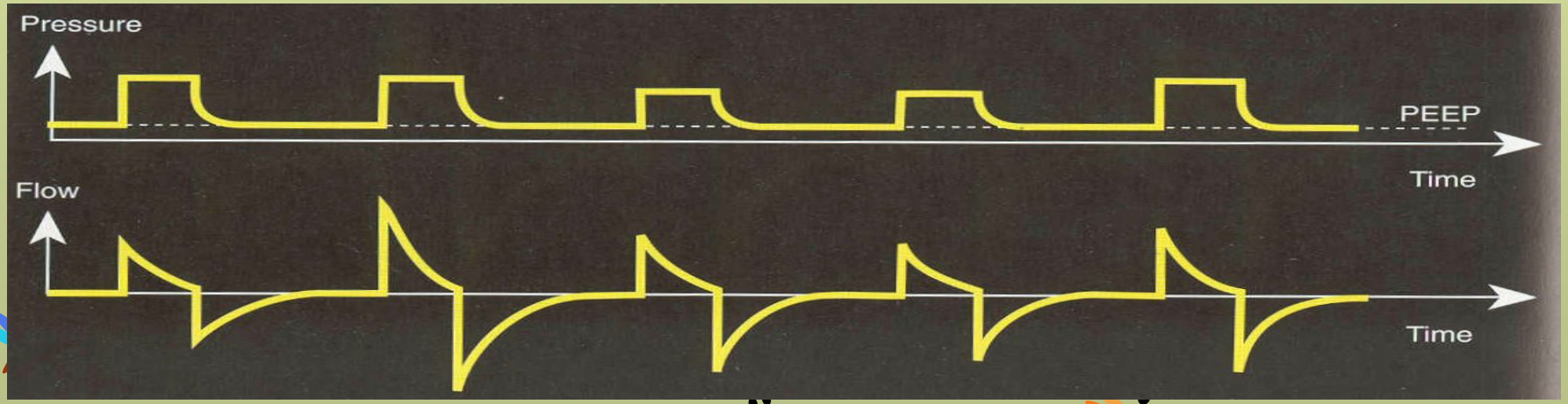


Pressure-regulated volume control (PRVC)

目的：提供預設的通氣量，以預設的呼吸速率及吸氣時間給予，同時提供吸氣期恆定的壓力，遞減的flow rate，可以控制呼吸速率及I/E ratio。並在最低的PIP下提供預設的通氣量。

應用：可以用在lung injury，asthma， COPD，開完刀的病人，兒科病人，需要一開始較高flow使肺葉張開的病人，需要避免高氣道壓力的病人。

特色：呼吸器根據前一次呼吸的通氣量，自動調整PIP，以維持恆定的通氣量。呼吸的型態接近pressure control，但又兼有volume control可控制分鐘通氣量的優點，可說是較理想的呼吸器模式，爲近年來先進呼吸器發展的趨勢。唯應用在兒科病患，若是氣管內管的因爲沒有cuff，而有較顯著的漏氣情形時，會影響通氣量的測量，較不適用。



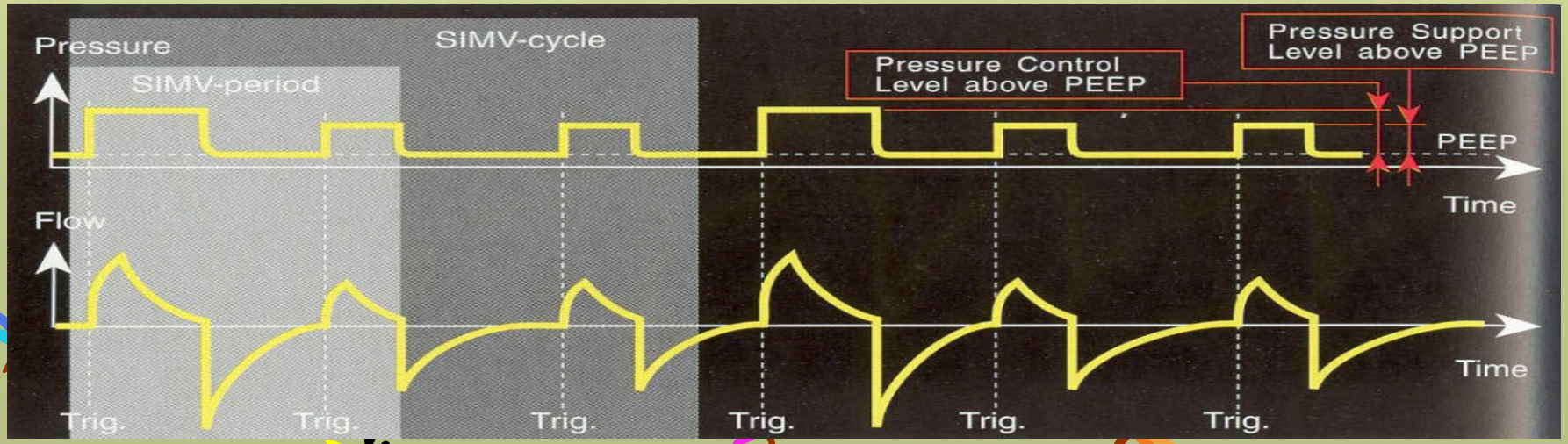
常用呼吸器mode的基本介紹: Weaning modes

SIMV(PC)+pressure support

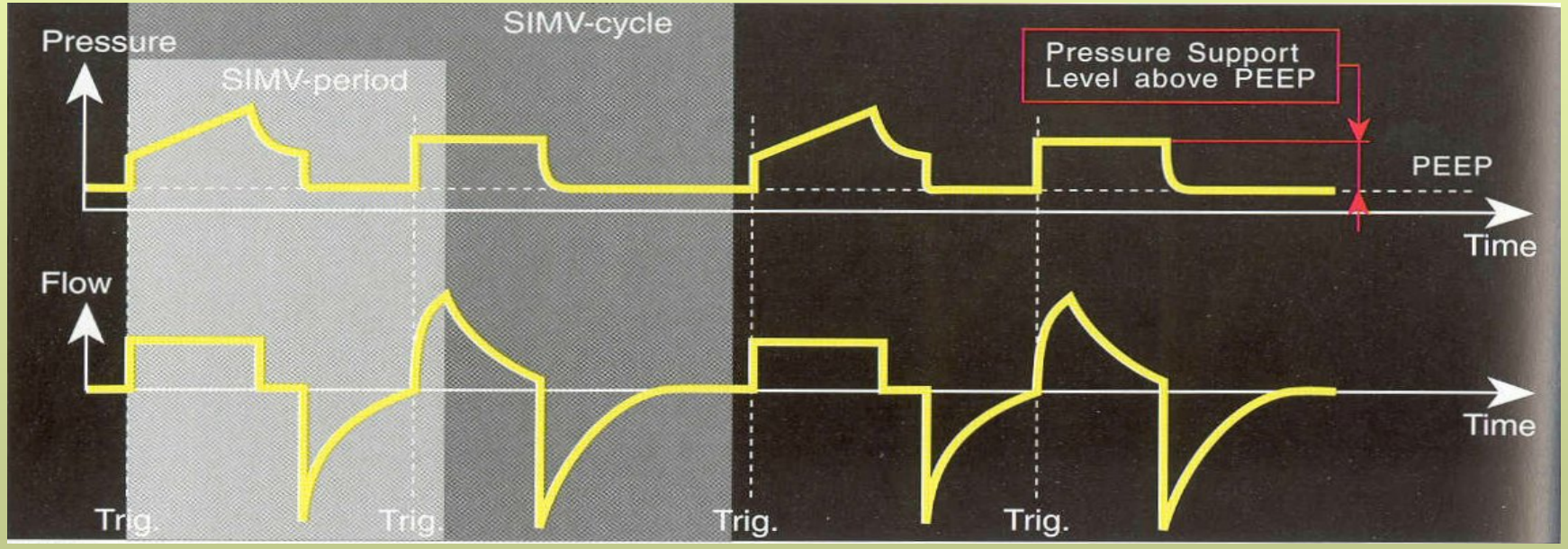
目的：在吸氣期間以一定的氣道壓力，提供部分的強制呼吸。可藉由降低SIMV的次數，來逐步脫離呼吸器。

應用：用於一些有一部份自主呼吸，但是不夠的病人，需要一開始較高flow使肺葉張開的病人，需要避免高氣道壓力的病人。沒有cuff氣管內管或是氣管內管有漏氣情形的病人，提供遞減的flow rate。

注意事項：圖形中SIMV period是由機器上的SIMV cycle來決定(60/SIMV秒)，而SIMV period是由CMV rate決定（60/CMV秒）。病人在SIMV period內有呼吸的 trigger，他會得到一個預設大小的呼吸，而他在其他時間只會得到一個pressure support的，或是自主的呼吸。



- ***SIMV(VC)+pressure support***

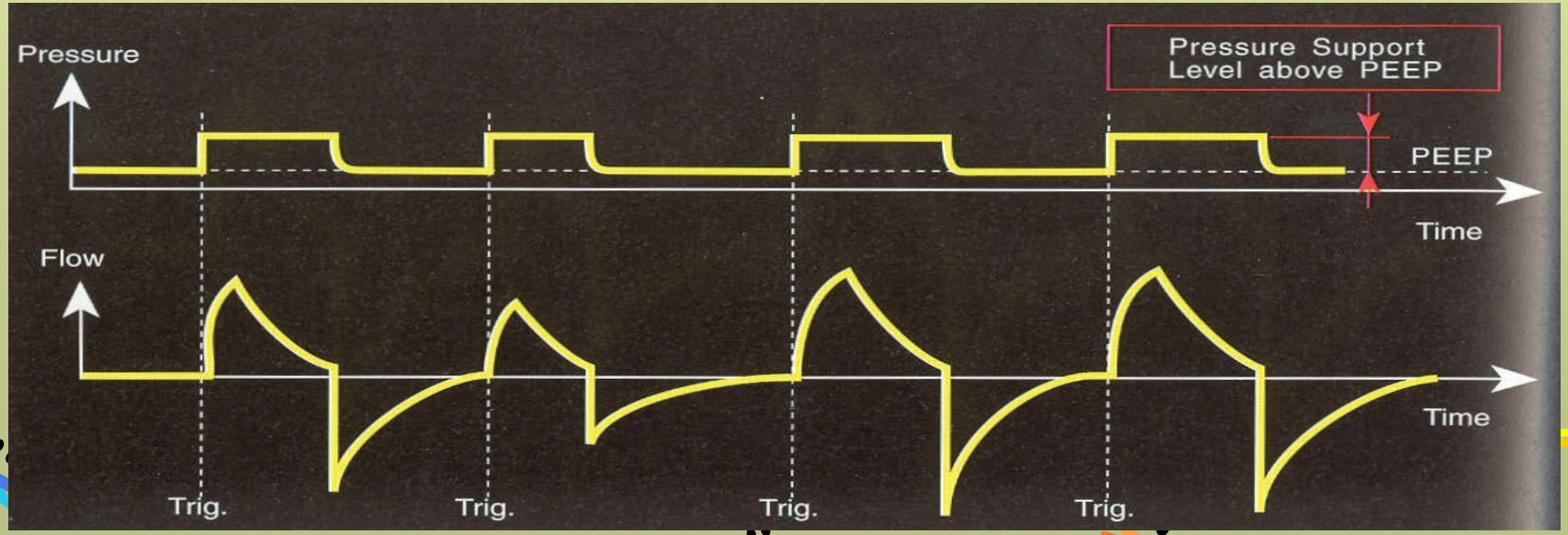


Pressure support /CPAP：

目的：根據病人需求，提供快速有彈性的呼吸協助，以利脫離呼吸器。並監視病人之呼吸狀態。

應用：用在呼吸drive健全，但仍需要部分機械協助，或是需要CPAP來維持換氣的病人，或是嘗試脫離呼吸器的病人。

特色：完全由病人自行驅動，無保證的通氣量。



呼吸器一招半式闖江湖

- Mode
  - SIMV + PS
- Rate (SIMV rate)
  - 30 for infants, up to 1 y/o
  - 20 for 1-6 y/o
  - 15 for greater than 6 y/o
- PIP
  - 20 cmH_2O
- PEEP
  - +6-8 cmH_2O for diseased lung, +4 cmH_2O for normal lung
  - 特殊狀況要low PEEP (e.g. Glenn shunt or Fontan procedure)

呼吸器一招半式闖江湖

- i-Time
  - LBW infant　　0.25 ~ 0.5 seconds
  - Term infant　　0.5 ~ 0.6 seconds
  - Toddler　　0.5 ~ 0.75 seconds
  - Children　　1.0 ~ 1.5 seconds
  - Adults　　1.0 ~ 2.0 seconds
- I/E ratio
  - 不小於 1 ，一般1:2 or 1:3

呼吸器一招半式闖江湖

- FiO2
  - 0.4 for normal lung
  - 0.9 for diseased lung (100% oxygen inducing lung collapse)
- Tidal volume
  - 10 cc/kg (8-12) for normal lung
  - 6-8 cc/kg for diseased lung (ARDS)

呼吸器調整

- 血氧
  - FiO2
  - PEEP
  - I/E ratio
- 二氧化碳
  - RR
  - TV (PIP)

Acute Respiratory Distress Syndrome in Children

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What is ARDS?

- First described by Ashbaugh et al. in 1967, *Lacet 1967; 2(7511): 319-23*
- American-European Consensus Conference
  - Acute onset of respiratory symptoms
  - Frontal CXR with bilateral infiltrate
  - No clinical evidence of left atrial hypertension

  (Am J Respir Crit Care Med 149; 818-24, 1994)
- *No Gold Standard for diagnosis*

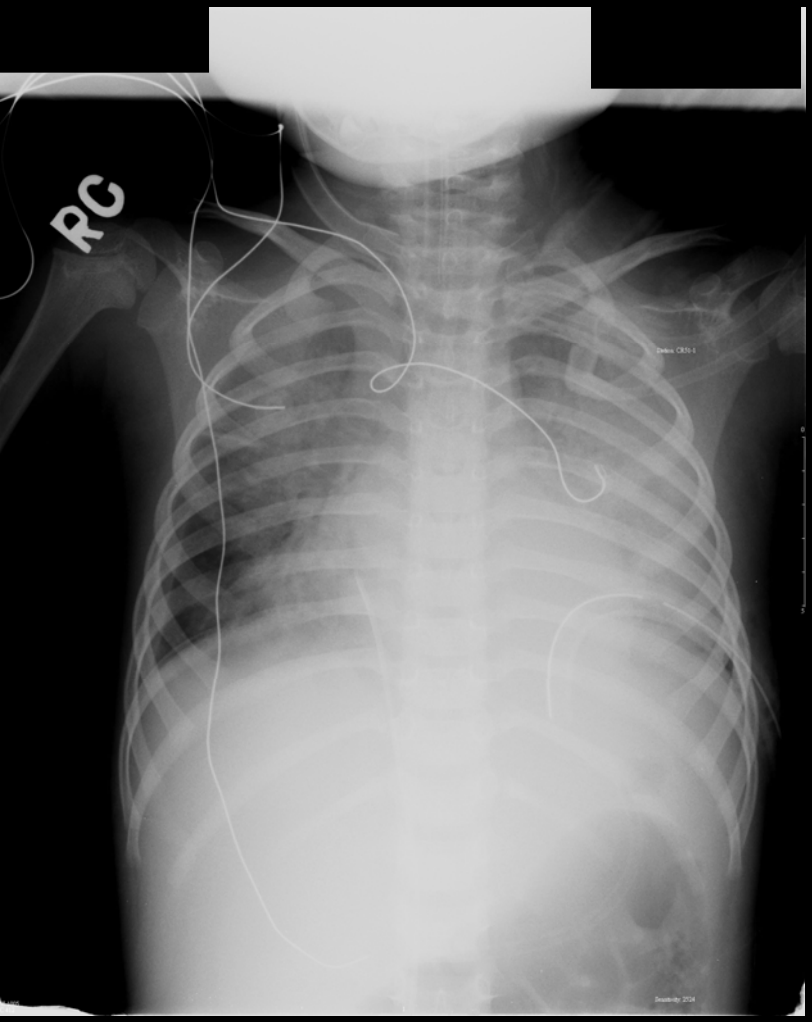
AECC Criteria

	Timing	Oxygenation	Frontal CXR	Pul. A. wedge pressure
Acute Lung Injury	Acute	PaO_2/FiO_2<= 300 mmHg	Bilateral Infiltrate	<= 18 mmHg if measured, or no clinical evidence of LAE
ARDS	Acute	PaO_2/FiO_2<= 200 mmHg	Bilateral Infiltrate	<= 18 mmHg if measured, or no clinical evidence of LAE

Etiology

Indirect Injury	Direct Injury
Sepsis	Pneumonia
Major Trauma	Aspiration
Multiple blood transfusion	Pulmonary contusion
Pancreatitits	Toxic inhalation
Cardiopulmonary bypass	Near drowning
Drug overdose	Reperfusion injury (e.g. post-lung transplantation)
Adverse effect of medication	

Mason: Muray & Nadel's Textbook of Respiratory Medicine, 4th ed.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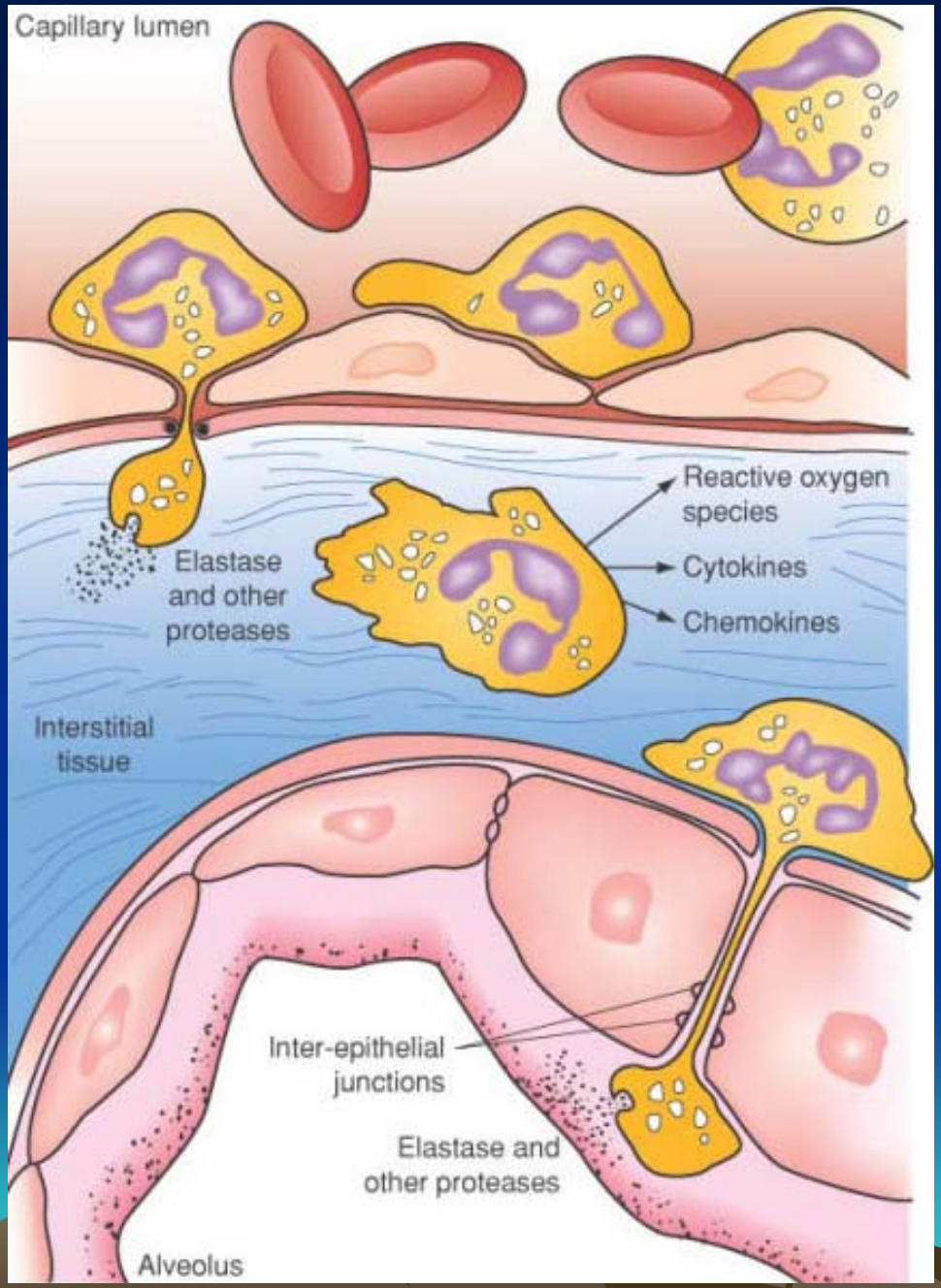


Role of neutrophils in the pathogenesis of acute lung injury. Activated neutrophils exit the bloodstream and transmigrate across the alveolar-capillary membrane, releasing cytokines, proteases, reactive oxygen species, and other compounds. Although crucial to host defense against pathogens, the compounds secreted or released by the neutrophil have the capacity to damage the tissue of the host. (Adapted from Lee WL, Downey GP: Leukocyte elastase: Physiological functions and role in acute lung injury. A state of the art review. Am J Respir Crit Care Med 164:896–904, 2001.)

Ventilator Strategy for ARDS

- 6 mL/kg with PIP < 30 cmH_2O compared with 12 mL/kg PIP < 50 cmH_2O
  - 22% reduction in mortality
  - Increased ventilator free day during the first 28 hospital days
  - Adult patients

    (ARDS Network, NEJM 2000, 342: 1307-8)
- Permissive hypercapnia
  - CO_2 allowed to rise
  - Maintain pH > 7.2 with buffered solution

Parameter	protocol
Mode	Volume assist-control
Tidal Volume	≤6 mL/kg predicted body weight
Plateau pressure	≤30 cm H2O
Frequency	6–35 breaths/min, titrated for pH 7.30–7.45
IE ratio	1:1 to 1:3
Oxygenation Goal	PaO_2 55–80 mm Hg, or SaO_2 88–95%
FiO2/PEEP (cmH2O) combination allowed	0.3/5, 0.4/5, 0.4/8, 0.5/8, 0.5/10, 0.6/10, 0.7/10, 0.7/12, 0.7/14, 0.8/14, 0.9/14, 0.9/16, 0.9/18, 1.0/18, 1.0/20, 1.0/22, 1.0/24
Weaning	By pressure support, required when FIO2/PEEP ≤ 0.4/8

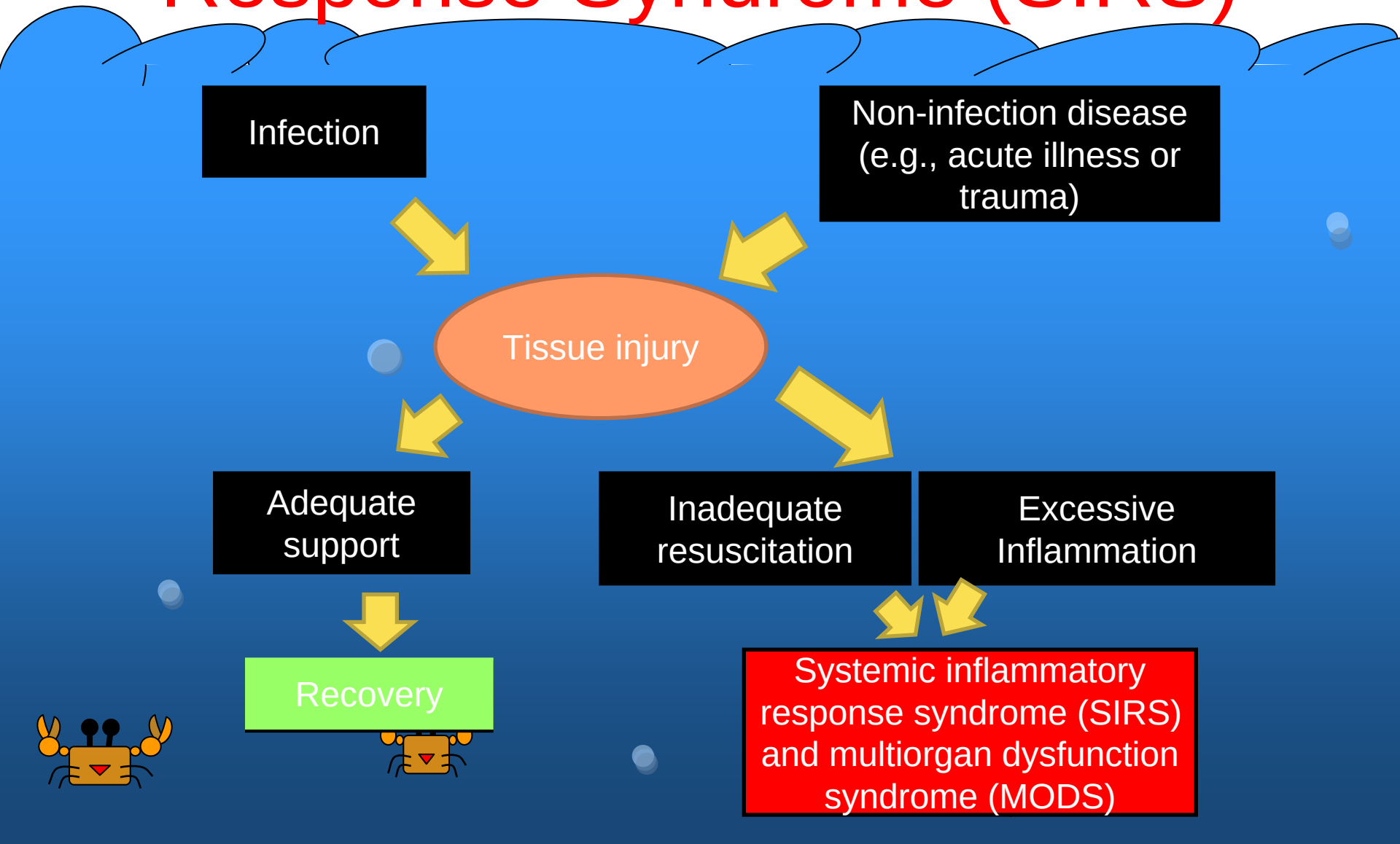
(ARDS Network, NEJM 2000, 342: 1307-8)

Sepsis

台中榮總 兒童醫學部

林明志 醫師

Systemic Inflammatory Response Syndrome (SIRS)

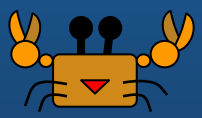
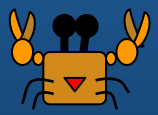
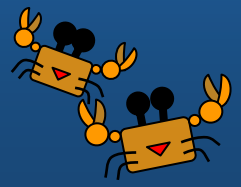


定義

- SIRS: >=2 criteria
  - 發燒 Core Temp > 38.5 or < 36 ℃
  - 心跳加速Unexplained tachycardia or bradycardia < 1 y
  - 喘 Tachypnea or mechanical ventilation for an acute process
  - 白血球降低或上升band form
    - Leukopenia or 10% immature neutrophiles
- Sepsis: 感染相關的SIRS
- Severe sepsis:
  - Cardiac vascular dysfunction
  - ARDS
  - >= 2 organs dysfunctions
- Septic shock:
  - sepsis and cardiovascular organ dysfunction

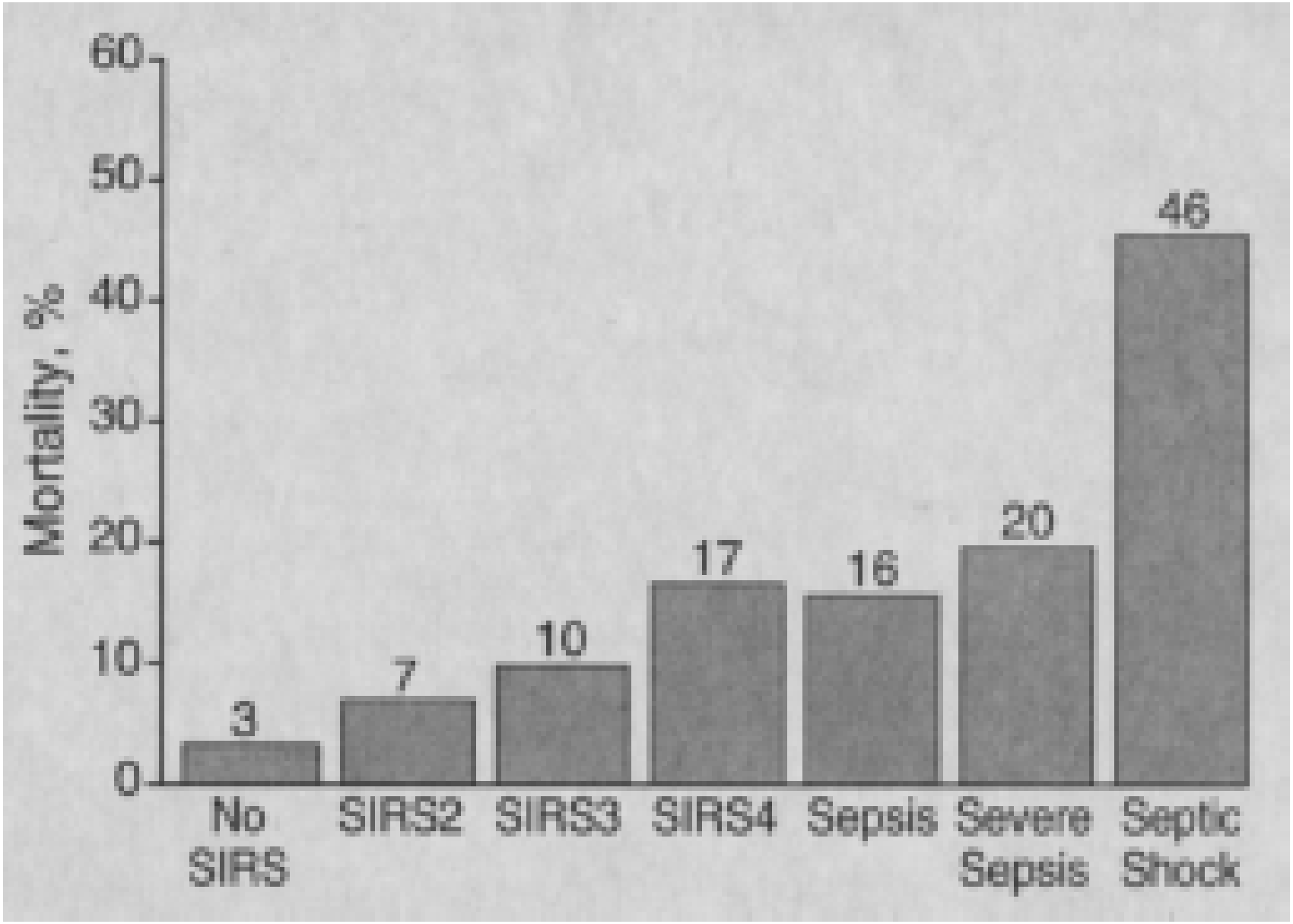
流行病學

- SIRS/sepsis 750,000 American adults, mortality 28~60%
- Children 0.56 cases/1000 person-year
- In-hospital mortality 10%
- Death rate increased with the numbers of organ failure
  - 7% single organ, 53.1% four organ
- Mean length of stay 31 days
- Cost US$ 40,600, annually $1,970,000,000

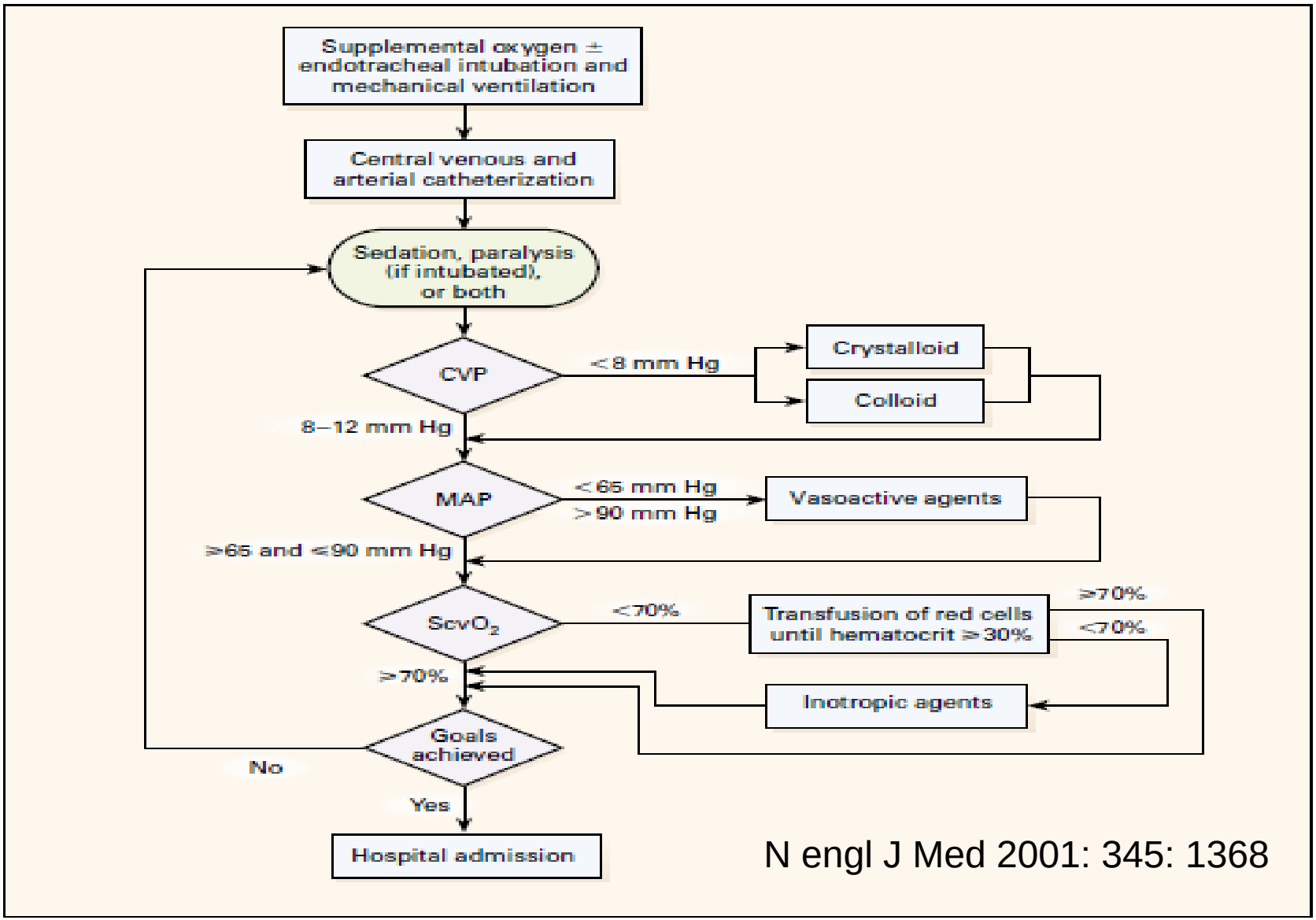
Organ dysfunction

系統	表現
心血管系統	在fluid bolus >= 40 mL/kg in 1 hr仍 低血壓 需使用強心劑 或以下兩個以上： 1. 代謝性酸中毒 2. 乳酸升高兩倍以上 3. 寡尿 4. 微血管回填>=5 sec 5. 中心與周邊體溫差大於3度
呼吸	1. PaO2/FiO2 < 300 2. PaCO2 > 65 mmHg or 20 mmHg above baseline >50% FiO2 to maintain O2Sat > 92%
神經系統	GCS <=11 or change >=3
血液	Plt < 80000 mm3 or decline > 50%, or INR > 2
腎臟	Cr >= 上限兩倍，或兩倍上升
肝臟	Bil. Total > 4 mg/dL （NB例外）or ALT 兩倍上升



JAMA 1995; 273: 117

2008戰勝敗血症，黃金六小時



N engl J Med 2001: 345: 1368

第一小時

1. Monitor ECG, SpO2, NIBP

2. Consider intubation and mechanical ventilation if respiratory failure

3. Artery-line placement & ABP monitor

4. Placement of a CVP catheter (PreSep CVP with ScvO2 is preferred)

5. Obtain smear and related cultures
Obtain 2 or more blood culture
(Previous colonized fungus → fungus culture)

6. Check CBC+DC, INR/PTT, AST, ALT, Bil T/D, Glu, electrolytes, BUN/Cr,CRP or Procalcitonin as needed

7. Check chest x-ray or other image study as needed

8. Check ABG, electrolytes, and lactate

9. **Initiate empiric broad spectrum and adequate dose antibiotics therapy**

10. Start early goal-directed treatment for shock
Goals: MAP > 65 mmHg, ScvO2>70%
Urine output > 1 ml/kg/h

11. Fluid supplement to target CVP as needed
CVP→ 8-12 mmHg (12-15 mmHg if intubated)
Push NS or colloid 20 ml/kg first, repeated over 60cc/kg as needed

12. If MAP still < 65 mmHg after adequate fluid supplement:
1st line Dopamine 5-20 mcg/kg/min
Dobutamine 2-20 mcg/kg/min (if low cardiac output and elevated systemic vascular resistance states)
2nd line Levophed 0.5-2 mcg/kg/min, or
Epinephrine 0.04-0.2 mcg/kg/min

1-6 hour

1. Ongoing early goal-directed treatment for shock

2. If shock is refractory to vasopressor and inotropic,
may use Solu-Cortef 50 mg/m^2/24hr if at risk for absolute adrenal insufficiency, remember to taper down steroid once the shock is resolved（小兒參考劑量 2 mg/kg）

3. If MAP > 65 mmHg, but ScvO2 < 70%
Consider further fluid supplement as tolerated
PRBC supplement for Hct < 30%

4. If shock persisted, evaluate heart function
Check cardiac echo, PiCCO, PAC, or CCO as needed

5. Control blood sugar < 150 mg/dL

5. Check ABG, electrolytes, and lactate as needed

6-24 hour

1. Ongoing goal-directed treatment for shock
2. Recheck ABG, electrolytes, and lactate as needed
3. Remove source of infection if possible Site:_____ Intervention: _____
4. Protective ventilation strategy If PaO2/FiO2<300, PC mode, VT 6-8 mL/kg, Adequate PEEP, peak airway pressure < 35 cmH2O Head of bed raised to 30 - 45 °
5. RRT for acute renal failure CVVH for hemodynamic unstable patient SLED-f for hemodynamic stable patient
6. Prevent stress ulcer - Zantac 2-4mg/kg/day divided Q6-8H If ulcer history or being bleeding now - Losec 1mg/kg QD
7. Analgesia and sedation as needed
8. At 12-24h, check Modified PRISM III-APS score: _____
9. Control blood sugar

24-48 hour

1. Narrow antibiotics by available report and clinical improvement

2. If clinical condition deteriorated, consult ID doctor

3. Reassess removal of infection source
Site:_____
Intervention: _____

4. RRT for acute renal failure

5. Nutrition support
If enteral feeding is allowed and condition improved (like shock resolved, lactate < 3 mmol/L), start enteral feeding
TPN for NPO patients

6. Analgesia and sedation as needed
Perform daily interruption for continuous sedation

7. Prevent DVT and PE in postpubertal children with severe sepsis
Low risk - choose one of the followings,
(1) heparin loading 2000U then 100 U/h IV t itration to keep aPTT > 50 sec, (2) compressing stocking, or (3) intermittent pneumatic compression device
High risk - combine heparin and mechanical device

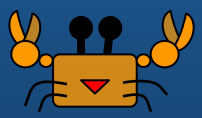
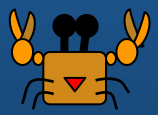
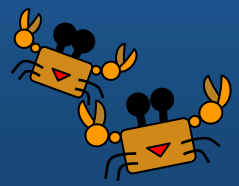
8. Discuss advance care plan with patient & family

9. IVIG may be considered in children with severe sepsis

10. ECMO be limited to refractory pediatric septic shock and/or respiratory failure that cannot be supported by conventional therapies

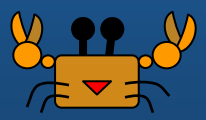
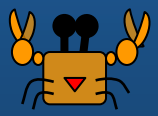
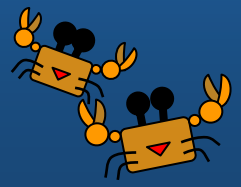
血行力學之支持治療

- 輸液治療：
  - Colloid v.s. crystalloid
  - CVP level
    - 心肺腎不好：8 mmHg
    - 單一器官：10 mmHg
    - 器官正常：12 mmHg
    - 呼吸器：12-15 mmHg

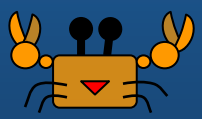
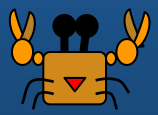
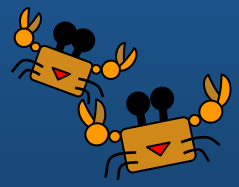
血行力學之支持治療

- 升壓劑
  - MAP > 65 mmHg
  - dopamine, norepinephrine
  - Epinephrine
  - Vasopression (0.03 units/min), not for 1st line
- 避免低劑量dopamine保護腎臟
- 盡快放置arterial line
- Dobutamine提高cardiac output
- 不建議以預設高於正常值的cardiac index治療病人

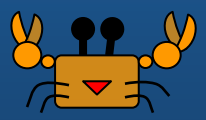
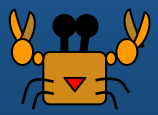
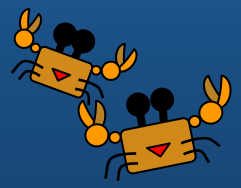
呼吸照護

- Low tidal volume, limited peak and plateau pressure
  - Tidal volume 6 mL/kg
  - Peak pressure < 35 mmH2O
  - Plateau pressure < 30 mmHg
- Permissive CO2 retention
- PEEP
- Prone position
- Head up 30-45 degress
- Pul. Artery catheterization not recommended
- Limited fluid therapy

輸血的原則

- 無心肌缺氧，組織血液灌流不足，嚴重低血氧，急性出血，缺氧性心臟病，乳酸血症，PRBC keep 7-9 g/dL
- FFP不該被常規使用，10-15 mL/kg
- Plt < 5000/mm3, 5000-30000 若有出血風險，手術前 > 50,000

感染的Issue

Diagnosis

- Obtain appropriate cultures before starting antibiotics provided this does not significantly delay antimicrobial administration. (1C)
  - Obtain two or more blood cultures (BCs)
  - One or more BCs should be percutaneous
  - One BC from each vascular access device in place > 48 h
  - Culture other sites as clinically indicated
- Perform imaging studies promptly in order to confirm and sample any source of infection; if safe to do so. (1C)

Antibiotic therapy

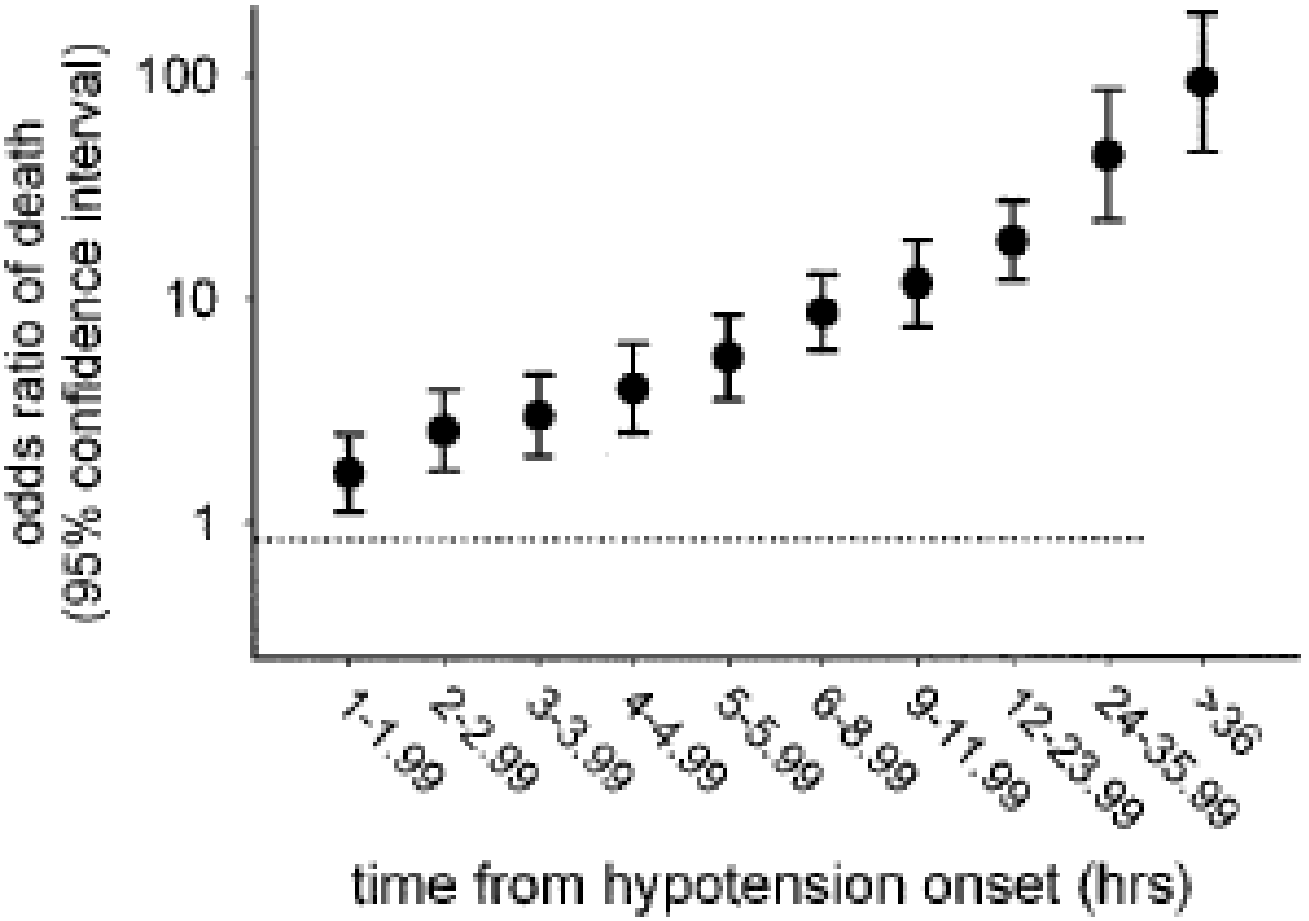
- Begin intravenous antibiotics as early as possible, and always within the first hour of recognizing severe sepsis (1D) and septic shock (1B).
- Broad-spectrum: one or more agents active against likely bacterial/fungal pathogens and with good penetration into presumed source.(1B)
- Reassess antimicrobial regimen daily to optimise efficacy, prevent resistance, avoid toxicity & minimise costs. (1C)
  - Consider combination therapy in Pseudomonas infections. (2D)
  - Consider combination empiric therapy in neutropenic patients. (2D)
  - Combination therapy no more than 3–5 days and deescalation following susceptibilities. (2D)
- Duration of therapy typically limited to 7–10 days; longer if response slow, undrainable foci of infection, or immunologic deficiencies. (1D)
- Stop antimicrobial therapy if cause is found to be non-infectious. (1D)

Source identification and control

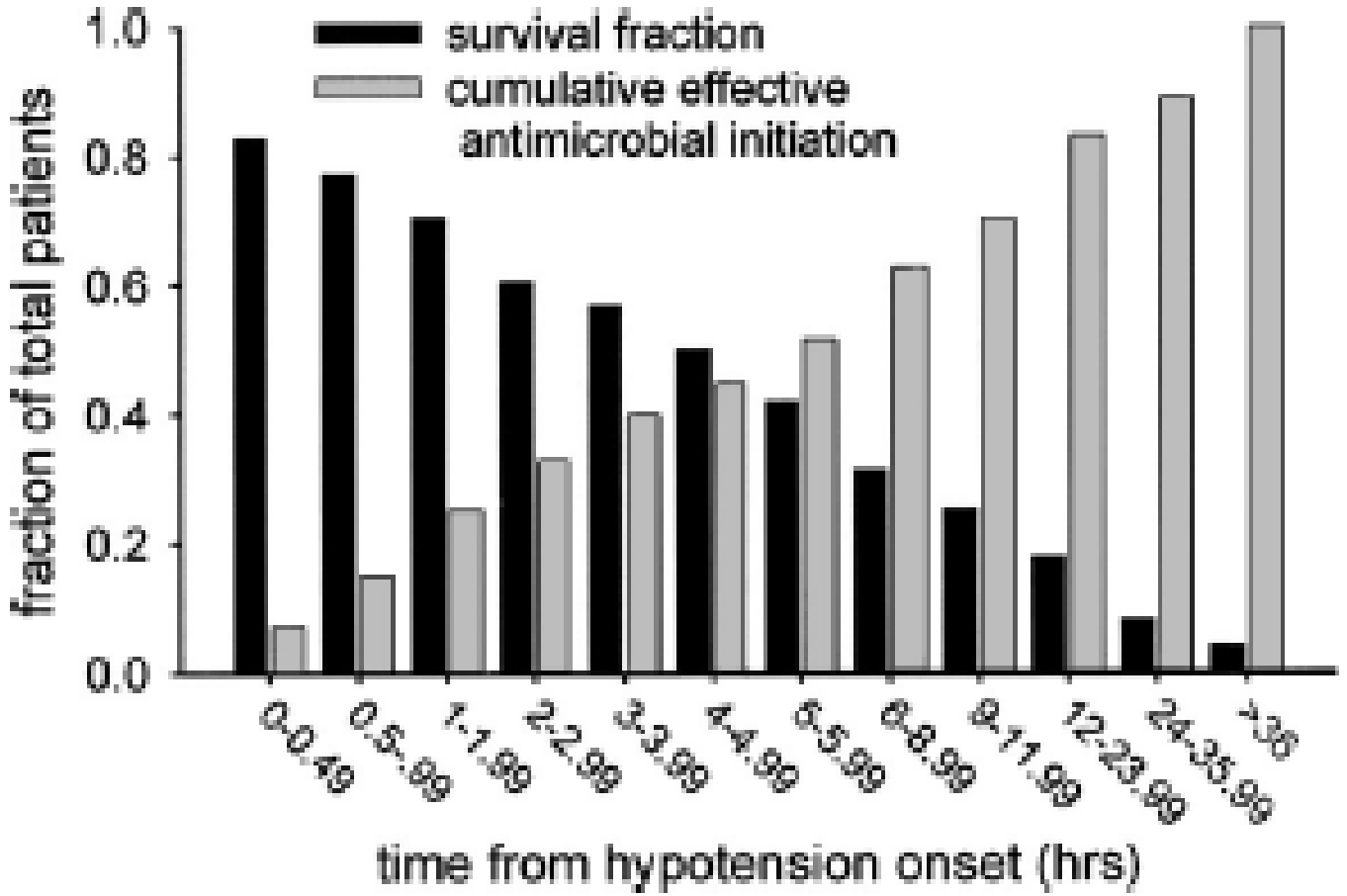
- A specific anatomic site of infection should be established as rapidly as possible (1C) and within first 6 hrs of presentation (1D).
- Formally evaluate patient for a focus of infection amenable to source control measures (eg: abscess drainage, tissue debridement). (1C)
- Implement source control measures as soon as possible following successful initial resuscitation. (1C)

Exception: infected pancreatic necrosis, where surgical intervention best delayed. (2B)

- Choose source control measure with maximum efficacy and minimal physiologic upset. (1D)
- Remove intravascular access devices if potentially infected. (1C)



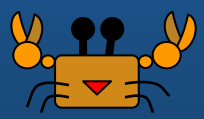
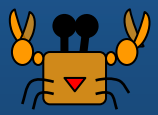
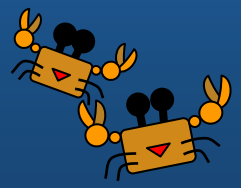
Crit Care Med 2006; 34: 1589



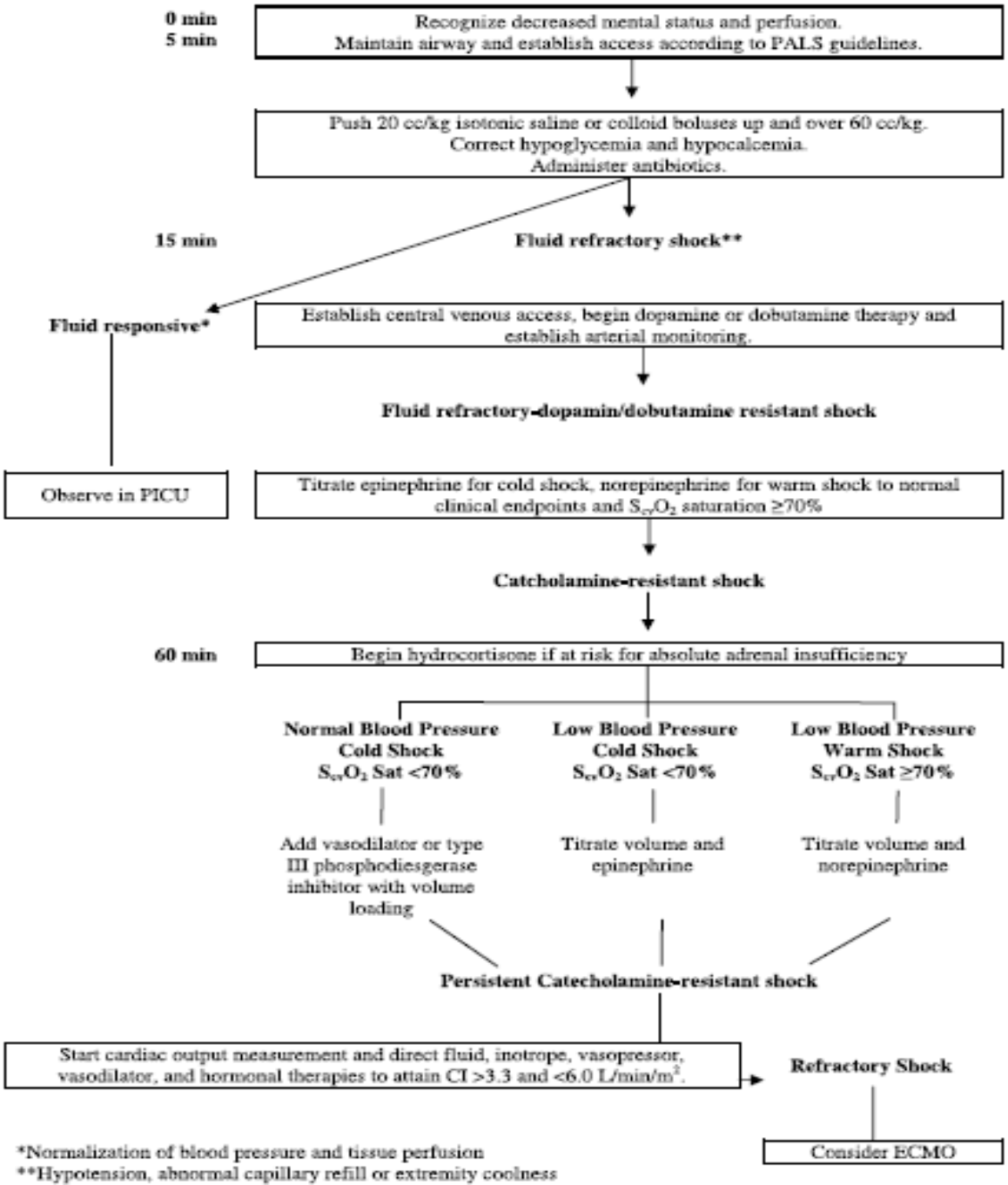
Crit Care Med 2006; 34: 1589

類固醇使用的時機

- Children with catecholamine resistance and suspected or proven adrenal insufficiency

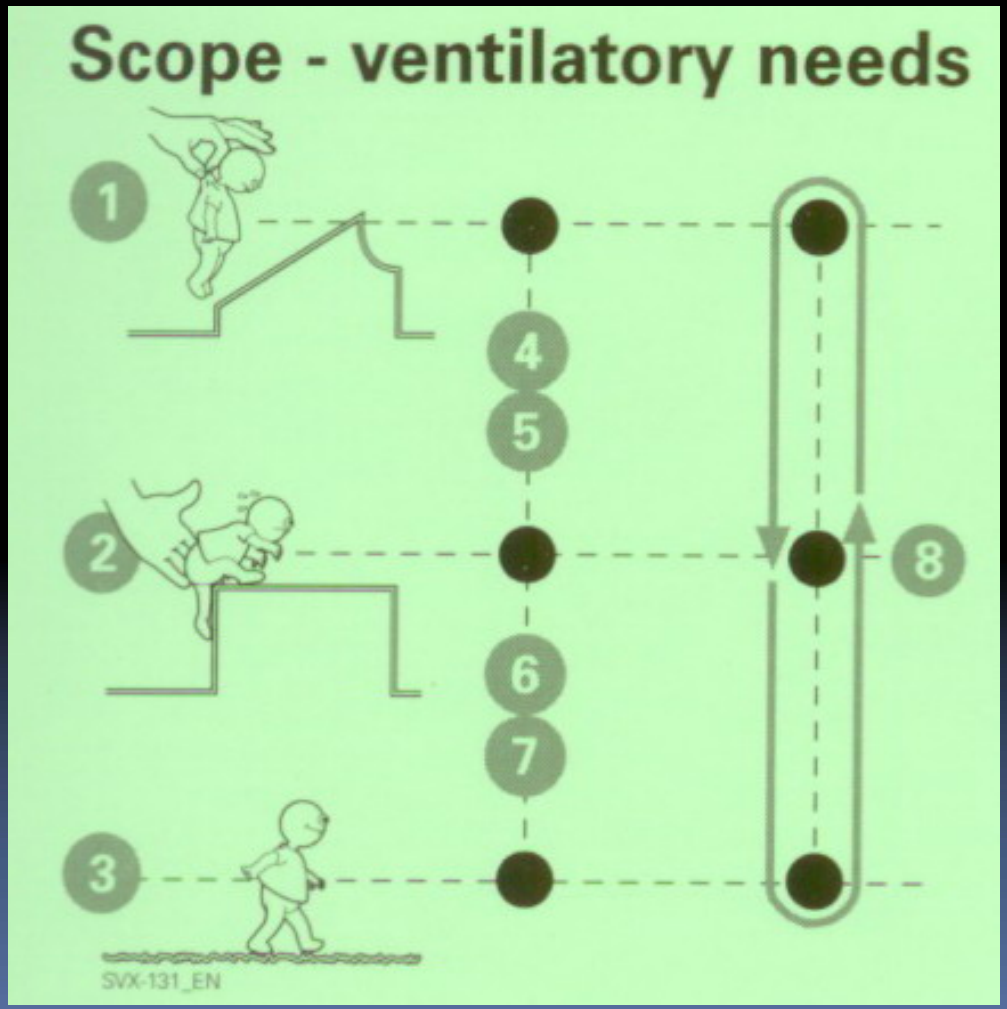
Special consideration in children



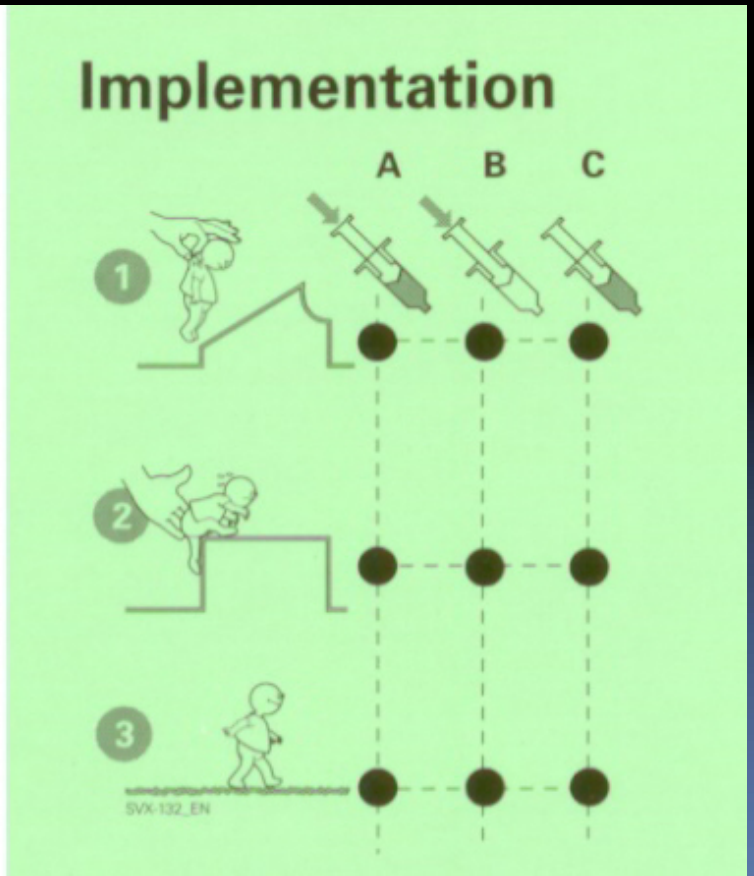
SERVO*i* Ventilator System

Ming-Chih Lin M.D.

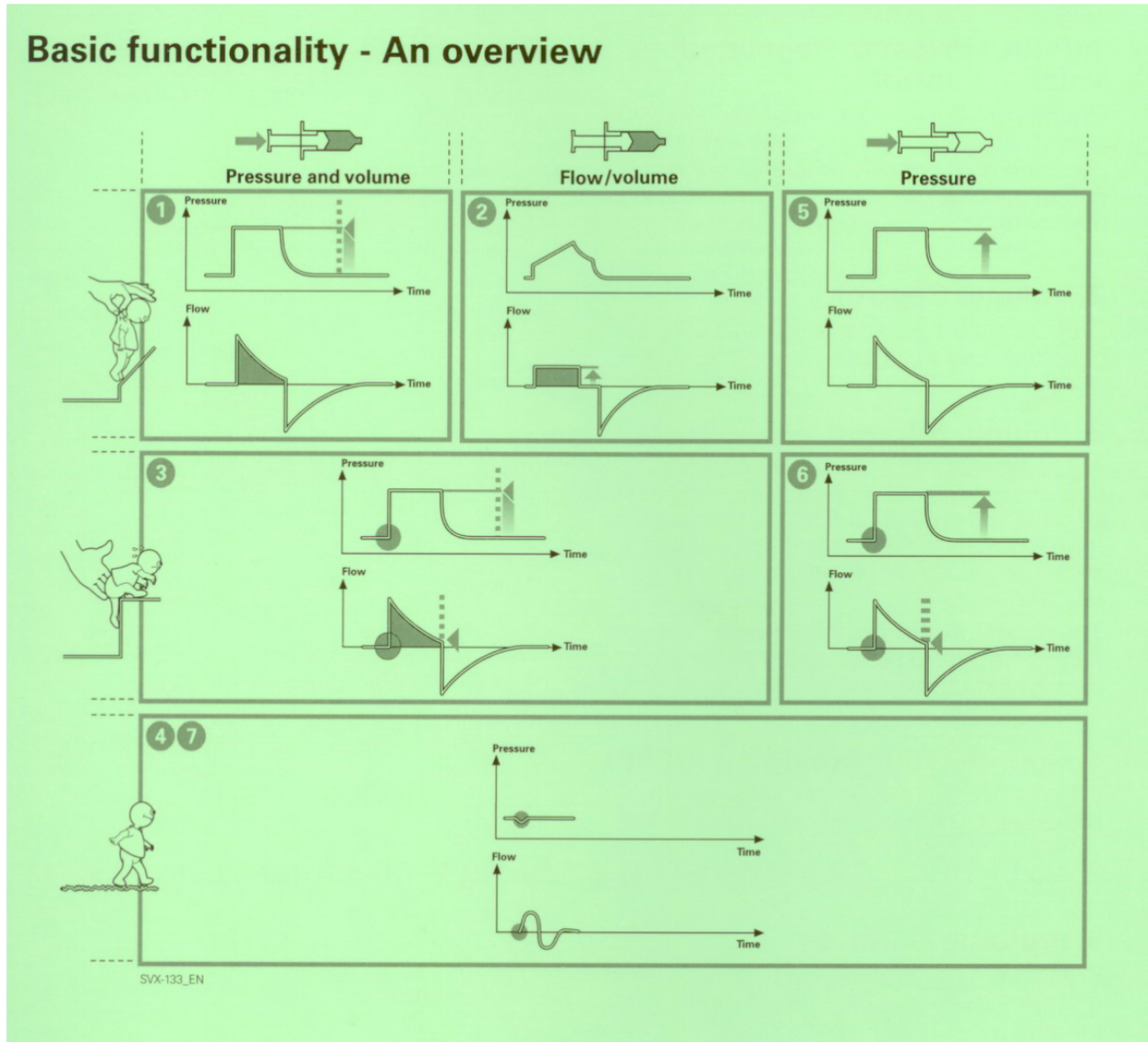
Controlled, Supported, and Spontaneous modes



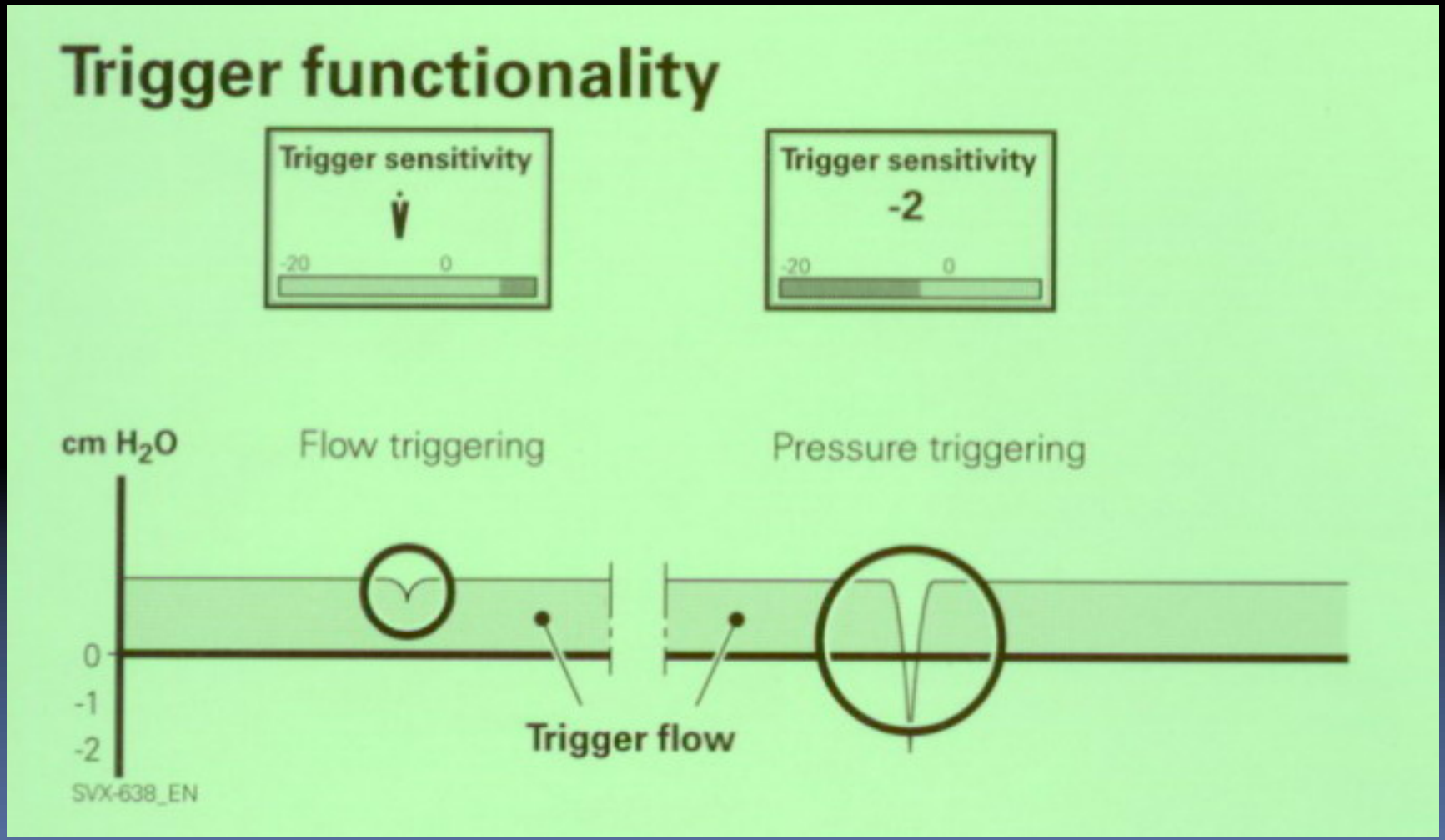
A. Pressure and Volume
B. Pressure
C. flow/volume
D. Extra flow and extra breath
E. timing



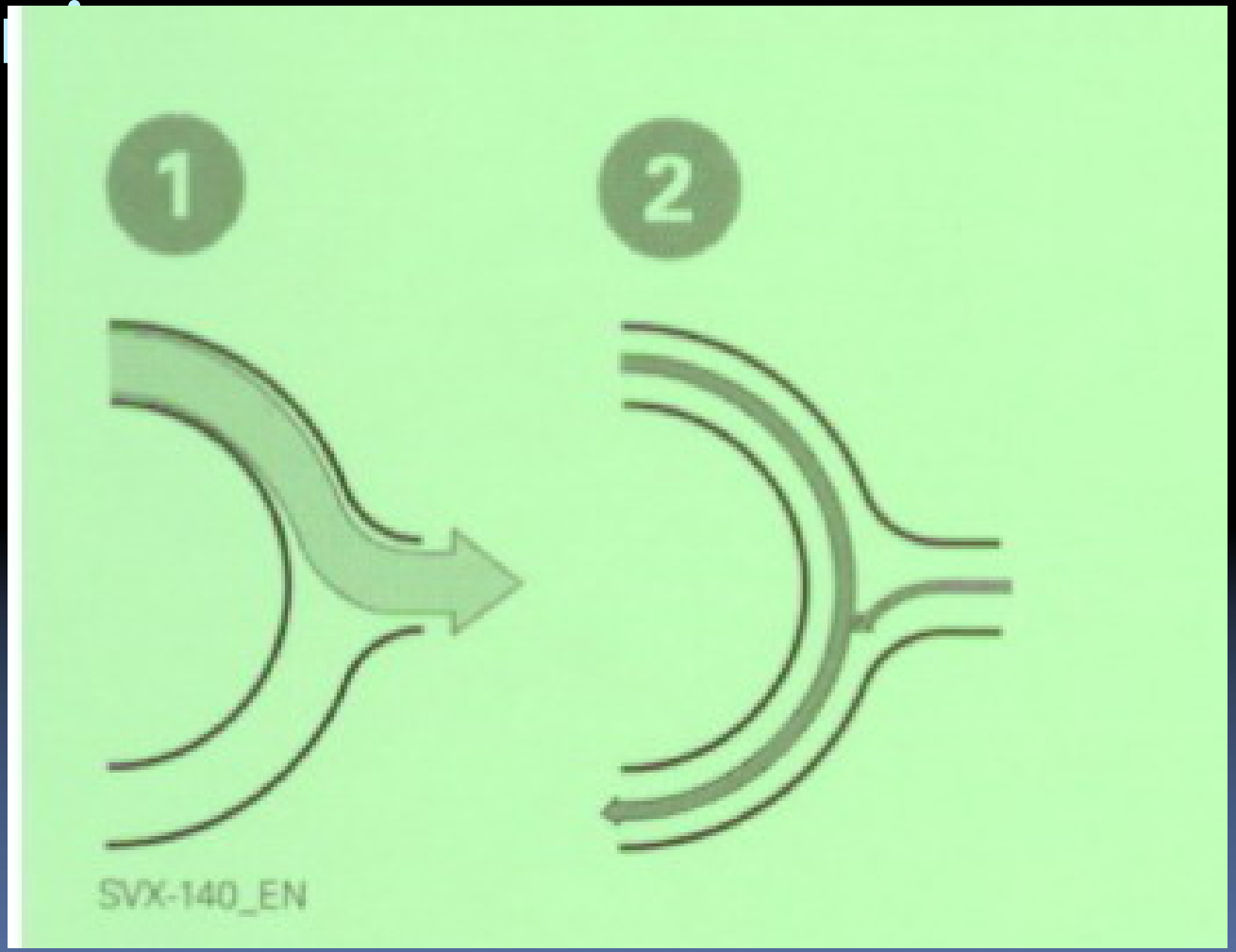
Basic function – an ove



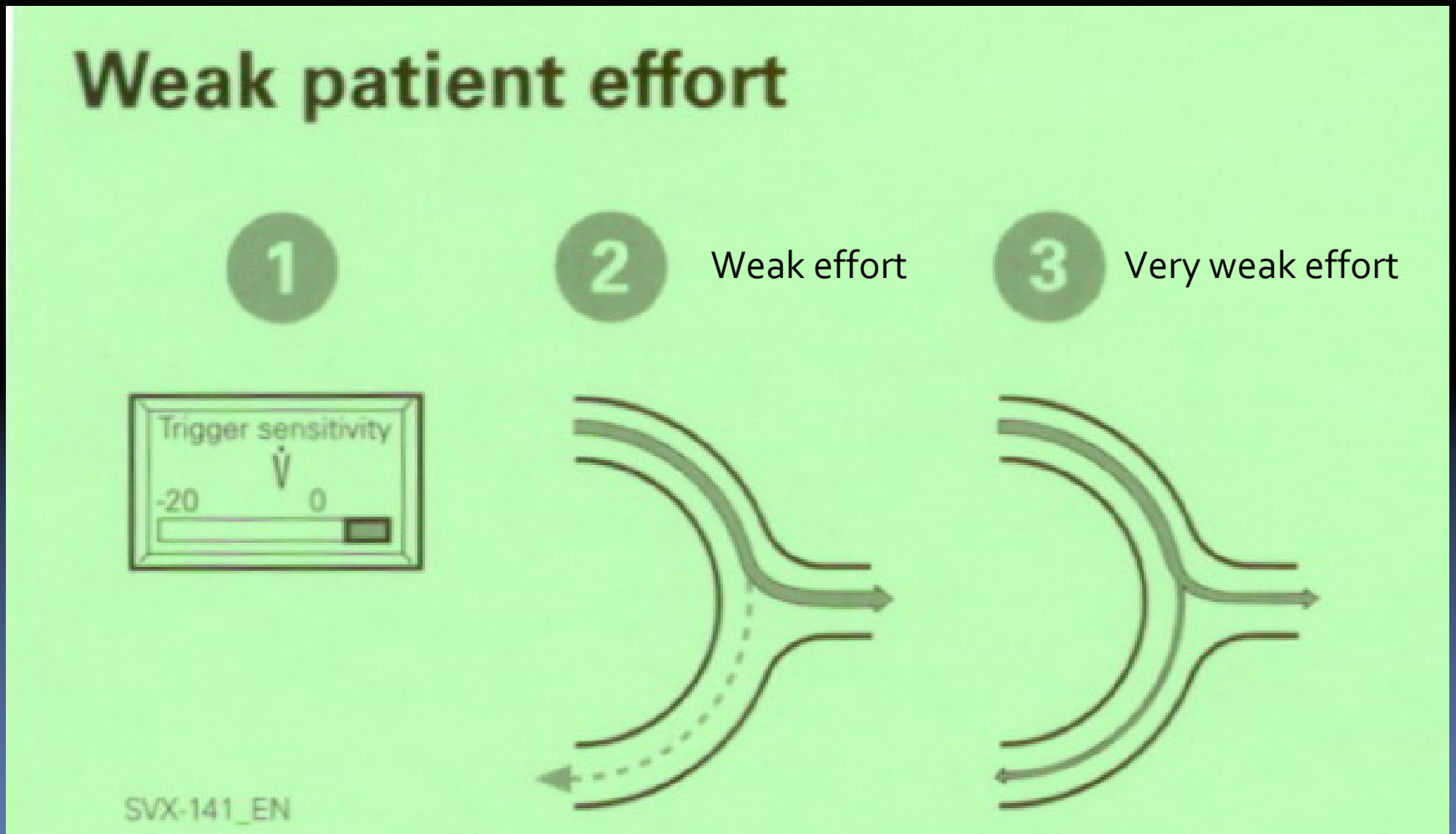
Trigger


Trigger functionality
Trigger sensitivity
-20
0
Trigger sensitivity
-2
-20
0
cm H_2O
Flow triggering
Pressure triggering
0
-1
-2
Trigger flow
SVX-638_EN

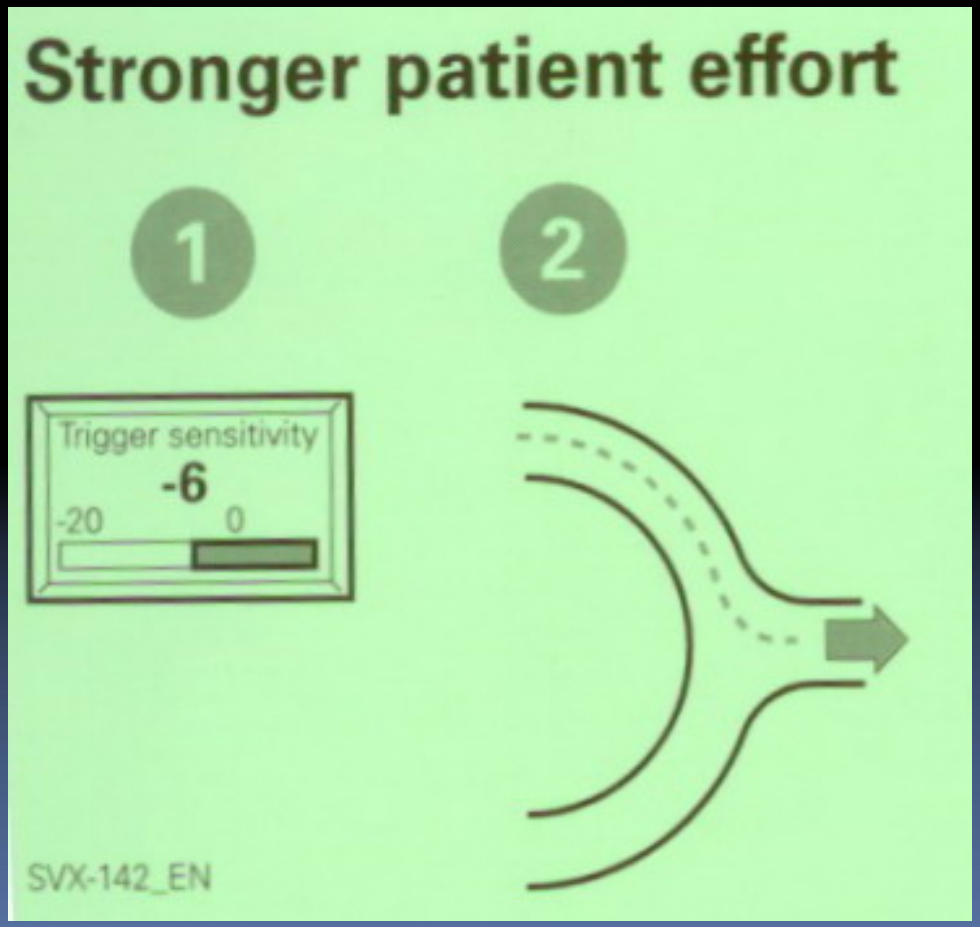
Bias flow
infant 0.5 l/min, adult 2 l/



Trigger sensitivity
auto-triggering if sensitivity too high

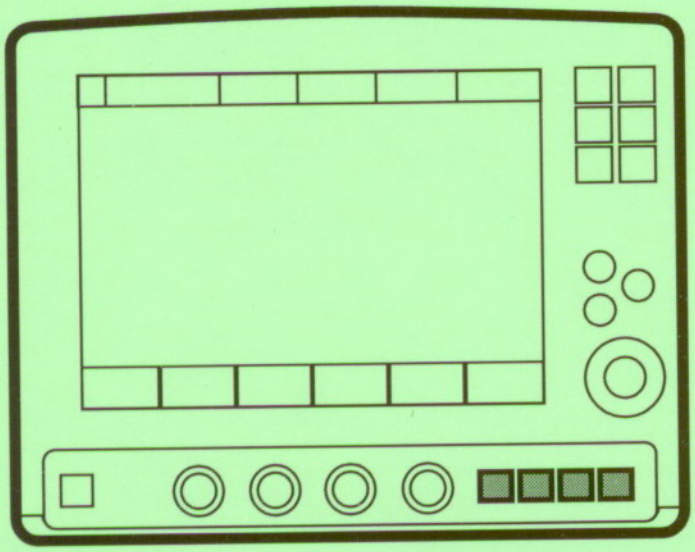


Green bar – flow trigger
yellow bar – pressure trigger
red – risk of self triggering



Start breath, O_2 breath, inspiratory hold, expiratory hold

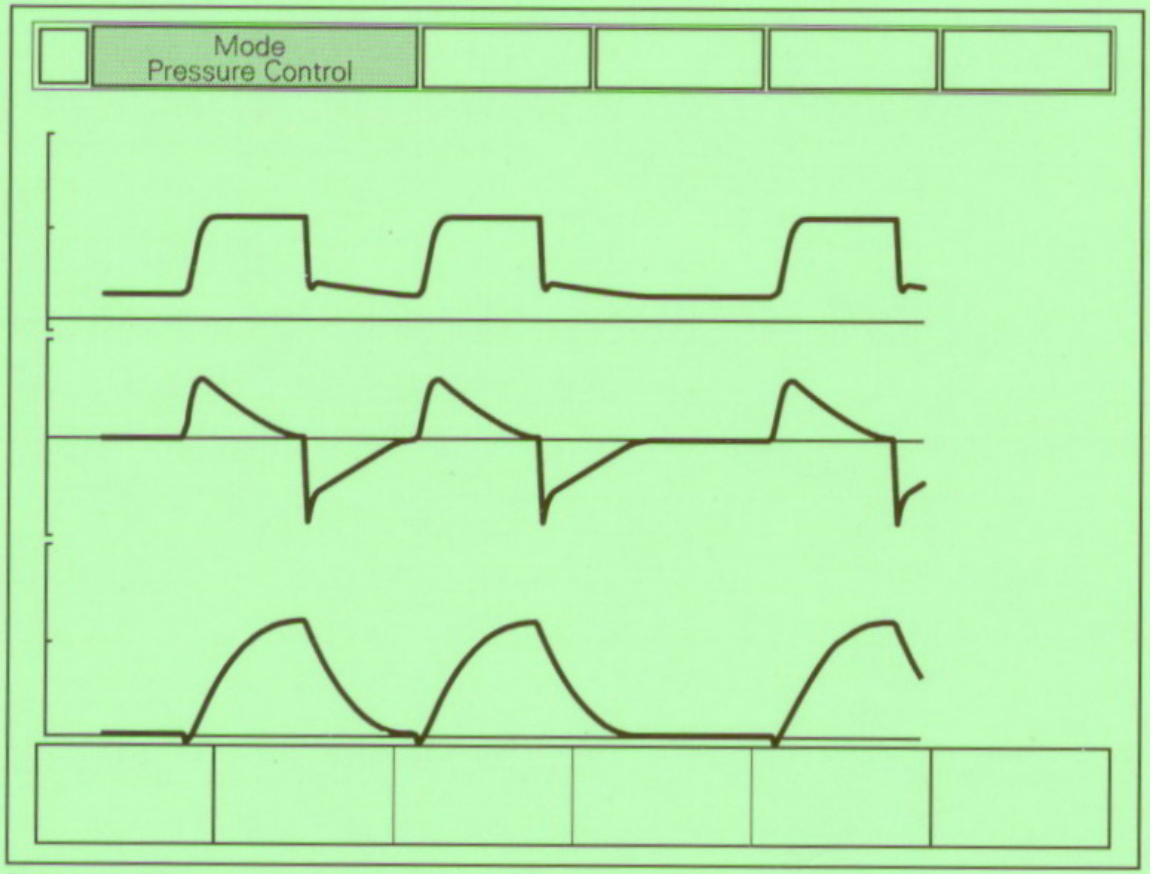
Fixed keys



SVX-637_EN

Start breath, O_2 breaths, Inspiratory hold and Expiratory hold can all be chosen by manually pressing the respective fixed key.

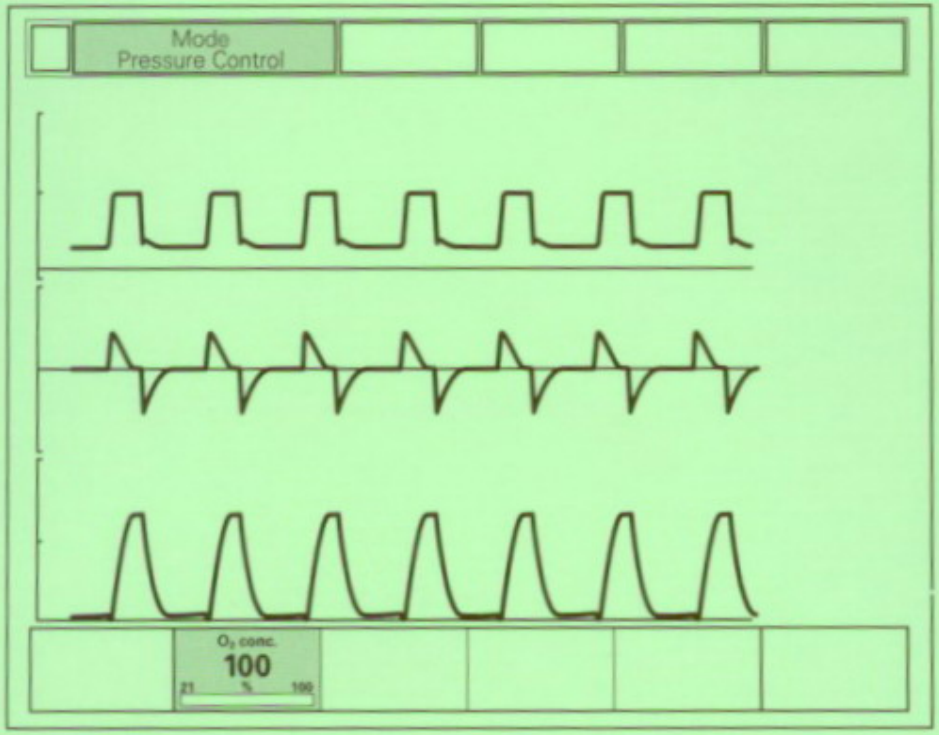
Start breath



SVX-640_EN

The ventilator will initiate a new breath cycle according to the current ventilator settings.

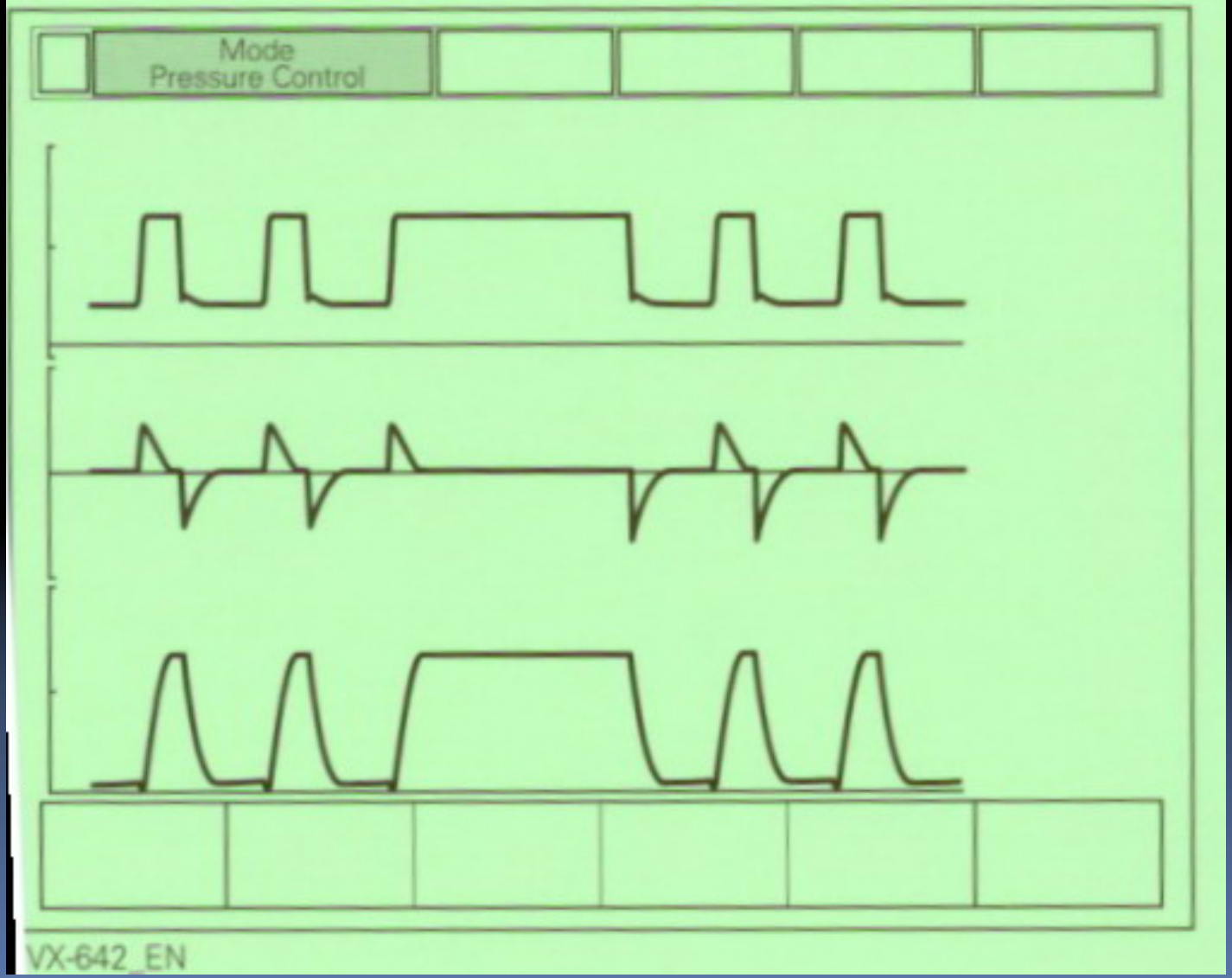
O_2 breaths



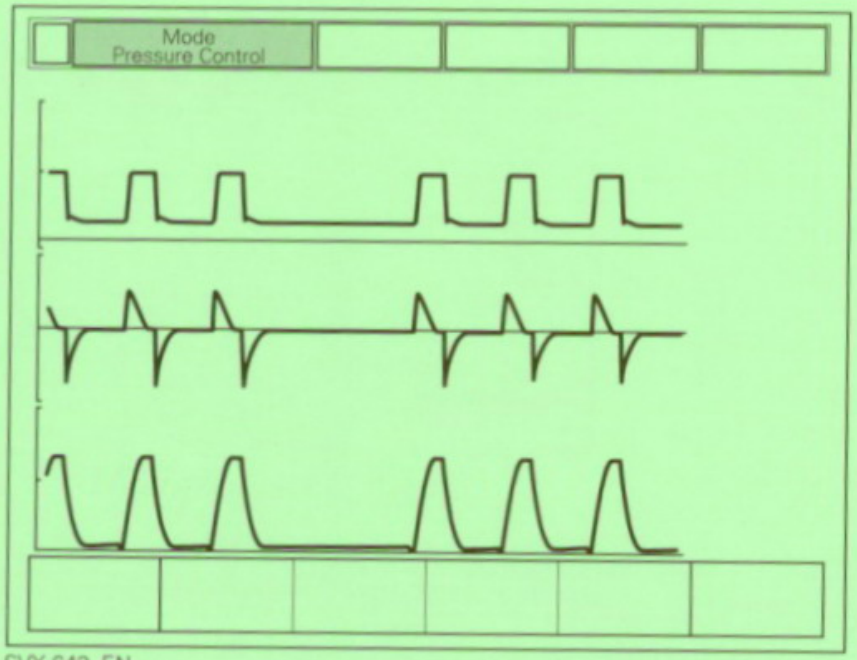
SVX-641_EN

This function allows 100% oxygen to be given for 1 minute. After this time the oxygen concentration will return to the pre-set value. The *oxygen breaths* can be interrupted by re-pressing the *O_2 breaths* fixed key during the 1 minute interval.

Inspiratory hold



Expiratory hold

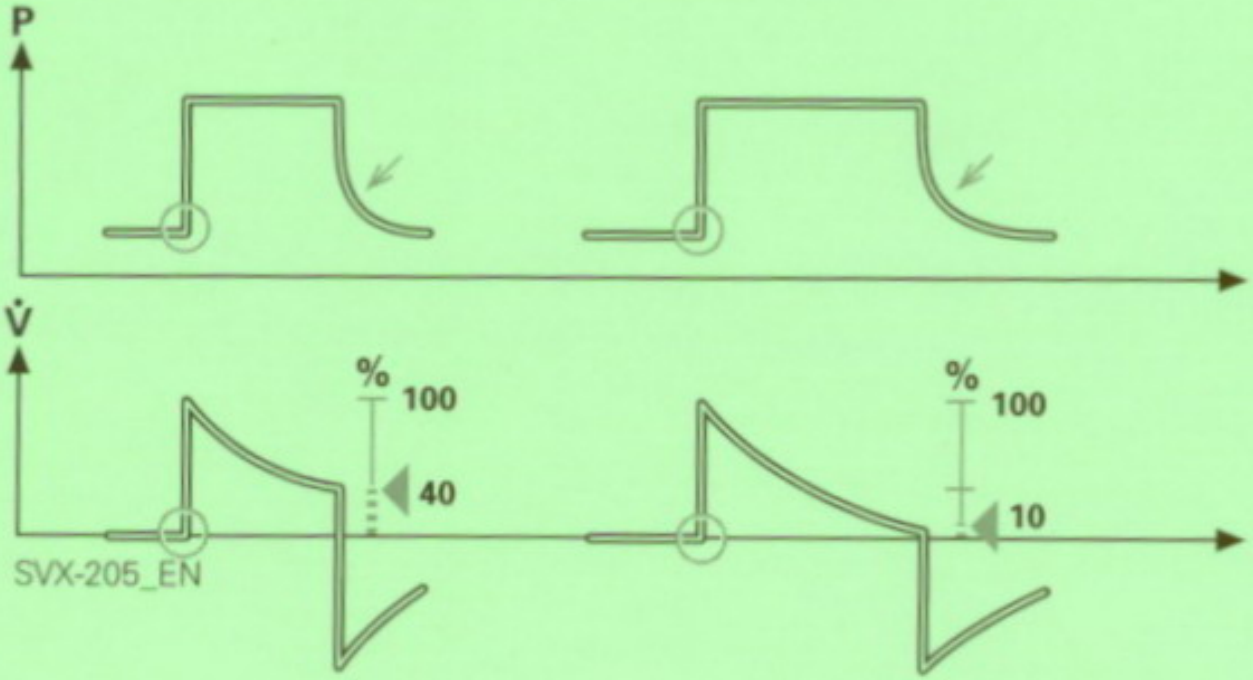


SVX-643_EN

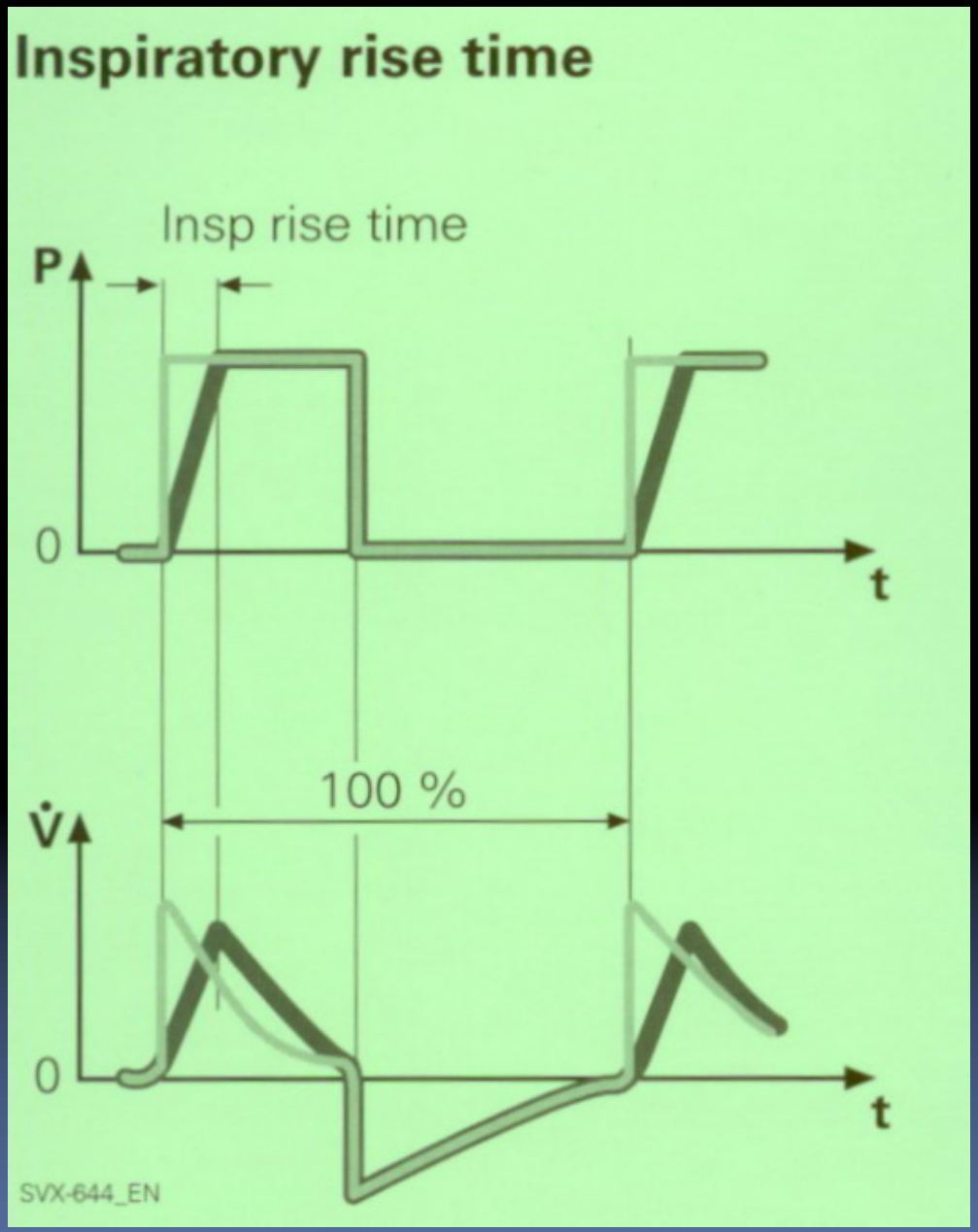
Expiratory and inspiratory valves are closed after the expiration phase is completed, for as long as the fixed key is depressed, up to a maximum of 30 seconds.

Expiratory hold provides an exact measurement of the end expiratory pause pressure. It can be used for static compliance measuring and to determine the total PEEP. The dynamic pressure is shown on the PEEP numerical value.

Inspiratory cycle-off



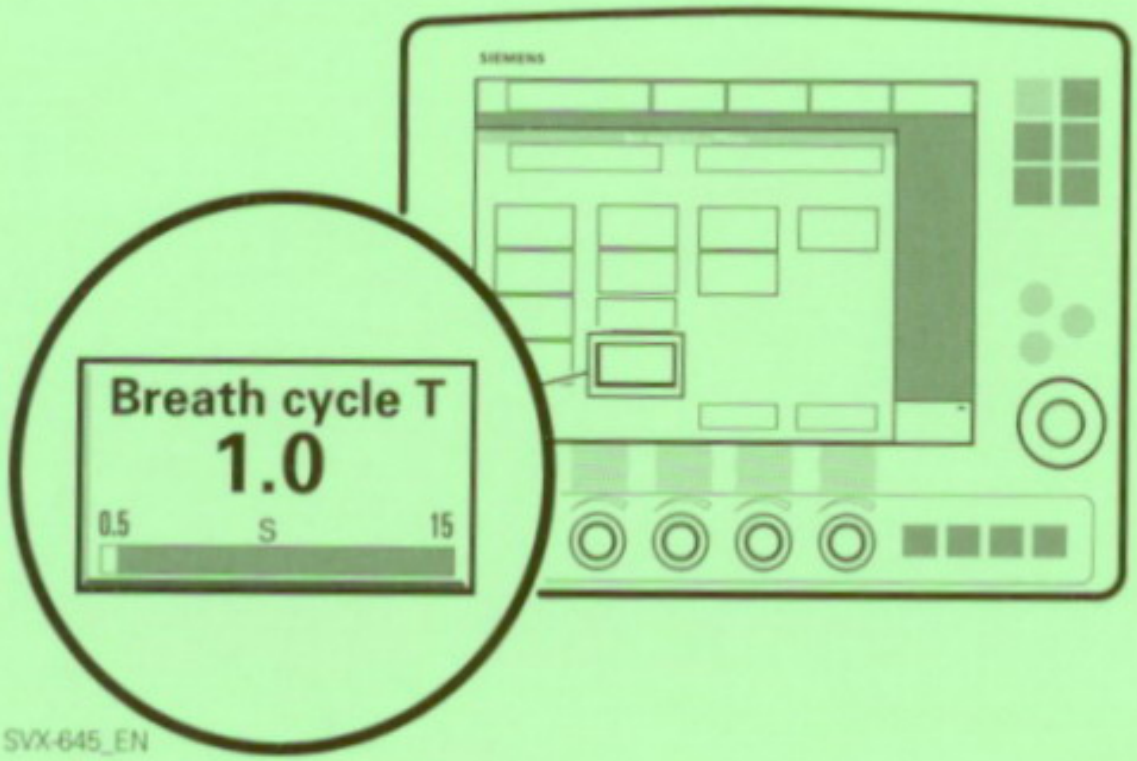
In the supported modes of ventilation a decrease of the inspiratory flow to a preset level causes the ventilator to switch to expiration. This preset level is measured as a percentage of the maximum flow during inspiration.The range off *Inspiratory cycle-off* is 1 - 40%.



Range 0-20%
Default 5%

In seconds PS, VS, and Bi-vent
Adult 0 ~ 0.4 sec
Infants 0~ 0.2 sec

Breath cycle time

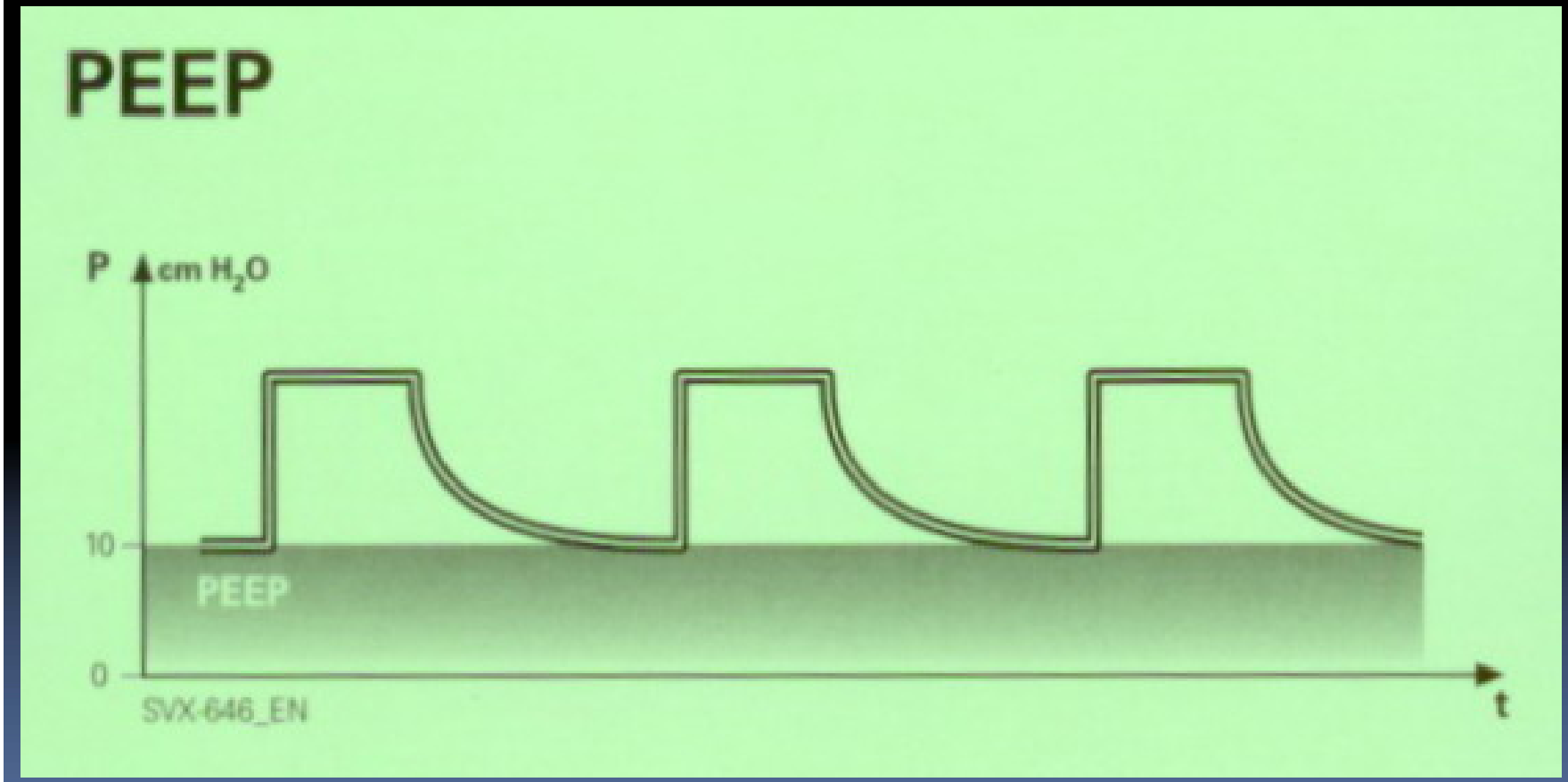


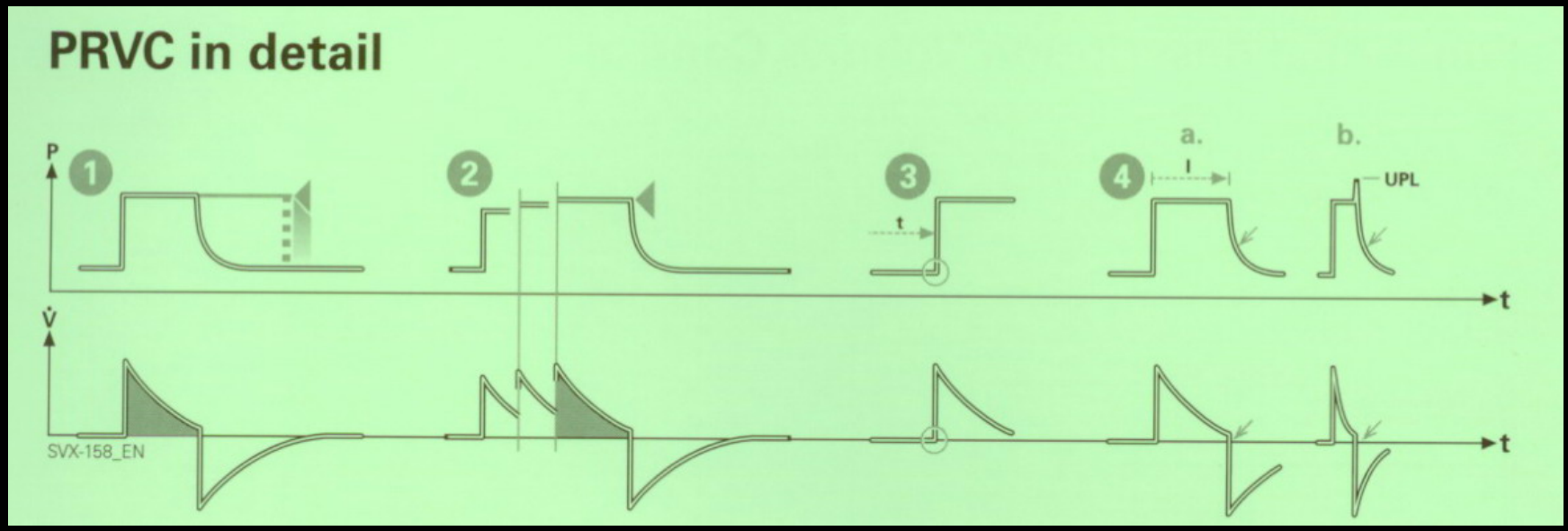
- This is the length of the breath i.e. the total cycle time of the mandatory breath in SIMV (inspiration, pause plus expiration).
- This is set in seconds within the range
- Infants 0.5 ~ 15 seconds in half second steps
- Adults 1 – 15 seconds in one second steps
- This default setting for infants is 1 second and for adults is 4 seconds

Trigger Timeout

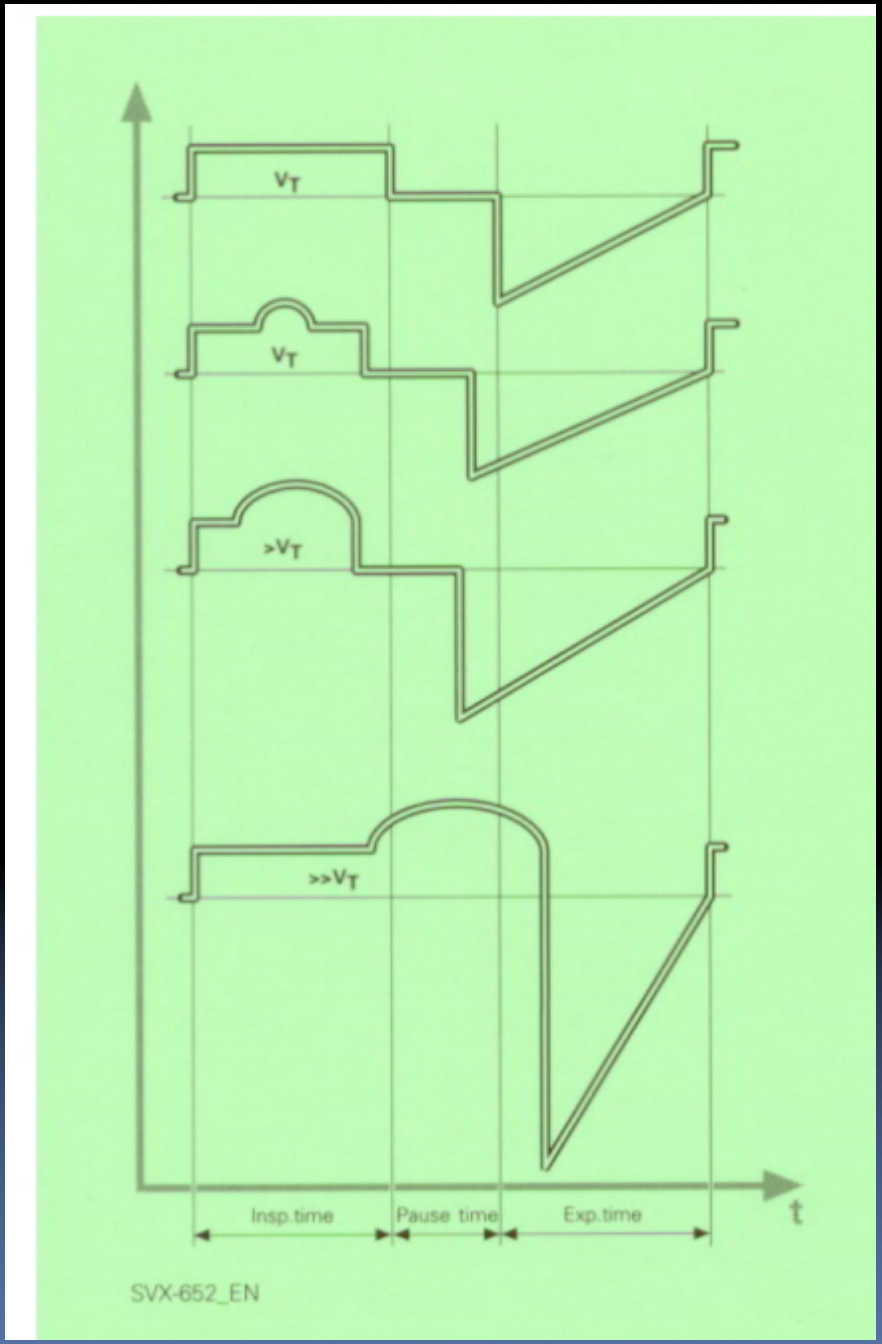
- Maximum allowed apnea time in Automode before controlled ventilation is activated
  - Infants 3-7 seconds
  - Adult 7-12 seconds

Range 0-50 cmH_2O

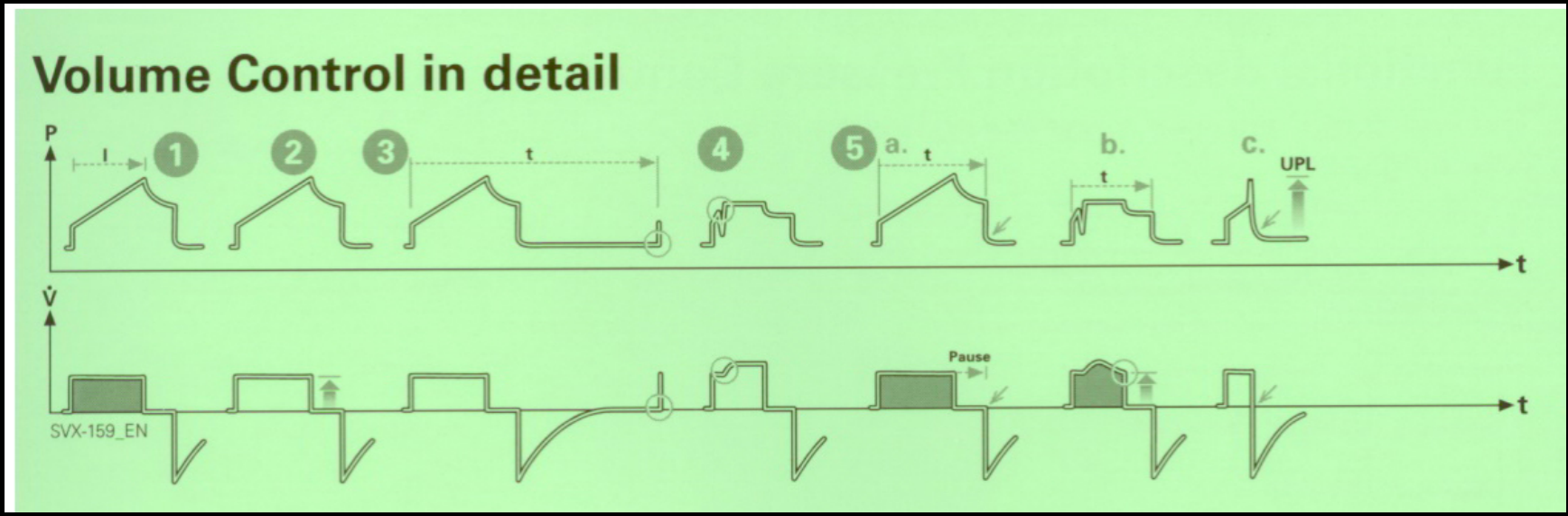




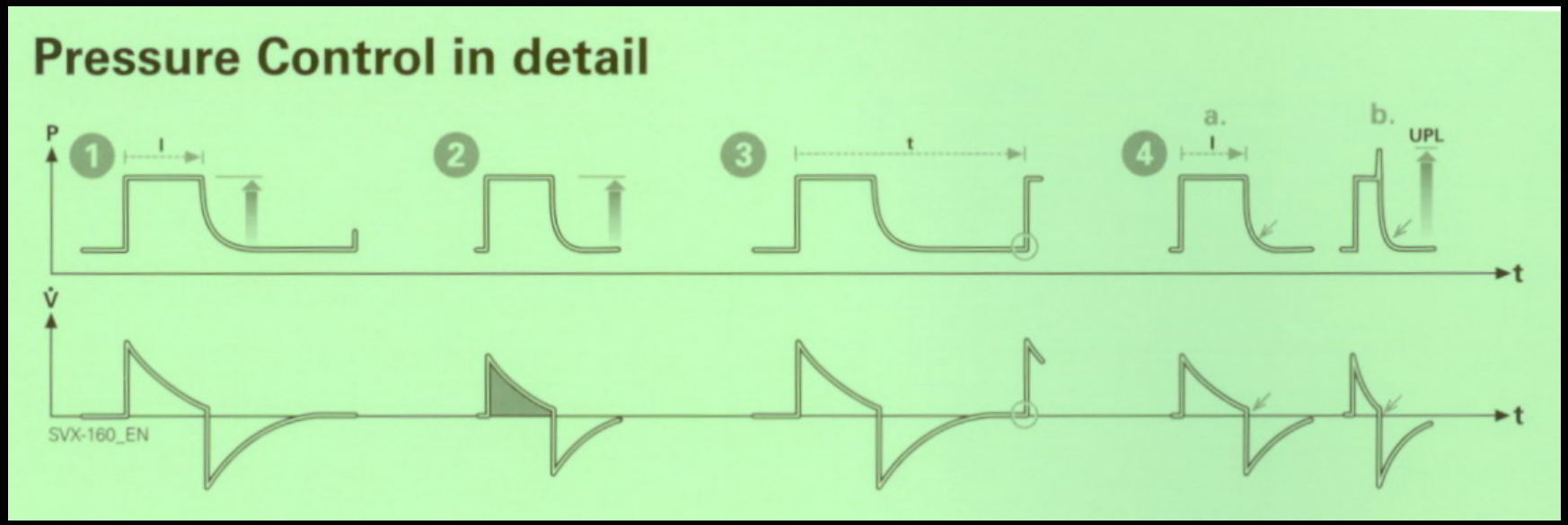
1. Target ventilation
    1. Tidal volume, frequency, and i time
2. Pressure level is constant, but automatically adapts in small increments breath by breath to match the patient.
3. Inspiration starts according to a present frequency or patient trigger
4. Expiration starts
    1. After termination of present i time
    2. If the upper pressure limit is exceeds



- Normal VC
- Inspiration prematurely interrupted as the set tidal volume is delivered.
- The patient maintains a flow rate higher than the calculated target value.
- Patient maintains the increased flow rate into the expiratory period.

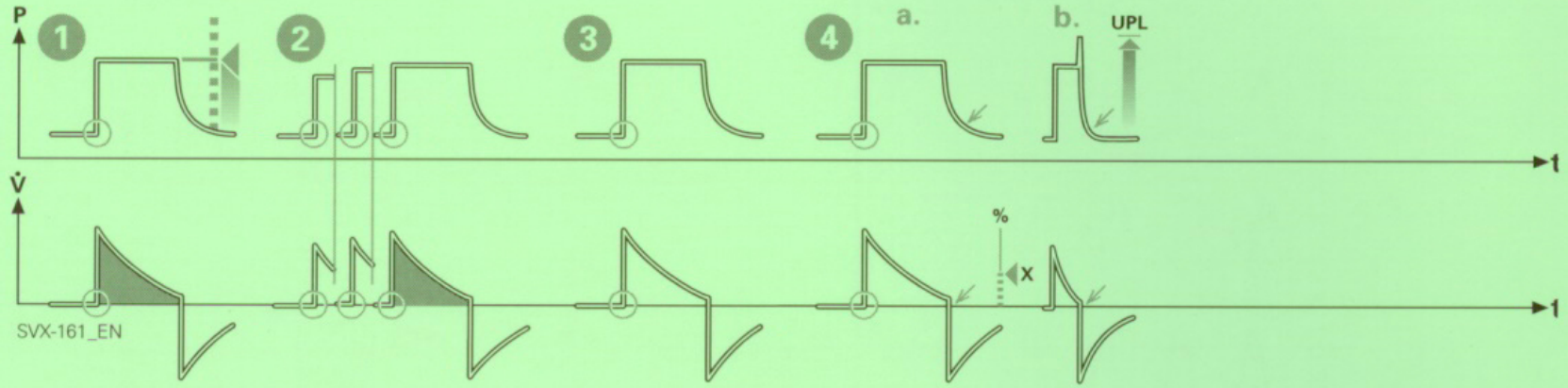


- Preset tidal volume and constant flow
- Inspiratory flow constant depends on user interface setting
- Present frequency of patient trigger
- If patient makes an inspiratory effort ventilator will switch to PS mode
- Expiratory starts
  - Tidal volume is delivered
  - Flow returns to the set value and after the preset pause time, guaranteed at least 20% expiration
  - Upper pressure limits exceeded



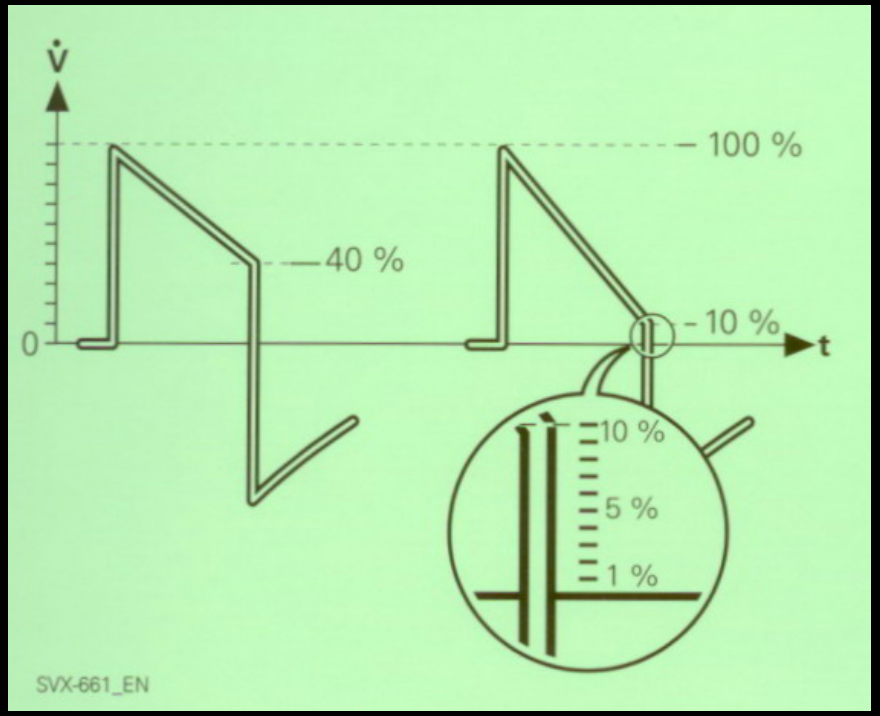
- Constant pressure
- Volume depends on the set pressure level, i time, and patient's lung mechanical property
- Inspiration starts according to the present frequency or patient triggers
- Expiration starts
  - After termination of preset i-time
  - If the upper pressure limit is exceeds

Volume Support in detail



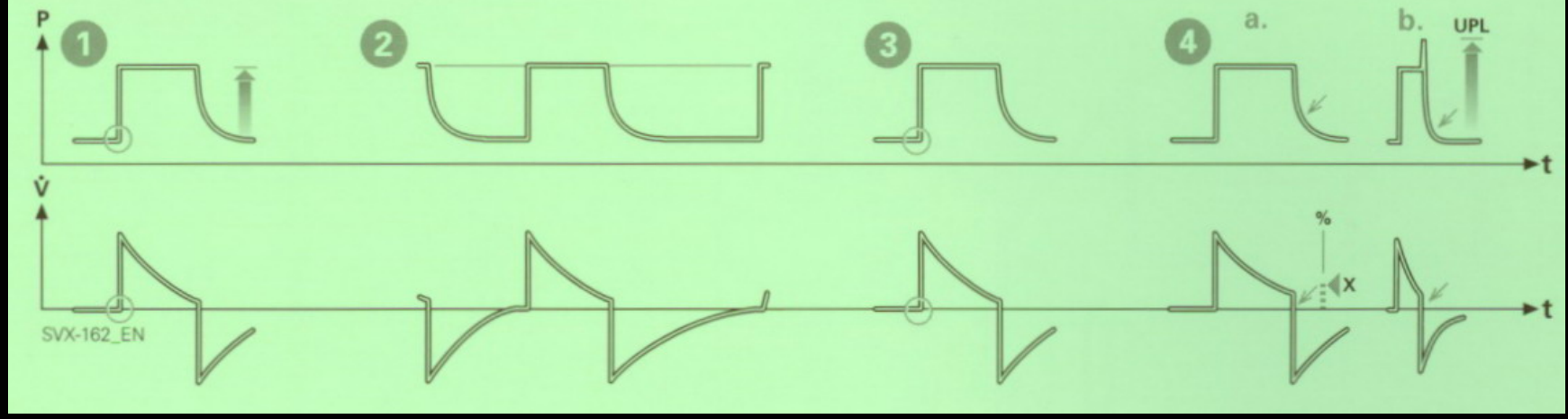
- Target tidal volume by an adapted pressure support
- Inspiratory pressure constant
- Starts when patient triggers.
- Expiration starts
  - Inspiratory flow decreases below a preset fraction of the peak flow (inspiratory cycle off)
  - If the upper pressure limit is exceeded
- Maximum time for inspiration
  - Infants 1.5 seconds
  - Adult 2.5 seconds

Inspiration Cycle-off

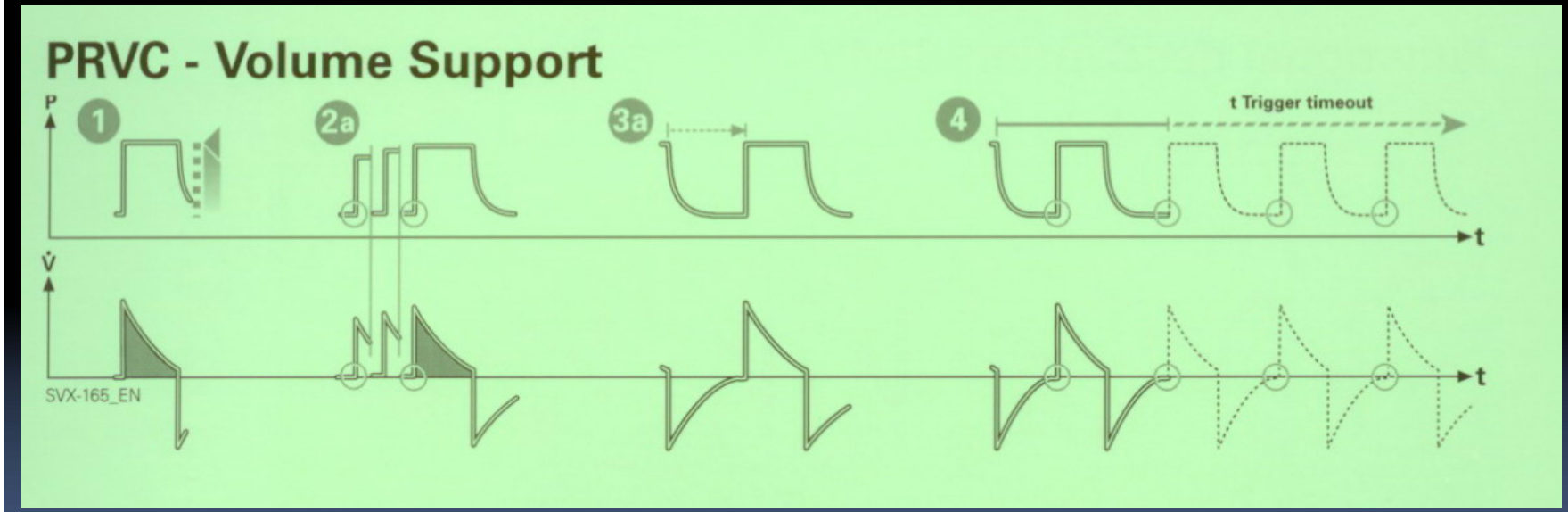


- Important for patient's comfort and ventilator synchronization
- A patient with expiratory resistance the Cycle-off should be set to a high level
- Expiration starts when:
  - Inspiratory flow decreases to the pre-set cycle-off level
  - Upper pressure limit exceeded
  - Flow drops to a flow range between 25% of the peak flow and lower limit for inspiratory cycle-off and the spent time within the range exceeds 50% of the time spent in between the start of the inspiration and entering this range

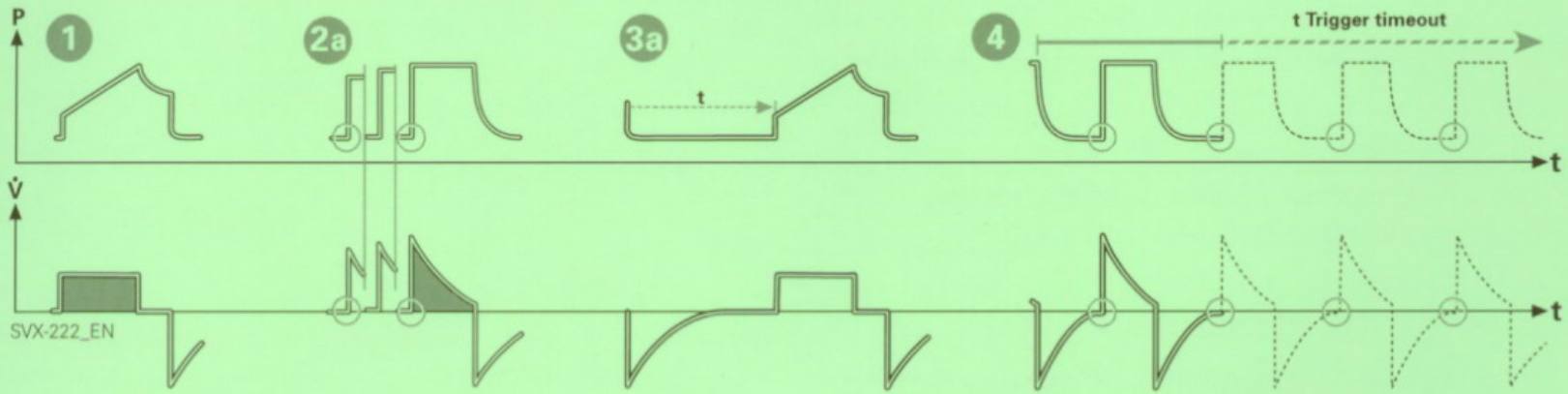
Pressure Support in detail

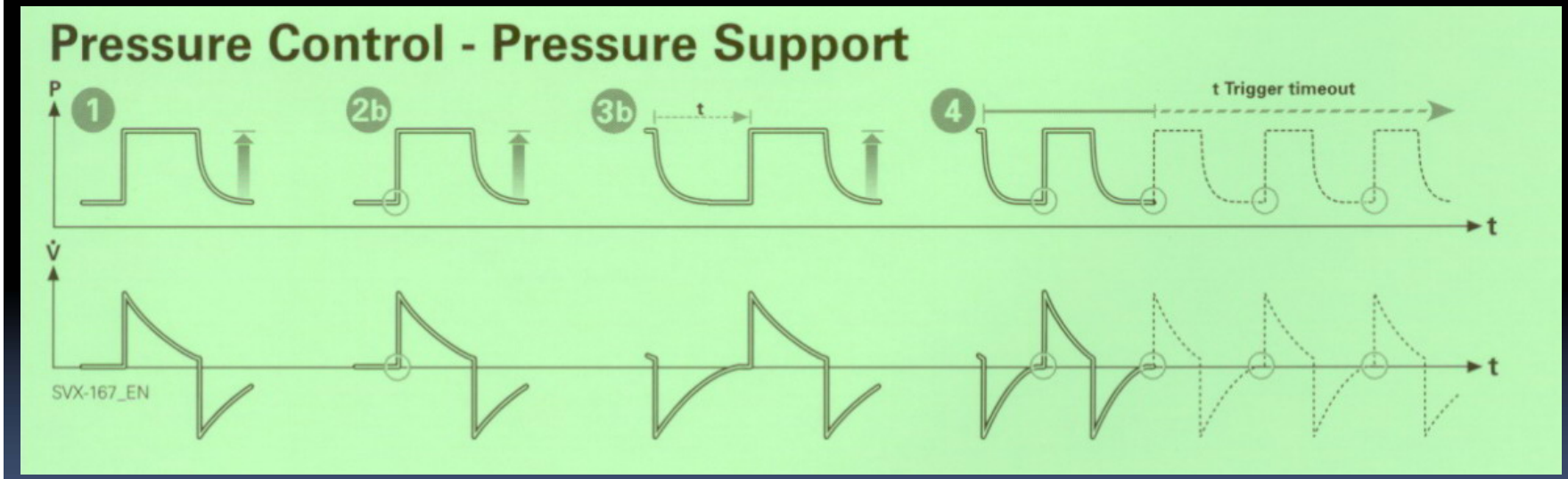


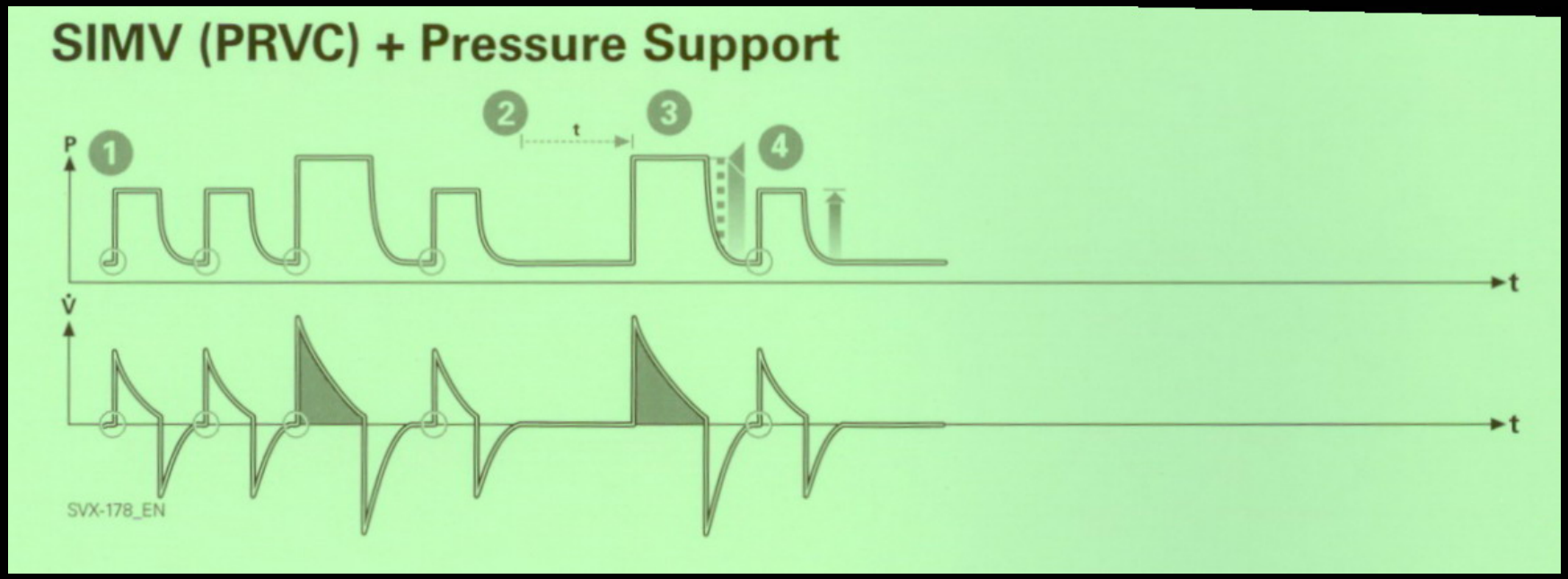
- Preset inspiratory pressure level
- Patient determines frequency and i-time
- Inspiration starts when patient trigger
- Expiration starts
  - When flow decreases to Cycle-off level
  - Upper pressure limit exceeds
- Maximum time
  - Infants 1.5 sec
  - Adult 2.5 sec


PRVC - Volume Support
P
1
2a
3a
4
t Trigger timeout
t
V̇
t
SVX-165_EN

Volume Control - Volume Support

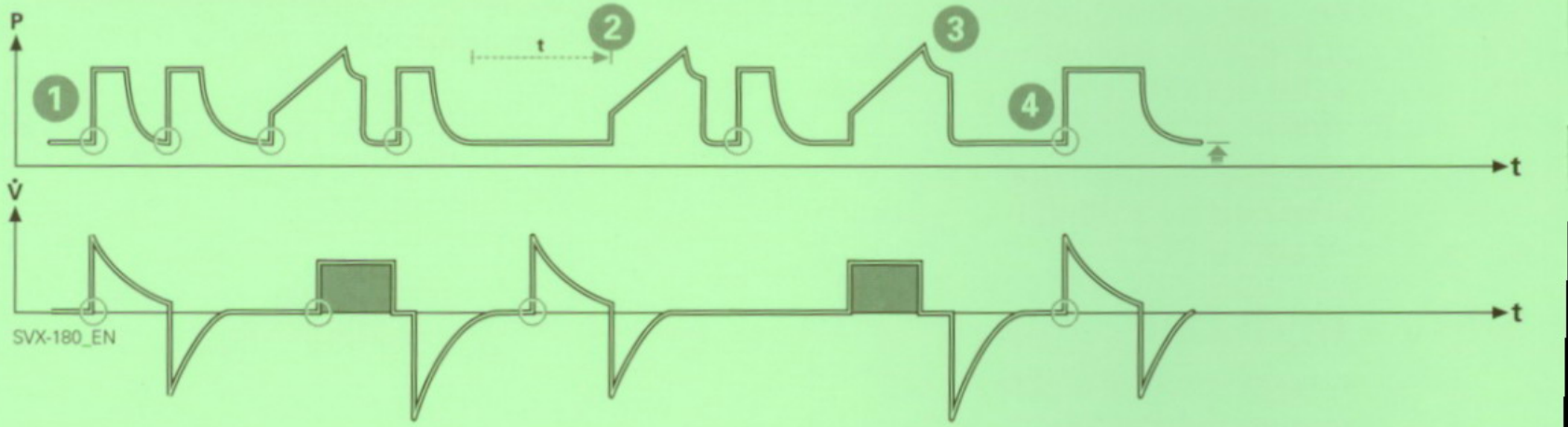



Pressure Control - Pressure Support
P
1
2b
3b
t
4
t Trigger timeout
t
V̇
t
SVX-167_EN

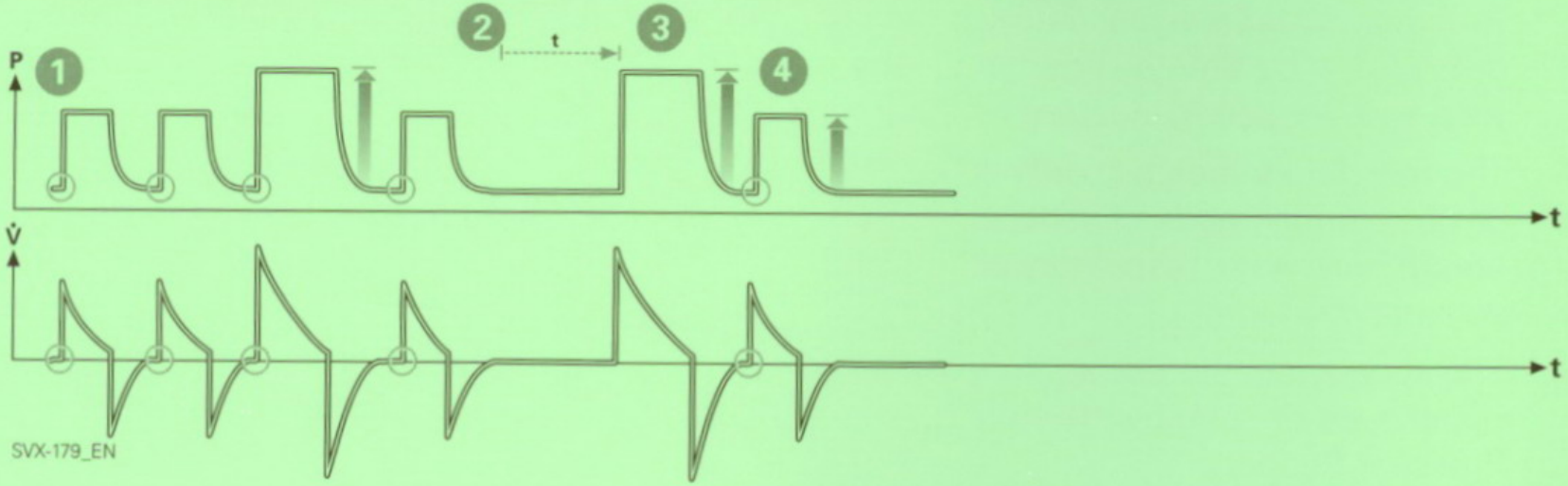


- Synchronized with patient's breathing
- If no trigger attempt within a time window equal to 90% of the set breath cycle (breath cycle time)
- The mandatory breath is defined by the basic setting
- The spontaneous/pressure supported breaths are defined by the setting for Pressure Support.

SIMV (Volume Control) + Pressure Support



SIMV (Pressure Control) + Pressure Support.



3 Ventilatory parameters

When a ventilation mode is selected, the only parameters shown are those affecting the actual mode.
Below are all the mode-related parameters presented.

1. Respiratory rate (RR) Rate of controlled mandatory breaths or used for calculation of target volume (b/min).

2. Tidal volume (V_T) Volume per breath or target volume (ml).
Minute volume (V_{min}) Volume per minute or target Minute volume (ml/min or l/min). Presentation can be configured to either tidal or minute volume.

3. PC above PEEP Inspiratory pressure level for each breath (cmH_2O) in Pressure Control.

4. PS above PEEP Inspiratory pressure support level for triggered breaths (cmH_2O) in Pressure Support.

5. Inspiratory rise time (T inspiratory rise) Time to full inspiratory flow or pressure at the start of each breath, as a percentage of the breath cycle time (%), or in seconds (s).

6. I:E ratio (I:E)
(Inspiration time + Pause time): Expiration time.

7. Pause time (T pause) Time for no flow or pressure delivery (%).

8. Trigger sensitivity
a) Below zero: Trigger sensitivity is pressure dependant. The pressure below PEEP which the patient must create to initiate an inspiration (cmH_2O) is indicated.
b) Above zero: Trigger sensitivity is flow dependent. As the dial is advanced to the right (step wise from the green into the red area) the trigger sensitivity increases i.e the inhaled fraction of the bias flow leading to triggering is reduced.

9. PEEP Positive End Expiratory Pressure (cmH_2O).

10. Inspiratory cycle-off Fraction of maximum flow at which inspiration should switch to expiration (%).

11. Breath cycle time (Breath cycle T) Total cycle time per mandatory breath in SIMV (inspiratory + pause + expiratory).
Set in seconds.

12. SIMV rate Rate of controlled mandatory breaths (b/min).

13. Trigger timeout The maximum allowed apnea time in Automode, after which the system switches to controlled ventilation (s).

– **O_2 concentration (O_2 Conc.)**
O_2 concentration in inspiratory gas.
(not shown in the figure)

14. Time$_{High}$ (T_{High}) Time at P_{High} level in Bi-Vent (s).

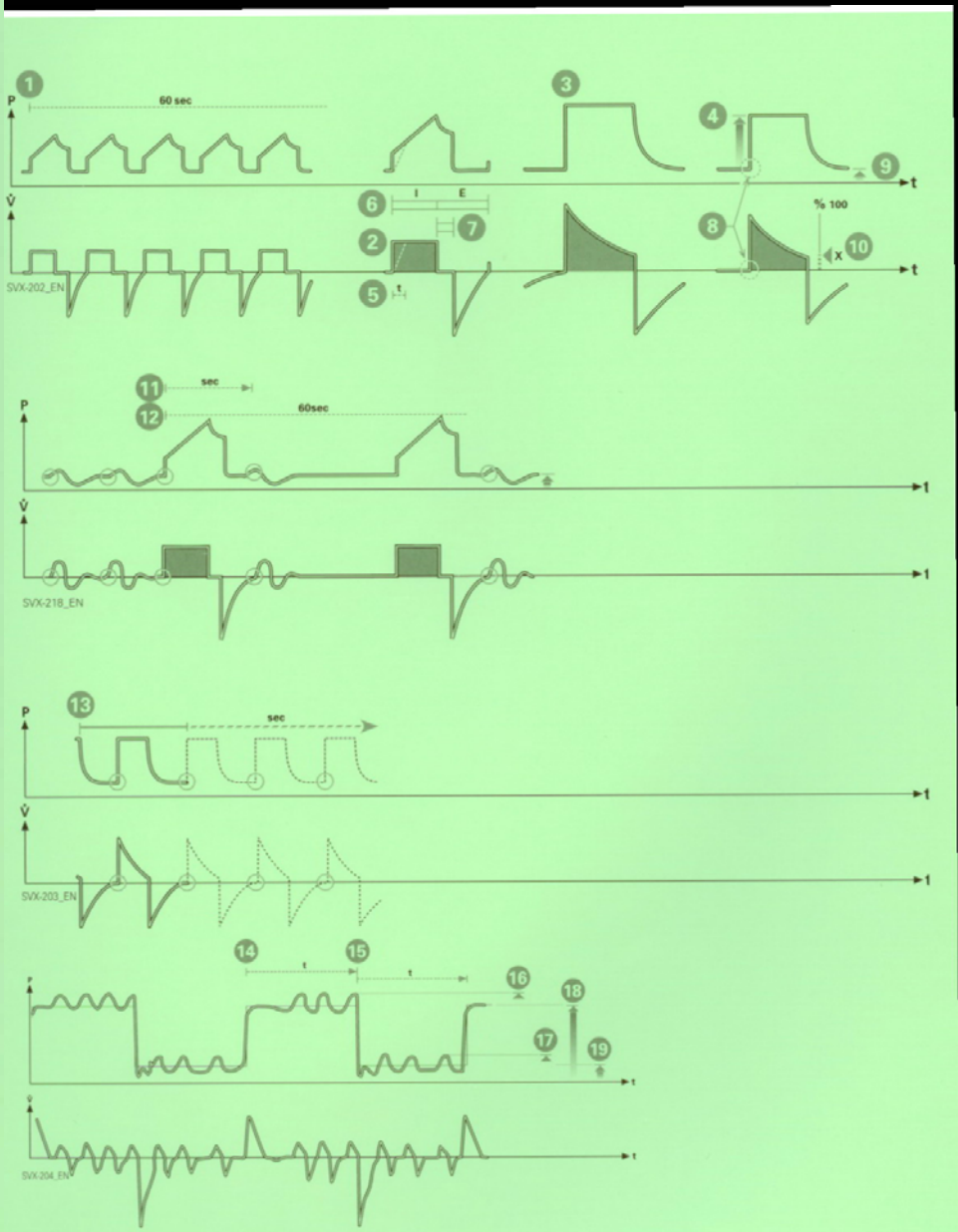
15. Time$_{PEEP}$ (T_{PEEP}) Time at PEEP level in Bi-Vent (s).

16. Pressure Support above P_{High} (PS above P_{High}) Inspiratory pressure support level for breaths triggered during the $Time_{High}$ period in Bi-Vent (cmH_2O).

17. Pressure Support above PEEP (PS above PEEP) Inspiratory pressure support level for breaths triggered during the $Time_{PEEP}$ period in Bi-Vent (cmH_2O).

18. Pressure$_{High}$ (P_{High}) Positive End Expiratory Pressure at the upper level in Bi-Vent (cmH_2O).

19. PEEP Positive End Expiratory Pressure at the lower level in Bi-Vent (cmH_2O).



References

- Servoi ventilator system V. 1.2 Use's Manual
  - Siemens-Elema AB, Electromedical Systems Division, 2002