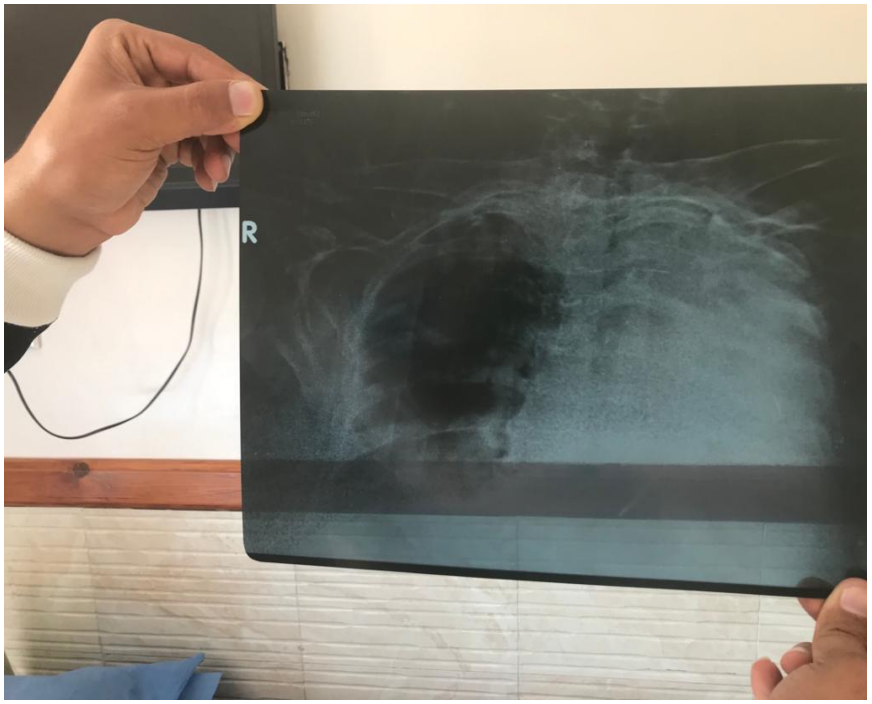
One of the main goals of the physiotherapist and respiratory therapist in the ICU is to prevent and treat respiratory complications in critically ill patients related to pulmonary secretion retention and atelectasis.

In the mechanically ventilated patient, the primary mechanisms of secretion clearance (ie, mucociliary transport and cough) are impaired. The presence of the artificial airway, poor humidification of inspired gases, and relative immobility .

Table 2 Time (hours) required for physiotherapy interventions in uncomplicated and complex situations

Intervention	Time (h)	
	Uncomplicated patient	Acutely unwell or complex patient
Initial assessment of all patients includes: ► History ► Physical examination ► Investigations and results ► Interpretation of imaging ► Tests of mobility, function or exercise capacity	0.5–0.75	1
Airway clearance techniques Initial exploration and teaching of appropriate technique	0.5–0.75	1
Airway clearance techniques Follow-up/review	0.25–0.5	0.5–1
Breathlessness management	0.50	0.75
Self-management/education	0.25	0.50
Individual help with mobility, physical activity/ exercise	0.50	1
Formal exercise test ± mobility aids	0.25–0.50	0.75–1
Ambulatory oxygen assessment	1	1.25–1.45
Non-invasive ventilation CPAP, NIV, IPPB: set up	1	1
Non-invasive ventilation CPAP, NIV, IPPB ongoing	0.50	1
Special interventions, eg: ► Bronchoconstriction trials ► Induced sputum ► Hypertonic NaCl trial	1	1
Pulmonary rehabilitation assessment	1 per patient or 10 per group	
Pulmonary rehabilitation 8-week programme	10/patient/programme, or 100/group or programme	

CPAP, continuous positive airway pressure; IPPB, intermittent positive pressure breathing; NIV, non-invasive ventilation.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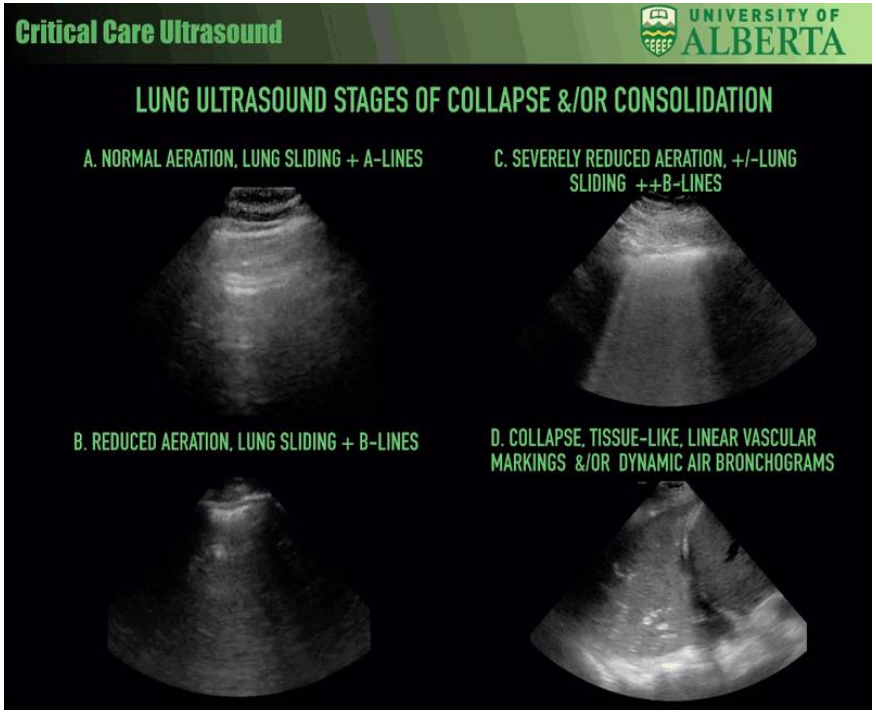
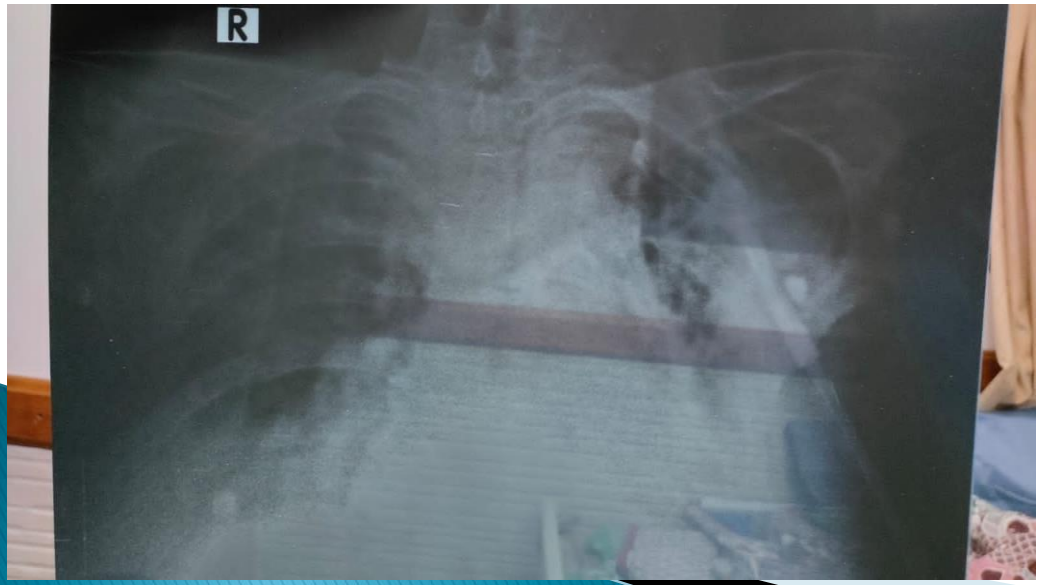

Critical Care Ultrasound
UNIVERSITY OF ALBERTA
LUNG ULTRASOUND STAGES OF COLLAPSE &/OR CONSOLIDATION
A. NORMAL AERATION, LUNG SLIDING + A-LINES
C. SEVERELY REDUCED AERATION, +/-LUNG SLIDING ++B-LINES
B. REDUCED AERATION, LUNG SLIDING + B-LINES
D. COLLAPSE, TISSUE-LIKE, LINEAR VASCULAR MARKINGS &/OR DYNAMIC AIR BRONCHOGRAMS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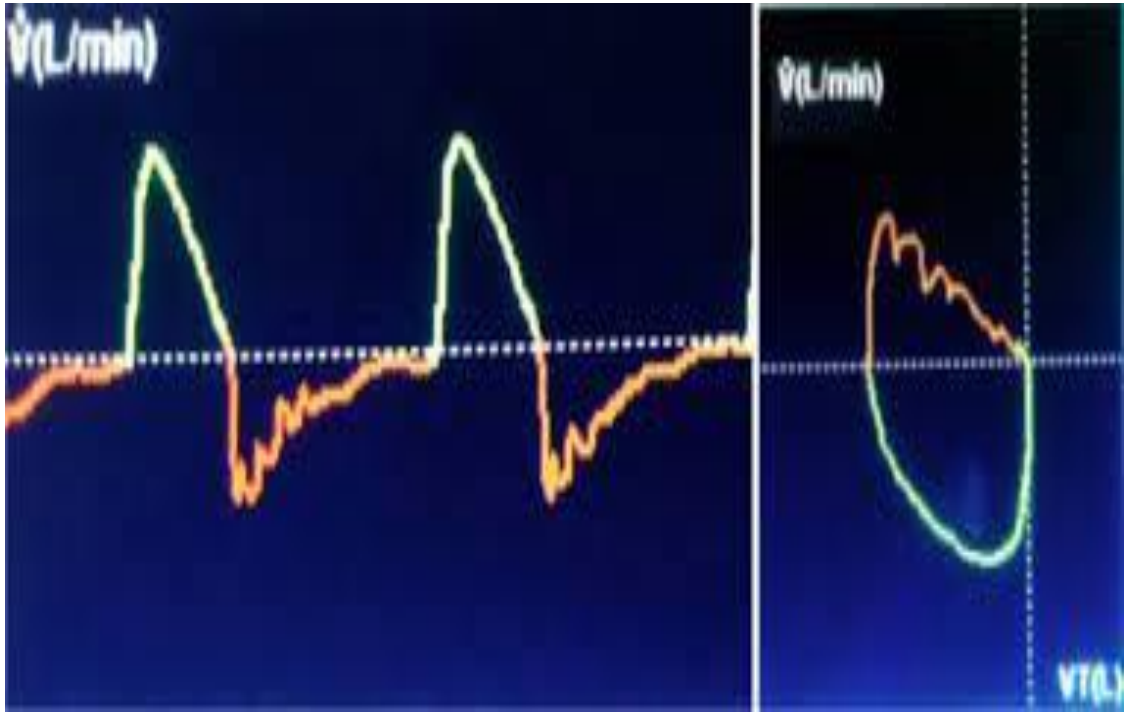


Auto-triggering

Table: Main asynchronies and their description.

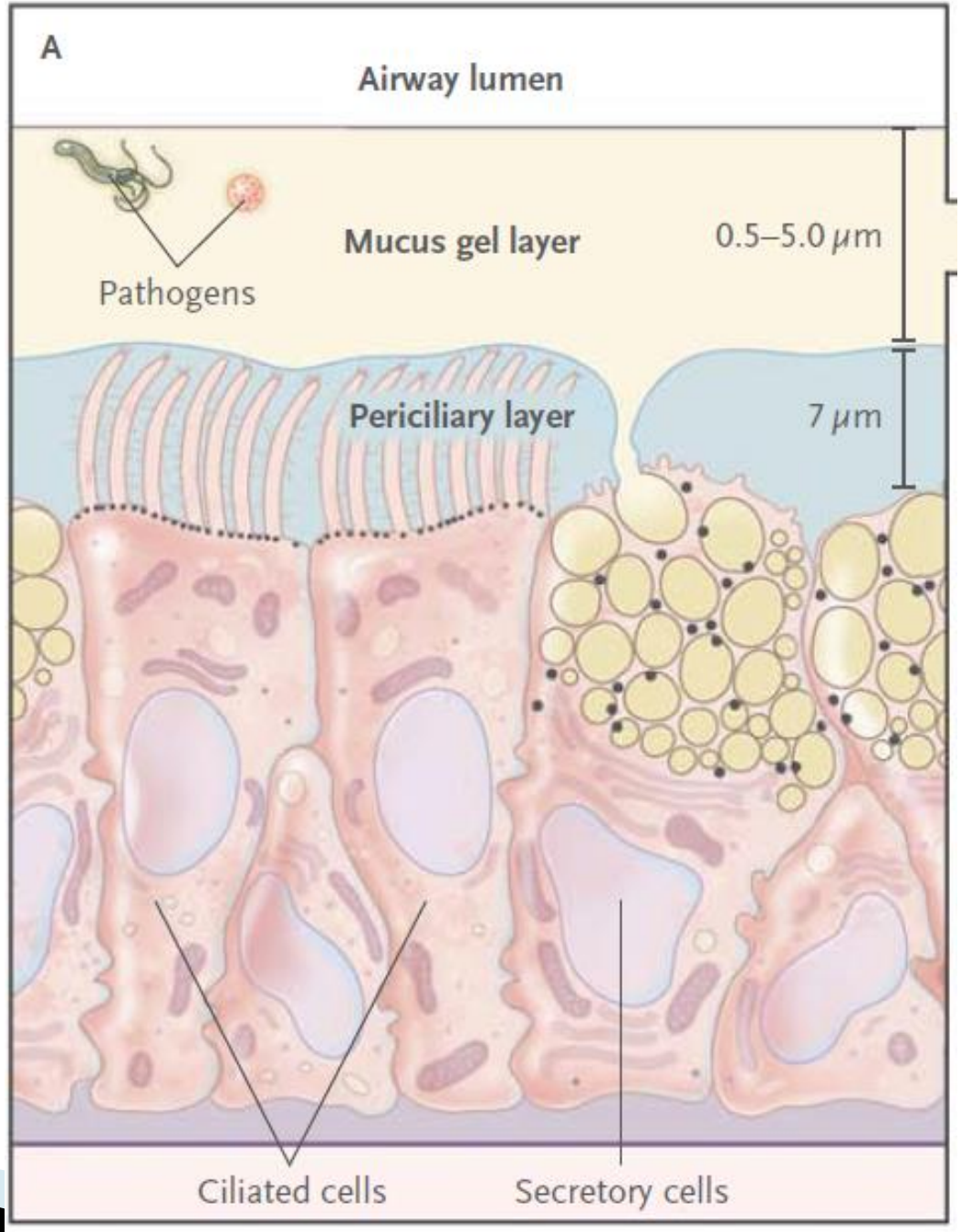
Asynchronies	Description	Related to
Inspiratory effort	Patient inspiratory effort not followed by a ventilator-delivered pressurization.	Triggering
Double triggering	Two ventilator-delivered pressurizations during one single patient inspiratory effort.	Triggering
Auto triggering	Ventilator pressurization without inspiratory effort.	Triggering
Reverse triggering	Inspiratory efforts occurring near the end of each mechanical inspiration in a repetitive and consistent manner.	Entrainment
Premature cycling	Duration of pressurization shorter than the duration of patient inspiratory effort.	Cycling off
Delayed cycling	Duration of pressurization twice as long as patient inspiratory effort.	Cycling off

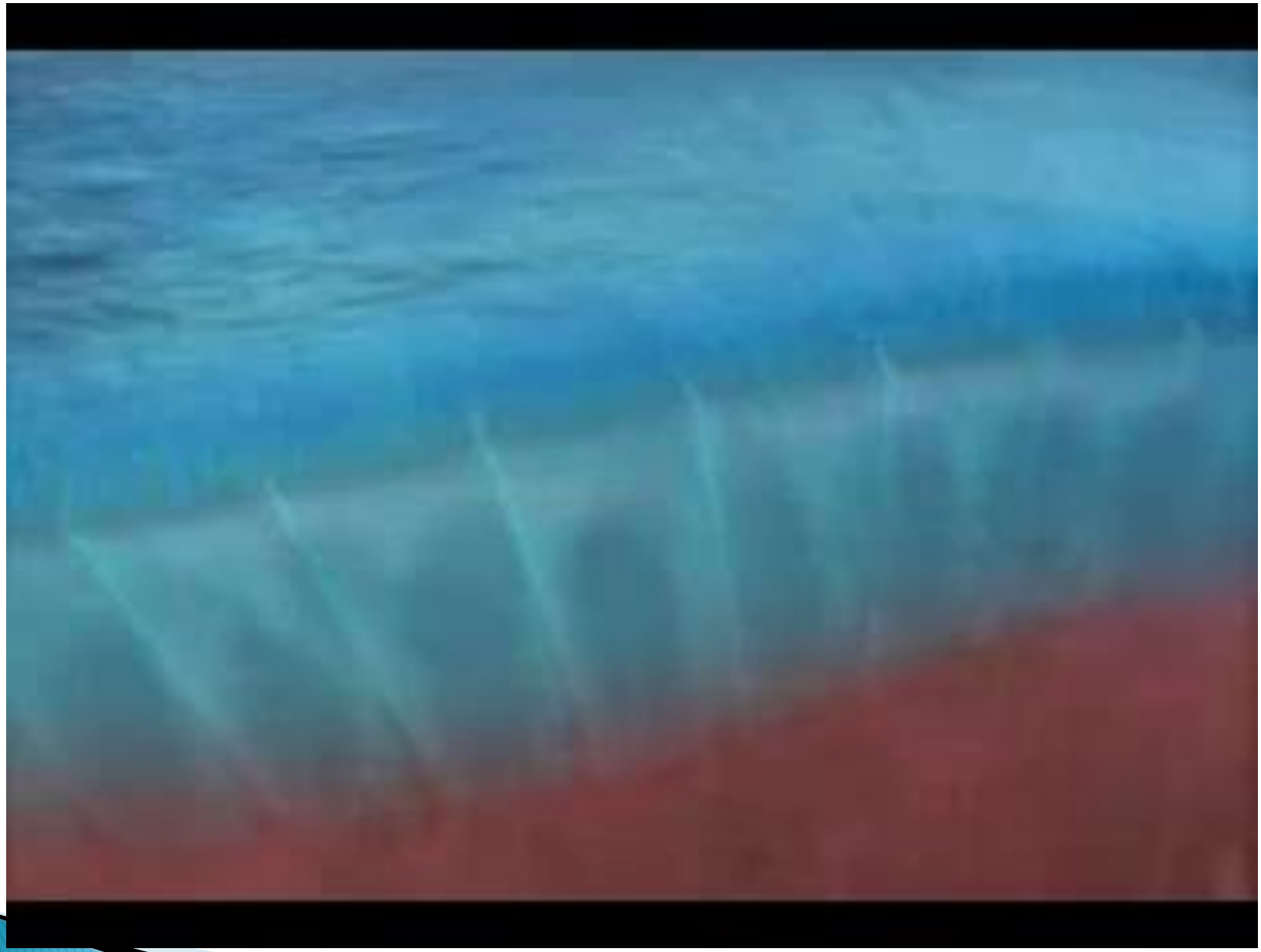
- Mucus and Normal airway clearance
- Impaired airway clearance in NM patients
- How to asses
- How to manage

Mucus

Mucociliary Transport

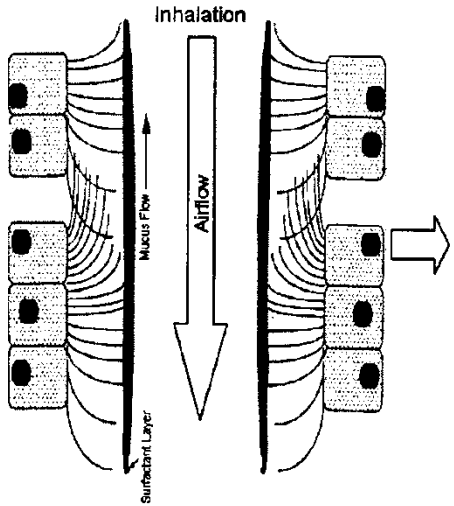
- **Gel Layer** (high viscosity and elasticity)
- **Sol Layer** (low viscosity and elasticity)

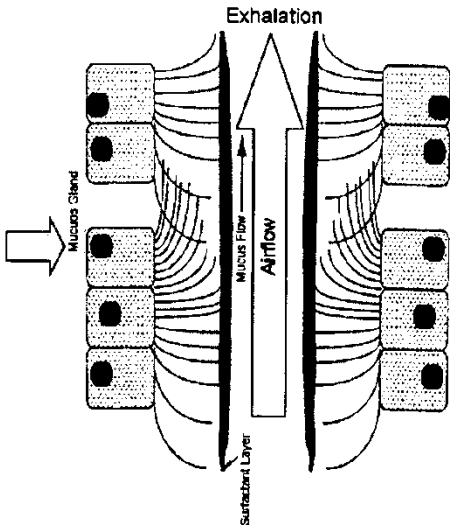




Cephalad Airflow Bias

- Decreased airway diameter during exhalation results in increased flow velocity Increased airflow velocity shears secretions and drives material in direction of flow Present in large and small airways but is the primary mechanism of transport in smaller conducting airways





A VICIOUS CYCLE

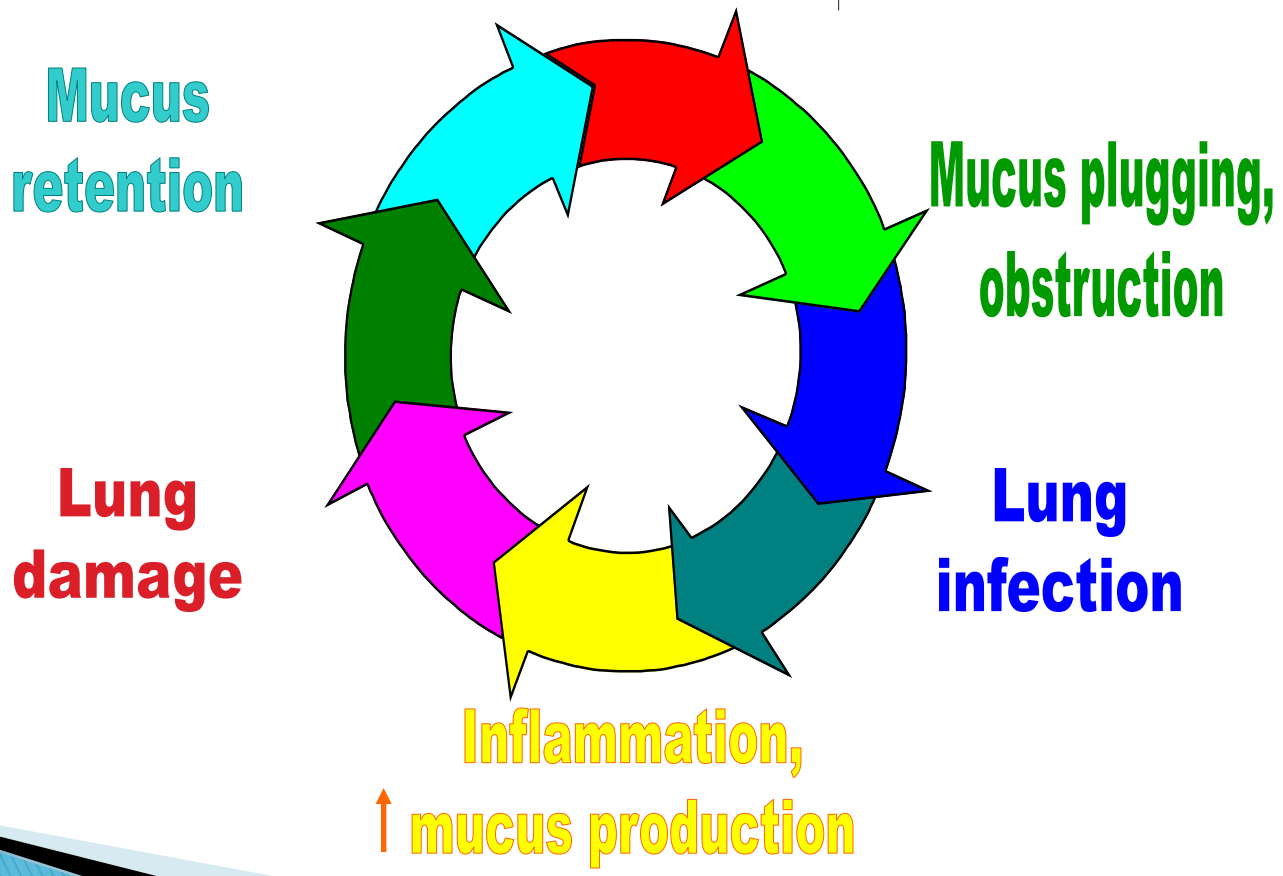
Ventilation/perfusion mismatch,

Gas-exchange impairment,

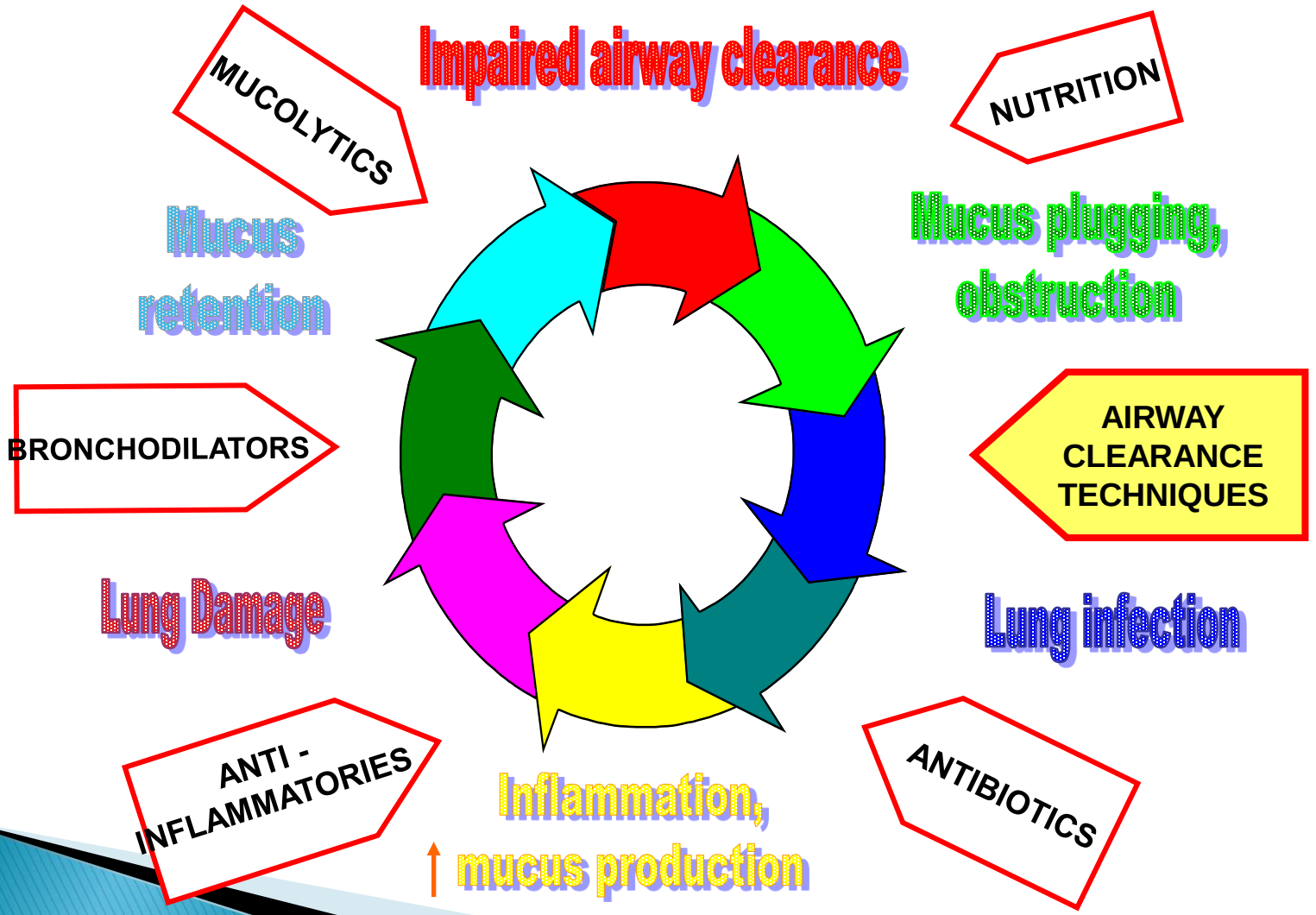
Increased work of breathing,

Mechanical ventilation dependence,

Increases the risk of pneumonia and keeps feeding this cycle.



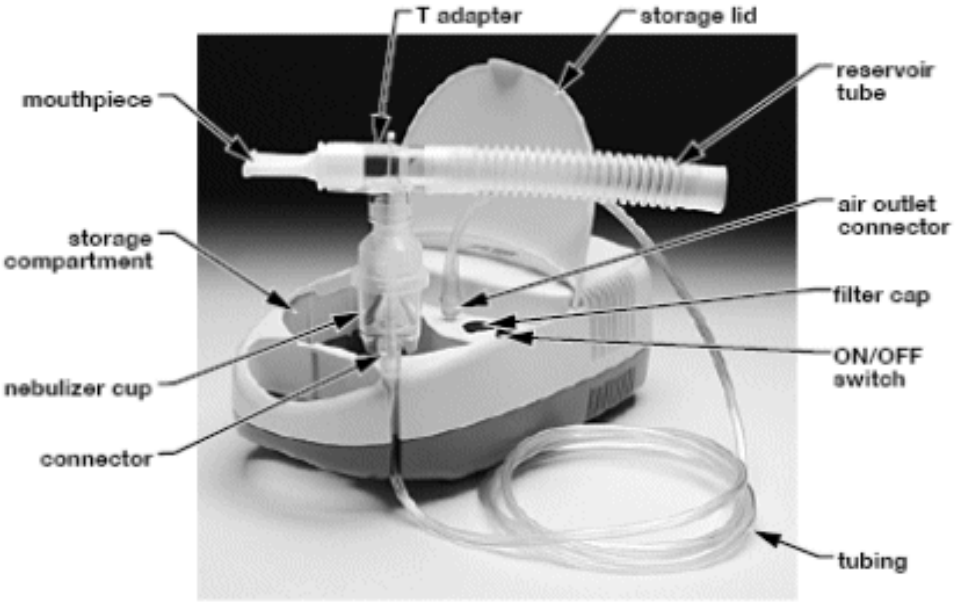
Interrupting the Vicious Cycle




Preparation
methods

- Antibiotics
- Bronchodilators
- Anti-inflammatory drugs
- Mucolytics
- Nutrition

Nebulized drugs



Neb-u-Lite LX2 Nebulizer Compressor

MUCOLYTICS

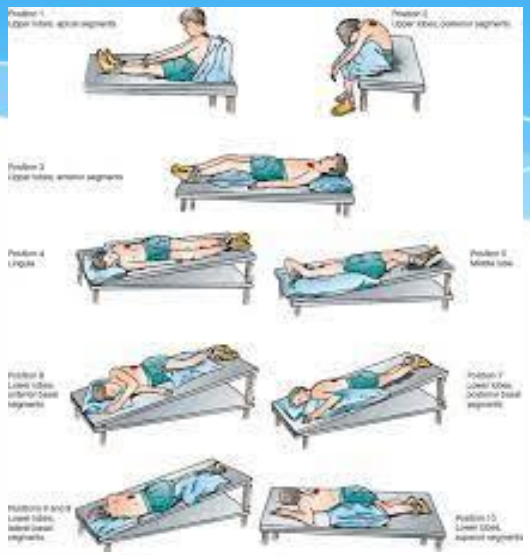
- **Mucomyst (acetylcysteine)**
  - Breaks disulfide bonds
  - Airway irritant
- **Pulmozyme (dornase alfa or DNase)**
  - Targets extracellular DNA in sputum
  - Specifically developed for cystic fibrosis
- **Hypertonic saline**
  - Sputum induction
  - Australian studies

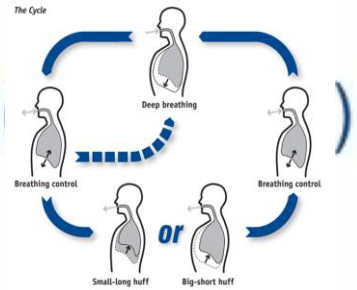
Listing of mucolytic agents

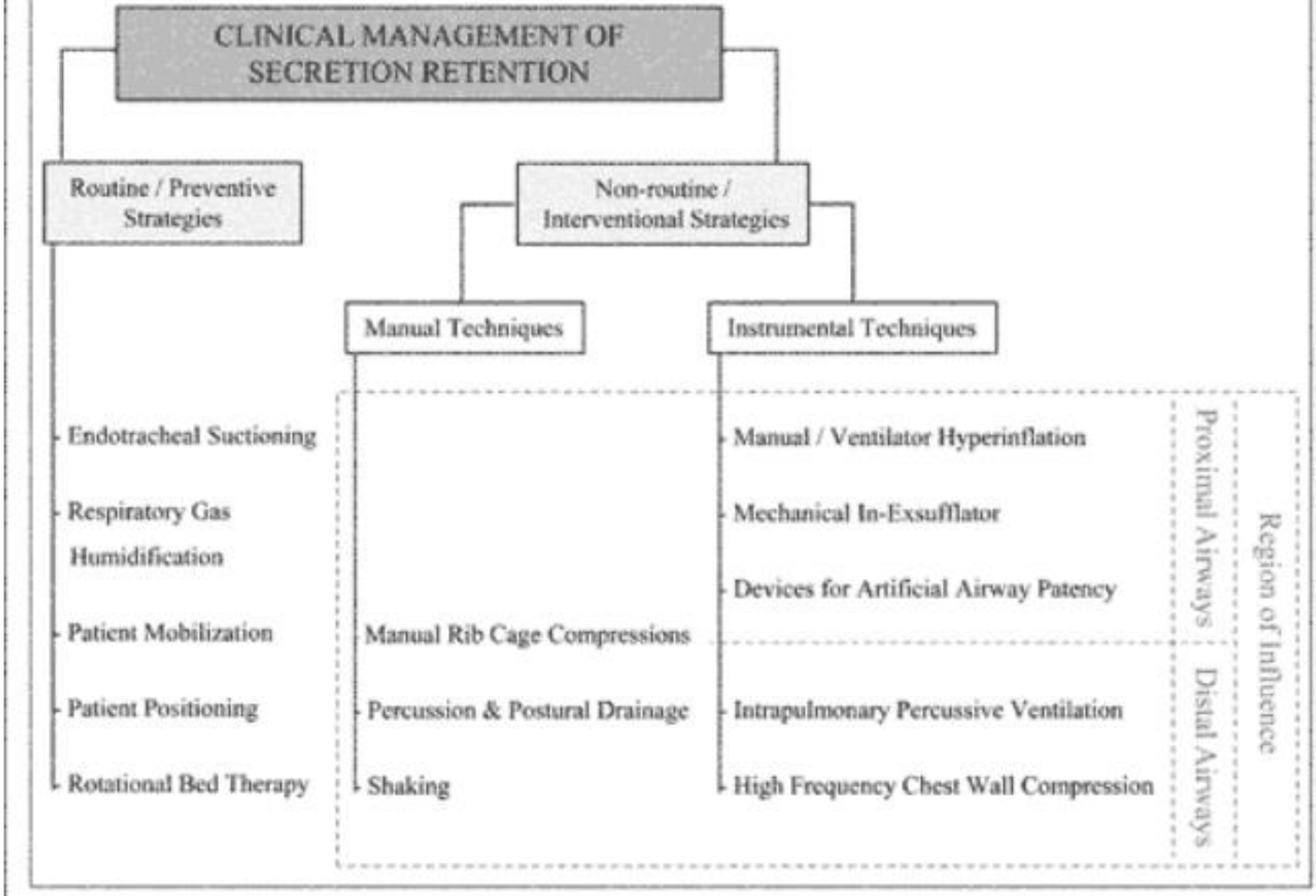
Generic name	Brand name	How it is given	Dosage
Erdosteine	**Erdostin**	Capsules, syrup	300 mg twice daily
	Mucotec	Capsules, syrup	300 mg twice daily
Acetylcysteine	**Bronkyl**	Tablets	200 mg twice daily
	Fluimucil	Tablets	600 mg daily
	Mucomyst	Tablets Liquid solution	200 mg twice daily
Bromheksin	**Bisolvon**	Tablets Liquid solution	8-16 mg, 4 times daily 6-10 mL of 10%, or 3-5 mL of 20% every 6-8 hrs.
Carbocysteine	**Mucodyne**	Syrup, capsules	375 mg
Guiafenesin	**Breonesin**	capsules	200-300 mg 4 times daily
	Guiatuss	Tablets Liquid solution	200-400 mg or 30 mg, 4 times daily
	Humibid	Tablets Liquid solution	200-400 mg or 30 mg, 4 times daily
	Humibid LA		600 mg
	Hytuss	Tablets Liquid solution	200-400 mg or 30 mg, 4 times daily
	Robitussin	Tablets Liquid solution	200-400 mg or 30 mg, 4 times daily
	Solvipect	Liquid solution	200 mg, 3-5 times daily
iodinated glycerol	**Expigen**		

Bronchial hygiene techniques

* Postural drainage
* Percussion & vibration
* Directed cough
* Forced expiratory technique (
* Active cycle of breathing
* Autogenic drainage
* Positive expiratory pressure

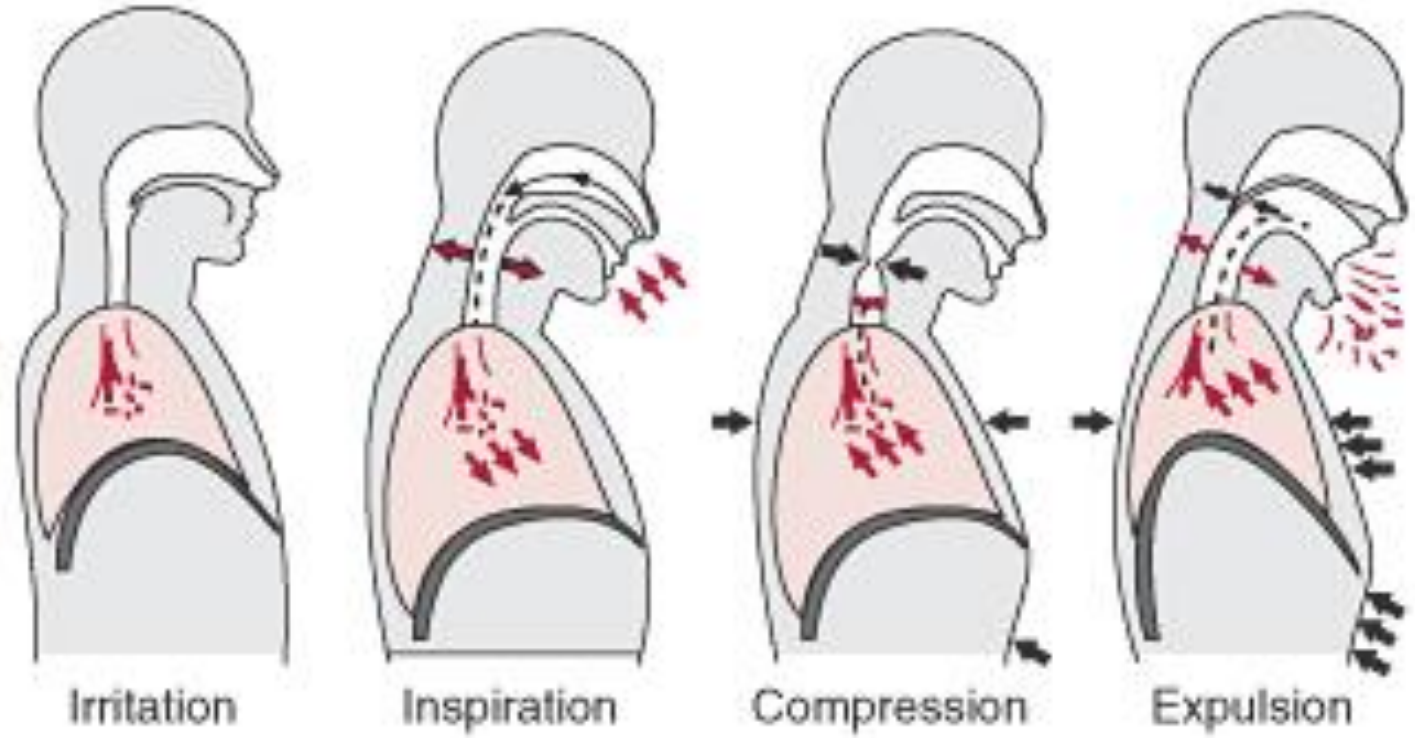






Retained airway secretions in patients who are intubated and mechanically ventilated may be managed using the above preventive and interventional strategies

FOUR PHASES OF COUGH

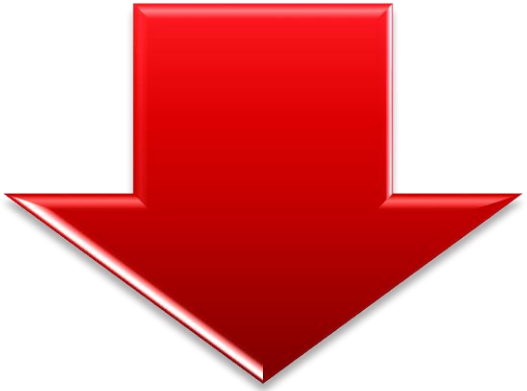


Airway Clearance Techniques

DEFINITION

ACTs utilize externally applied forces and manipulation of lung volumes, pulmonary pressures and gas flow with the aim of shearing sputum along the inner surface of the airway lumen towards the mouth

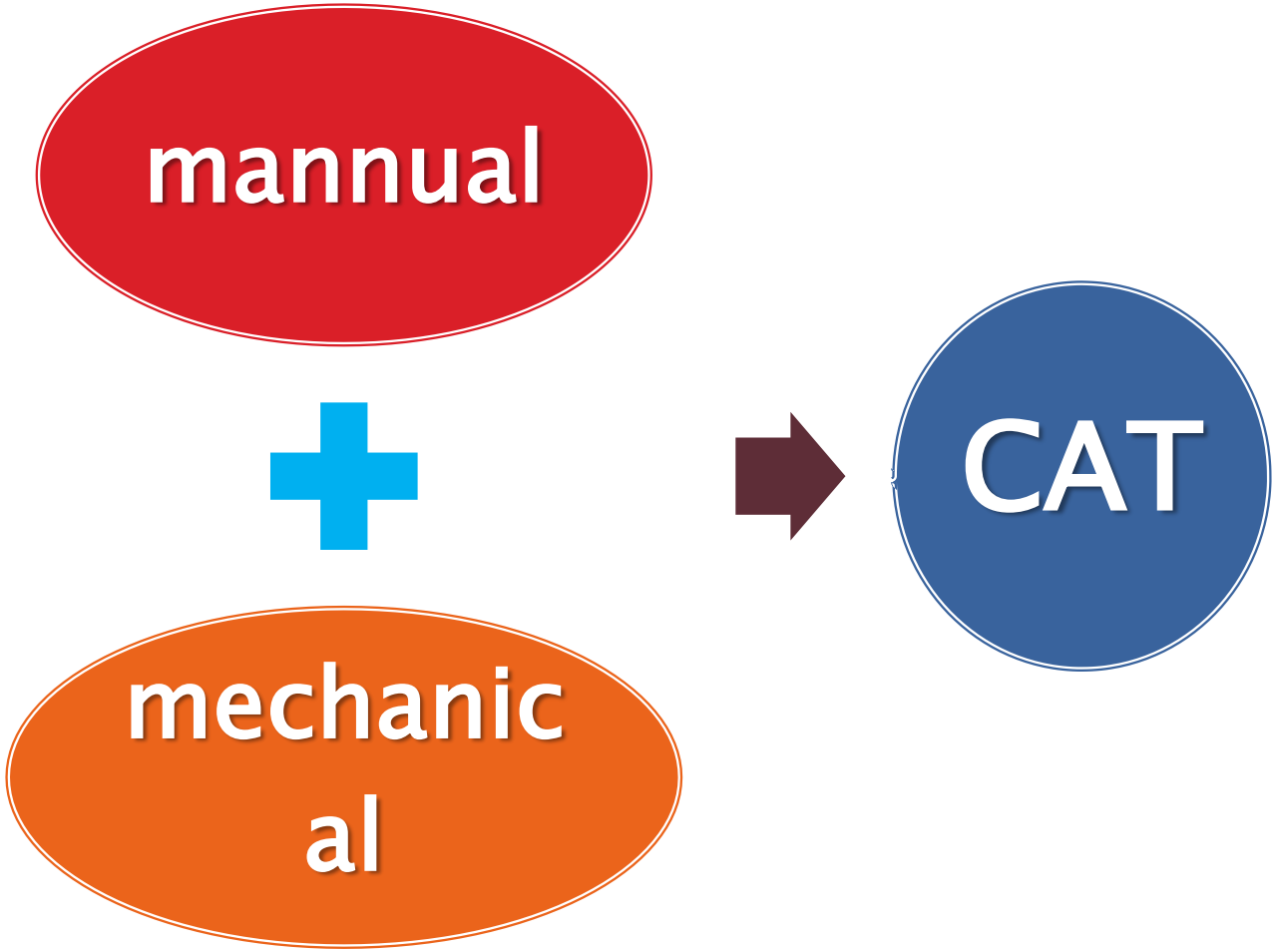

Non pharmacologic al
Pharmacologi cal



Cough augmentation therapy

Mucus mobilizing therapy

COUGH AUGMENTATION THERAPY



Stages of Airway Clearance Therapy

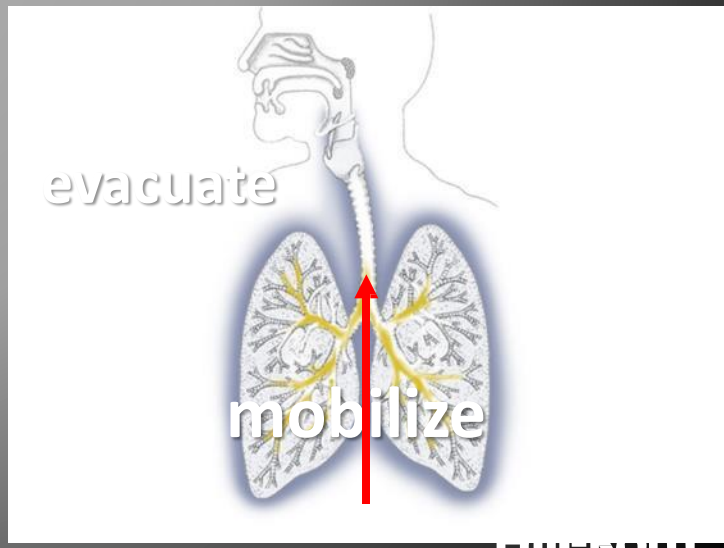
Preparation → **Mobilization** → **Evacuation** → **Evaluation**

- Nebulizers/ pharmaceuticals
- Humidification

Mechanical technique
- High Frequency Chest Wall Oscillation (The Vest®)
- Oscillatory Positive Expiratory Pressure (PEP)
- Intrapulmonary Percussive Ventilation IPV

Manual technique
- CPT / Autogenic drainage
- Active Cycle of Breathing Technique

- Self Managed/ Cough
- Cough Assist™
- Suction

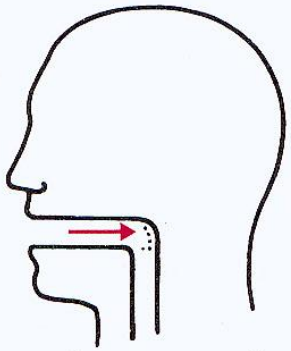


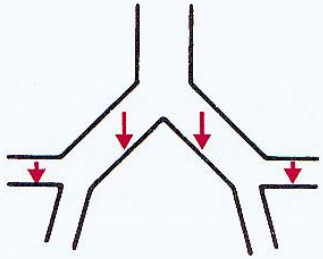
Considerations for Selecting ACT

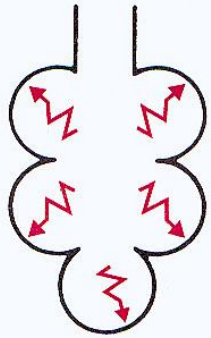
Box 40-6 Key Factors in Selecting a Bronchial Hygiene Strategy

- Patient's motivation
- Patient's goals
- Physician/caregiver goals
- Effectiveness of technique
- Patient's age
- Patient's ability to concentrate
- Ease of learning and teaching
- Skill of therapists/teachers
- Fatigue or work required
- Need for assistants or equipment
- Limitations of technique based on disease type and severity
- Costs (direct and indirect)
- Desirability of combining methods

Mechanisms of deposition of aerosol







	A	B	C
Mechanism:	Impaction	Sedimentation	Diffusion
Particle size:	Large (>5 μm)	Medium (1–5 μm)	Small (<0.1 μm)
Representative site:	Nasopharynx	Small airways	Alveoli


Mobilization
methods

MUCOLYTICS

- **Mucomyst (acetylcysteine)**
  - Breaks disulfide bonds
  - Airway irritant
- **Pulmozyme (dornase alfa or DNase)**
  - Targets extracellular DNA in sputum
  - Specifically developed for cystic fibrosis
- **Hypertonic saline**
  - Sputum induction
  - Australian studies

Listing of mucolytic agents

Generic name	Brand name	How it is given	Dosage
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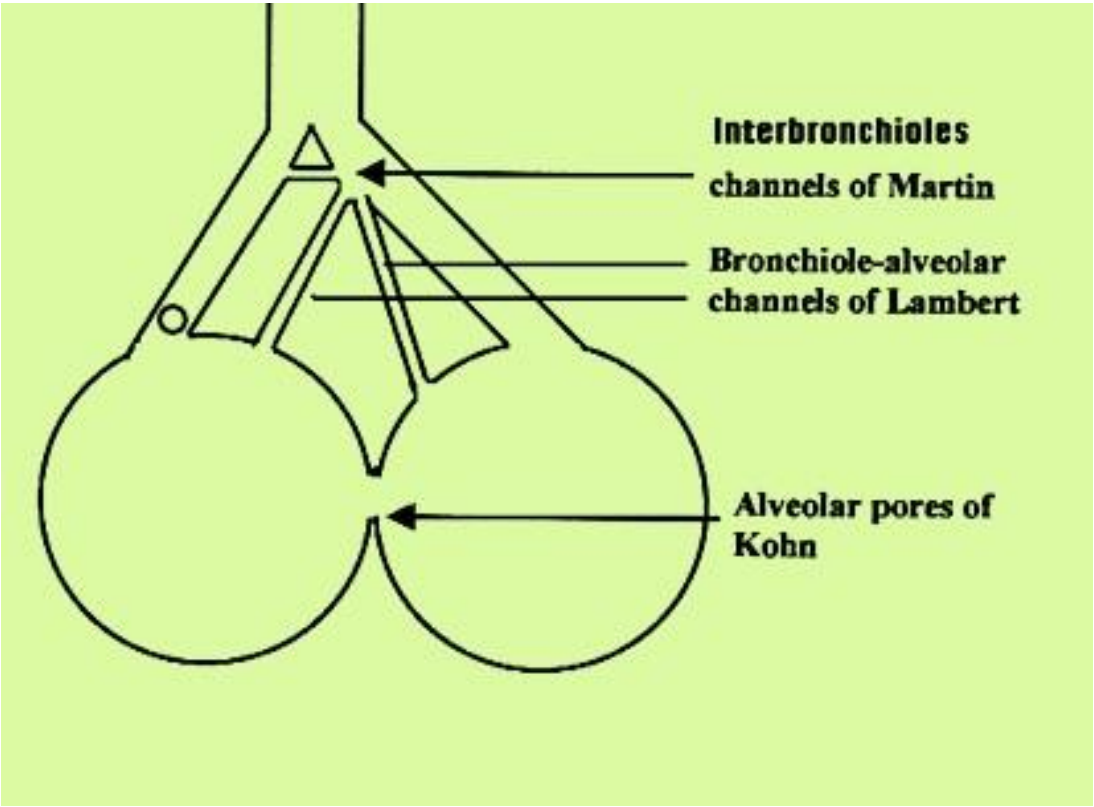
Carbocysteine	**Mucodyne**	Syrup, capsules	375 mg
Guiafenesin	**Breonesin**	capsules	200-300 mg 4 times daily
	Guiatuss	Tablets Liquid solution	200-400 mg or 30 mg, 4 times daily
	Humibid	Tablets Liquid solution	200-400 mg or 30 mg, 4 times daily
	Humibid LA		600 mg
	Hytuss	Tablets Liquid solution	200-400 mg or 30 mg, 4 times daily
	Robitussin	Tablets Liquid solution	200-400 mg or 30 mg, 4 times daily
	Solvipect	Liquid solution	200 mg, 3-5 times daily
iodinated glycerol	**Expigen**		


Mobilization
methods

- Use of gravity to aid mucus transport— postural drainage (PD).
- External application of forces against the chest wall—percussion, vibrations, shaking, high-frequency chest wall compression (HFCC).
- Breathing techniques—active cycle of breathing techniques (ACBT) and autogenic drainage (AD).
- Devices designed to introduce positive pressure and/or oscillation into the airways—positive expiratory pressure (PEP) masks, flutter, cornet, accapela, intrapulmonary percussive ventilation (IPV).
- Physical activity and prescribed systemic exercise programmes.

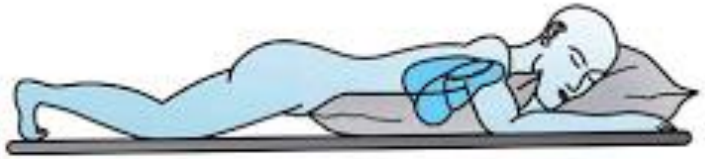


Use collateral airway in lower lungs and alveoli to go behind the mucus plugs and push mucus up with airflow

1. Postural Drainage

requires the patient to be placed in positions that anatomically favor the gravity directed movement of secretions towards the upper airways, from where secretions can be cleared by coughing.

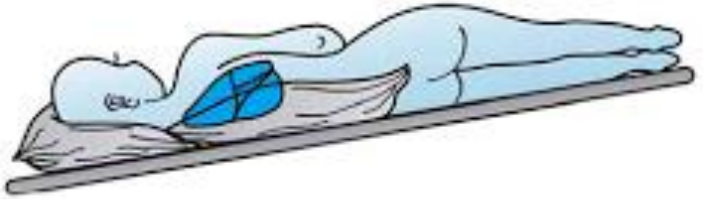
Apical segments of both upper lobes



Posterior segment of right upper lobe

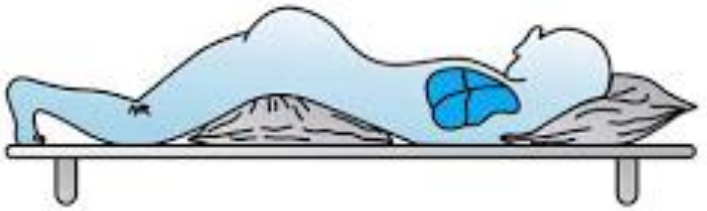
Posterior segment of the left upper lobe

Anterior segments of both upper lobes



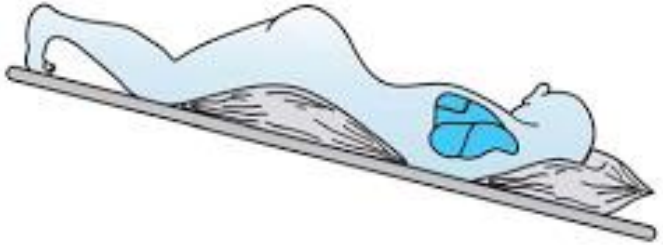
Lateral and medial segments of middle lobe

Superior and inferior segments of the lingula lobe



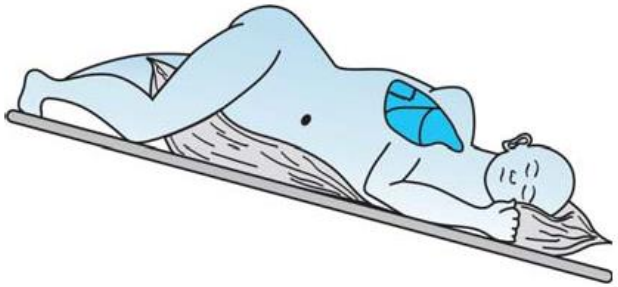
Apical segments of both lower lobes

Anterior basal segments of both lower lobes



Posterior segments of both lower lobes

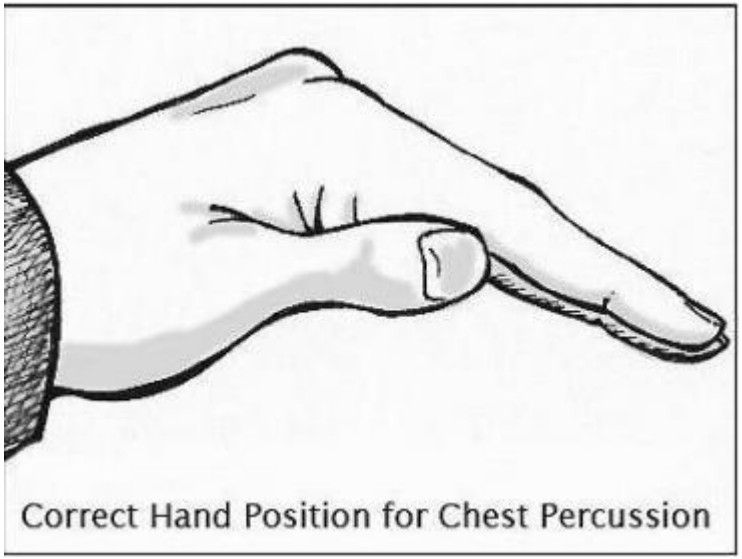
Lateral basal segment of the left lower lobe and the medial basal segment of the right lower lobe



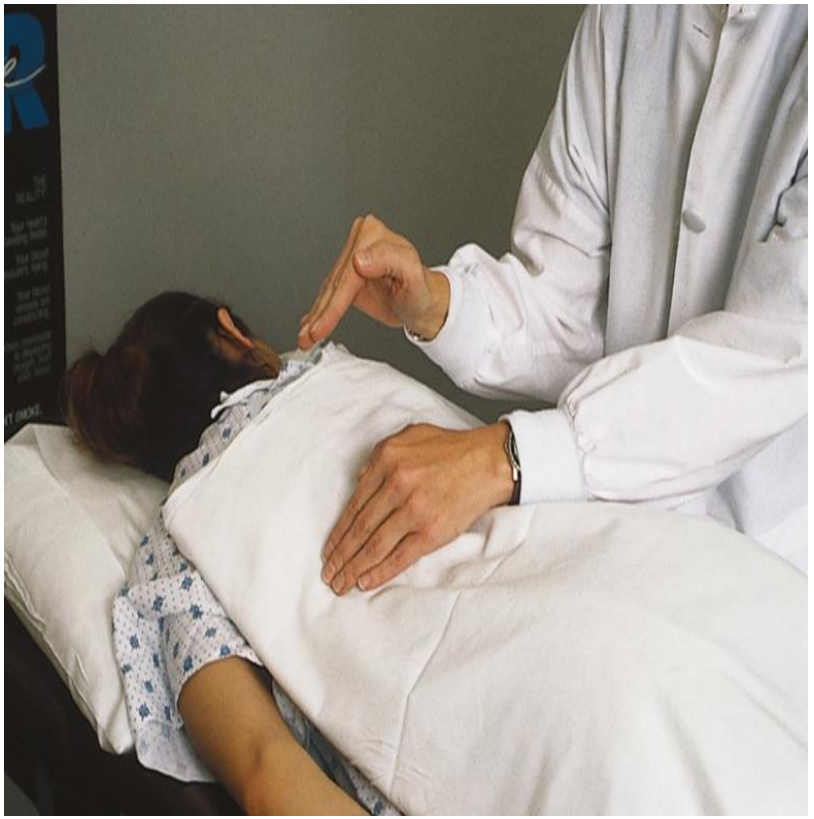
Lateral basal segment of the right lower lobe

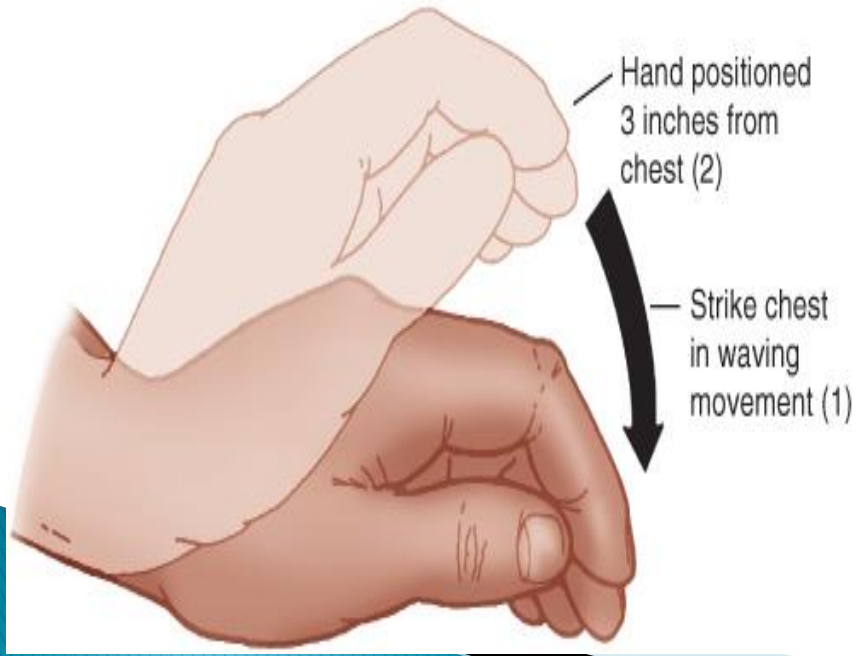
2. percussion

It consists of a rhythmical clapping on the patient's chest wall with a cupped hand, whilst the patient is asked to take deep breaths.



Correct Hand Position for Chest Percussion





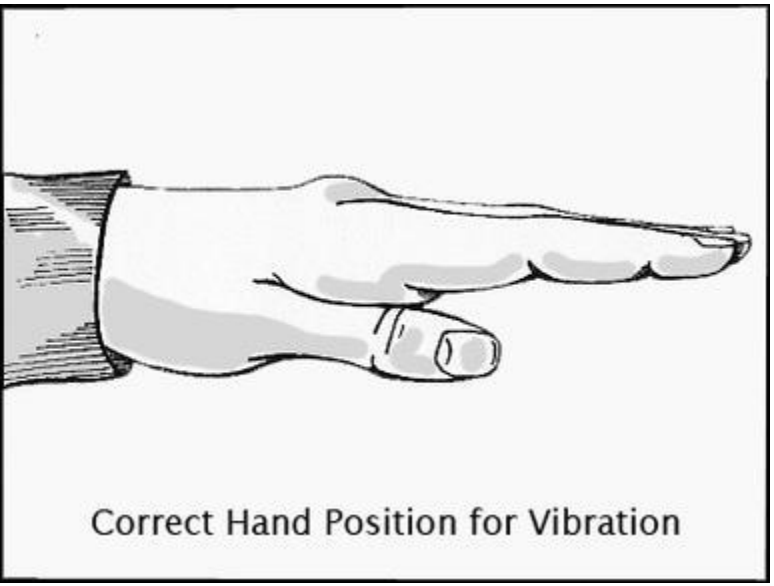
Mechanical Percussors

3. Vibrations & Shaking

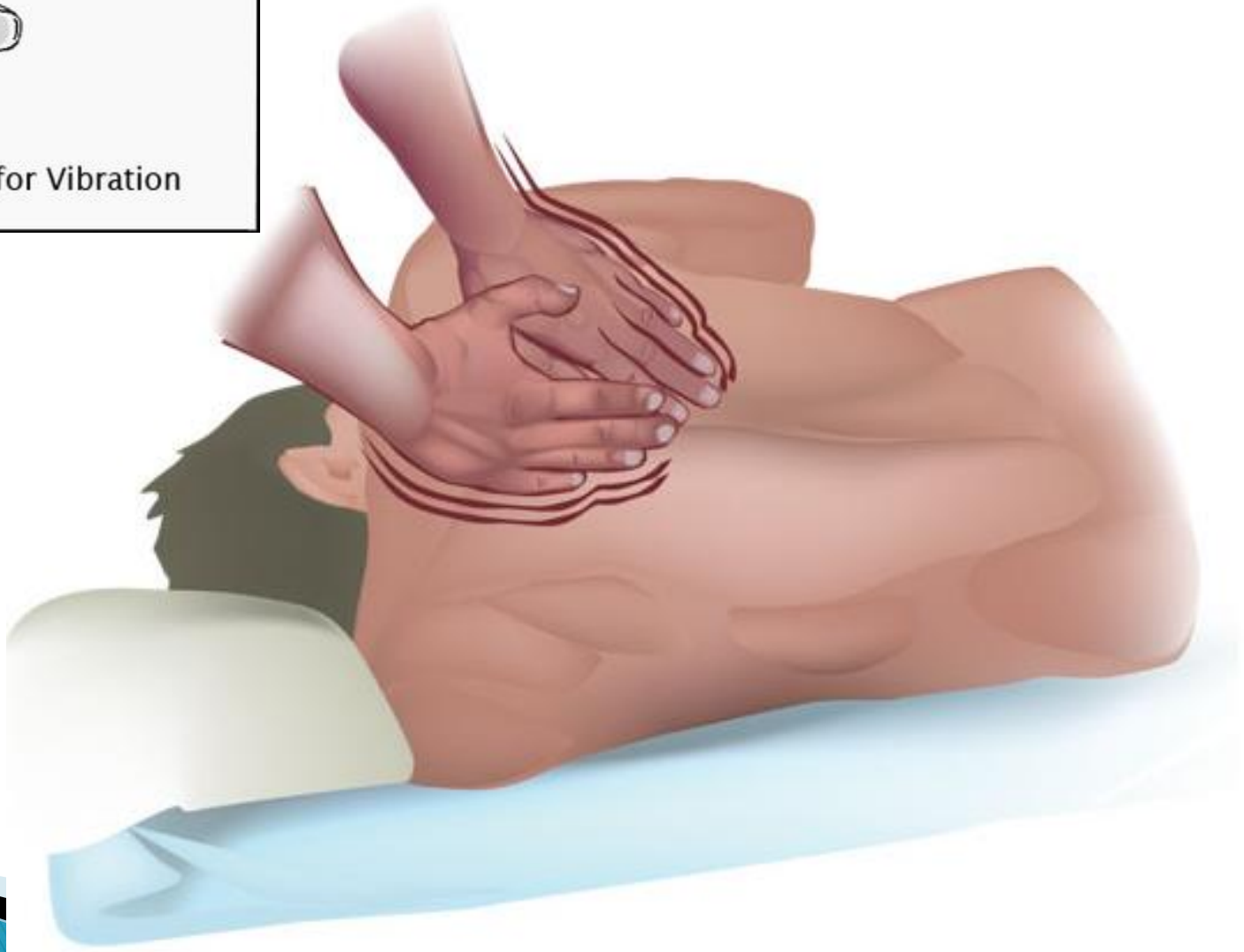
Vibrations consist of a fine oscillation of the therapist's hands placed either side of the patient's chest wall and directed inwards

Shaking is a similar but coarser movement in which the hands rhythmically compress the patient's chest wall again in an inwards direction.

- SIDE TO SIDE >>>>> vibration
- UP AND DOWN >>>>>> shaking

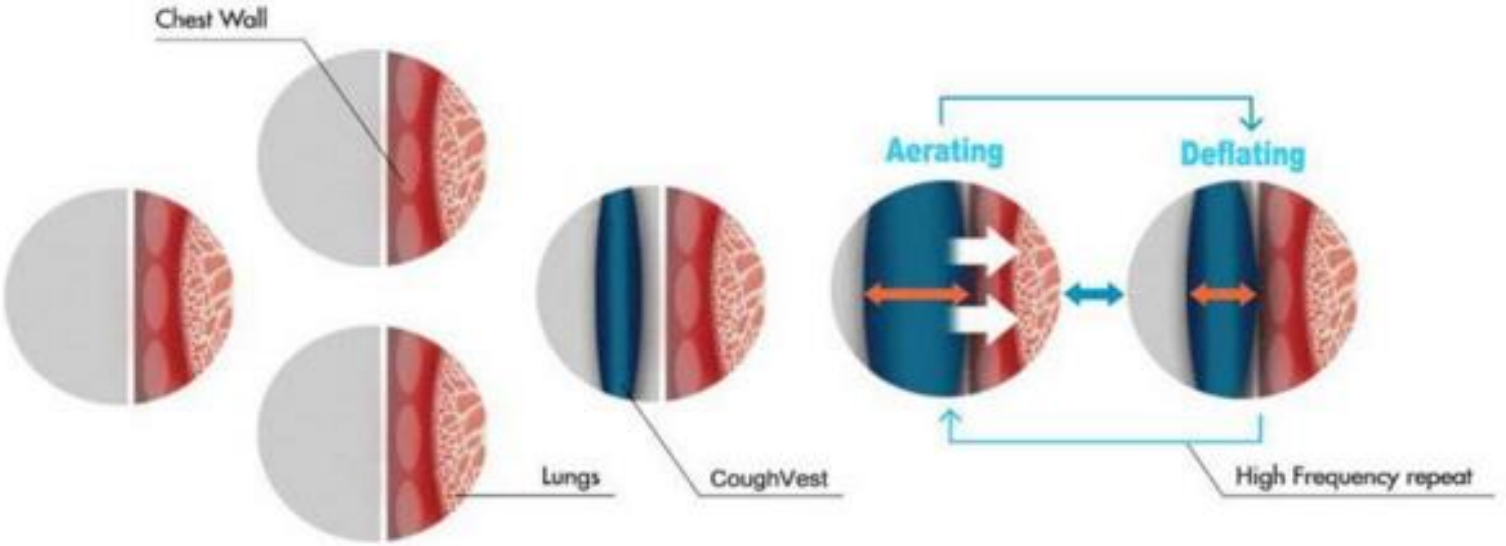


Correct Hand Position for Vibration



4. high-frequency chest wall compression

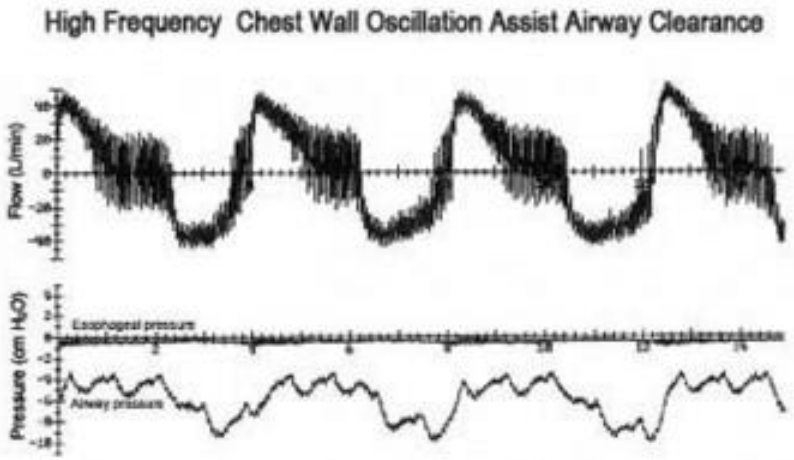
High frequency chest wall oscillation (HFCWO) draws its effectiveness from the science of fluid mechanics, the study of fluids and the forces which act upon them. Because mucus is a viscous fluid, it tends to resist movement. But sufficient and sustained airflow creates what physicists call "shear force," which can cause even high-viscosity fluids to shift and flow.



How the CoughVest Airway Clearance System Work

The Coughvest Airway Clearance System consists of an inflatable vest connected by tubes to an air-pulse generator. The generator rapidly inflates and deflates the coughvest, compressing and releasing the coughvest wall up to 25times per second. This technology is called High Frequency Chest Wall Oscillation (HFCWO).

The rapid chest movement minics"mini-cough" that dislodge and thin the mucus, moving it along to the central airways. The coughvest therapy treats all lobes of the lungs simultaneously and it technique indepent. It can be beneficial to patients across the continuum of care, including acute and post-acute facilities, as well as at home.



Flow.aiway pressure and esophageal pressure waveforms while breathing with the coughvest airway clearance system

5. EUROPEAN / CANADIAN TECHNIQUES

- **Huff cough (forced expiratory technique)**
- **Active Cycle of Breathing Technique (ACBT)**
- **Autogenic Drainage**

HUFF COUGH

"Huff Cough" or **Force Expiration Technique (FET)–** is an alternative to deep coughing

Huff coughing involves taking a deeper breath than normal. Then use the diaphragm and stomach muscles to make a series of rapid exhalations, with the airway open, making a, "ha, ha, ha," or "H" sound. This is then followed diaphragmatic breathing, and then a deep cough if mucus is felt moving within the larger airways or trachea.

Active Cycle of Breathing Technique (ACBT)

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and,
when secretions have reached the larger more proximal

GLOSSOPHARYNGEAL ("FROG") BREATHING

- GPB is a technique useful in patients with a reduced vital capacity due to inspiratory muscle paralysis.
- It was first described by Dail in 1951, when patients with poliomyelitis were observed to be **gulping air** into their lungs.
- It is a form of positive pressure ventilation produced by the patient's voluntary muscles, in which boluses of air are forced into the lungs.

AUTOGENIC DRAINAGE

- Three phases
  - Unsticking
  - Collecting
  - Evacuating

- AD aims to control expiratory flow at differing lung volumes whilst avoiding the generation of an EPP during expiration, allowing flow rates to last longer, therefore move secretions further during each expiration. During therapy, tidal volume breathing is maintained at low lung volume (un-stick phase), mid lung volume (collect phase) and high lung volume (evacuate phase) depending on whether the secretions are located within the peripheral, proximal or central airways, respectively.

Autogenic Drainage

6. Positive Expiratory Pressure valve

- Positive Expiratory Pressure
- Action: splints airways during exhalation
- Can be used with aerosolized medications
- Technique dependent
- Portable
- Time required: 10 - 15 minutes

7. Flutter

- This de
stainless
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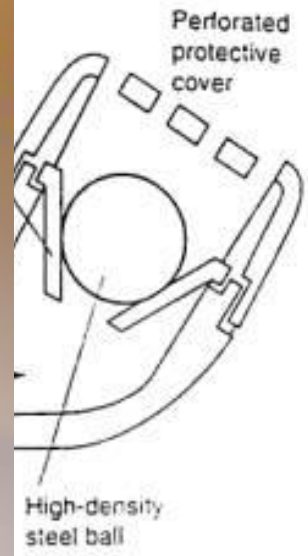
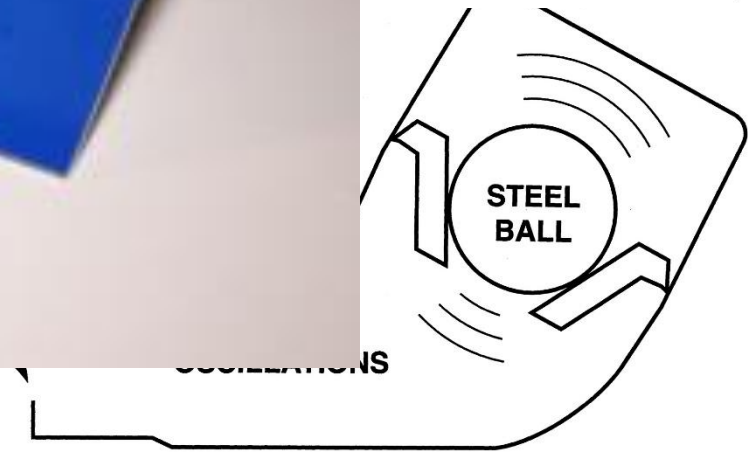
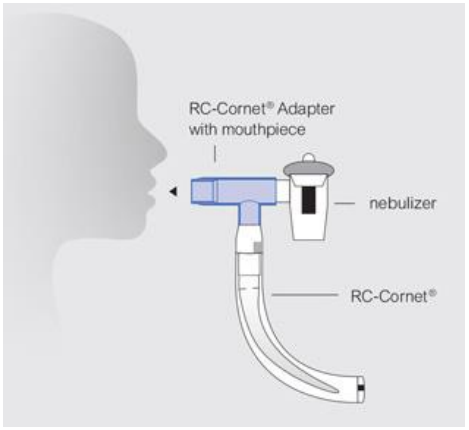
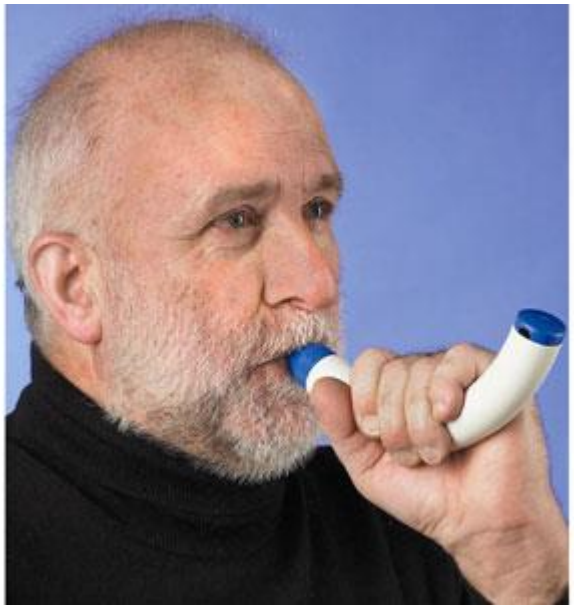




8. RC-Cornet



The RC-Cornet1 (Cornet) is a curved plastic tube containing a flexible latex-free valve-hose. During expiration through the Cornet, a positive expiratory pressure and oscillatory vibration of the air within the airways are generated.



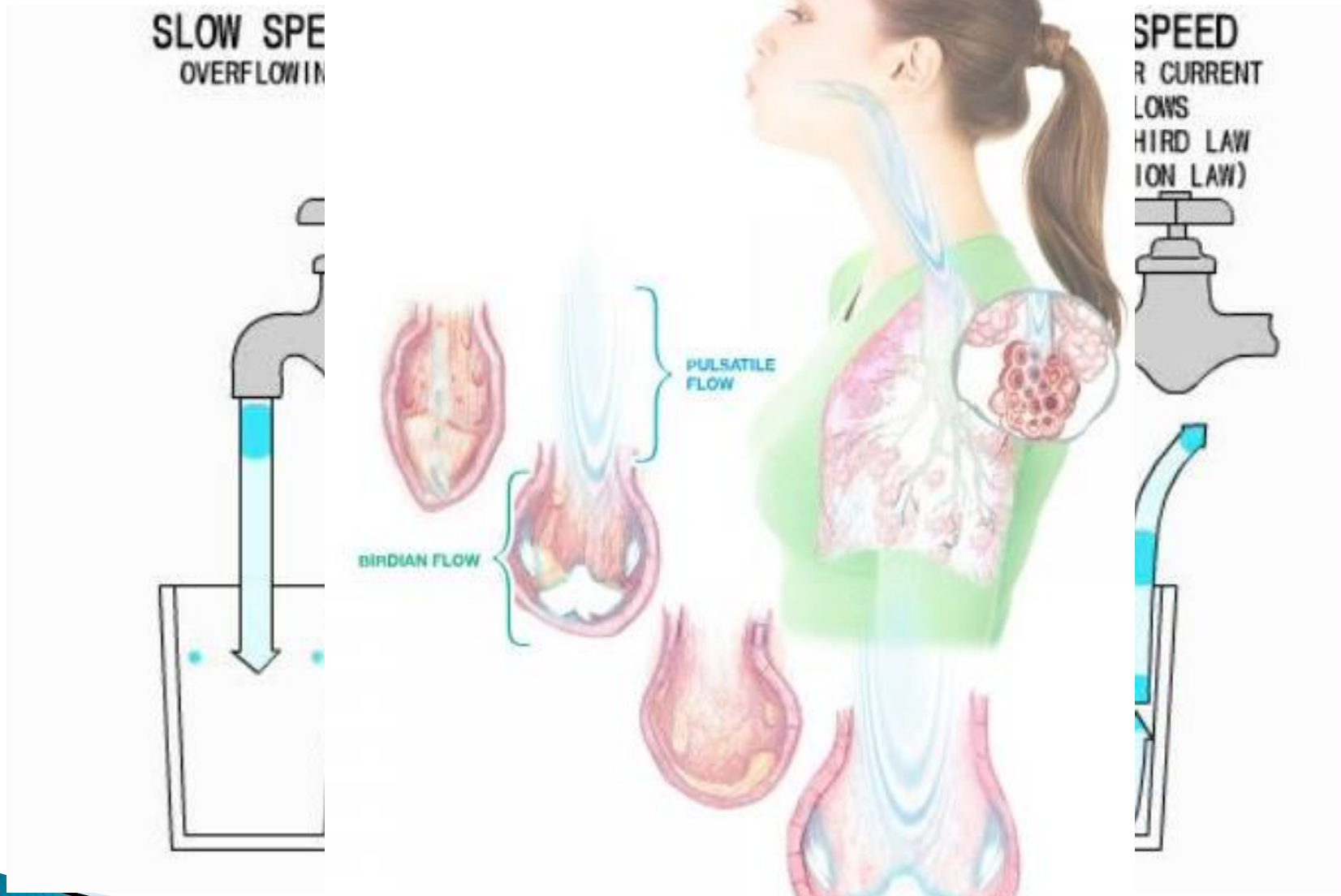
9. Acapella

- The acapella® is a ready-to-use small hand-held device that combines the resistive features of the positive
- expiratory pressure of a PEP valve and the vibratory features of a flutter valve to mobilize secretions in the airway.

10. Intrapulmonary percussive ventilation

- IPV is the delivery of a pulsatile flow of gas to the lungs during inspiration. The volume of gas released with each pulse can be preset and the pulsation frequency adjusted.
- The patient initiates the flow of gas and during inspiration the pulsatile flow results in an internal percussion.
- Interruption of the inspiratory flow allows for passive expiration.

Intrapulmonary Percussive Ventilation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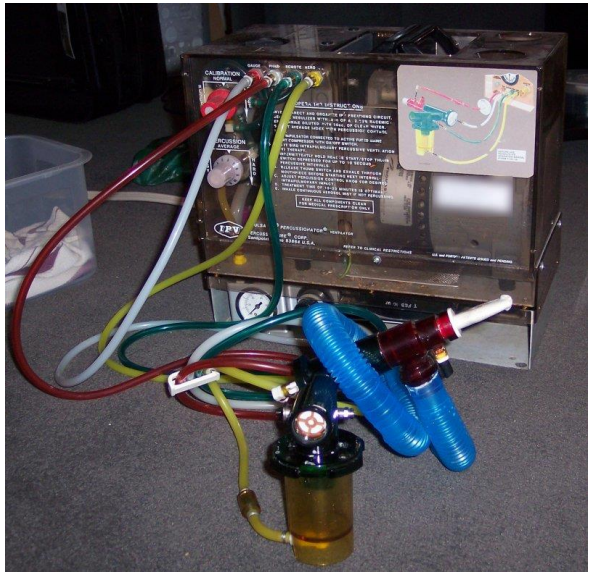
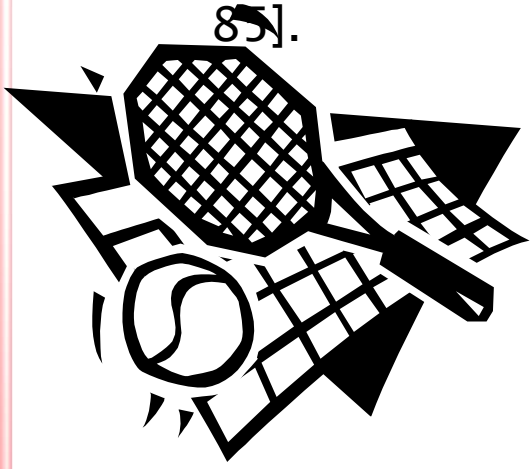
The key to IPV and all other Bird ventilators is the Phasitron – which delivers rapid, high flow, mini-bursts (percussions) of Air or Oxygen into the lungs while simultaneously delivering therapeutic aerosols.



11. Exercise

- General and respiratory exercises
- Exercise increases sputum production but is not as effective as the ACBT.
- The additional cardiovascular effects of exercise should be considered
- Many patients limited by physical disability




Evacuation
methods

- Manually assisted cough
- Mechanically assisted cough
- Suction

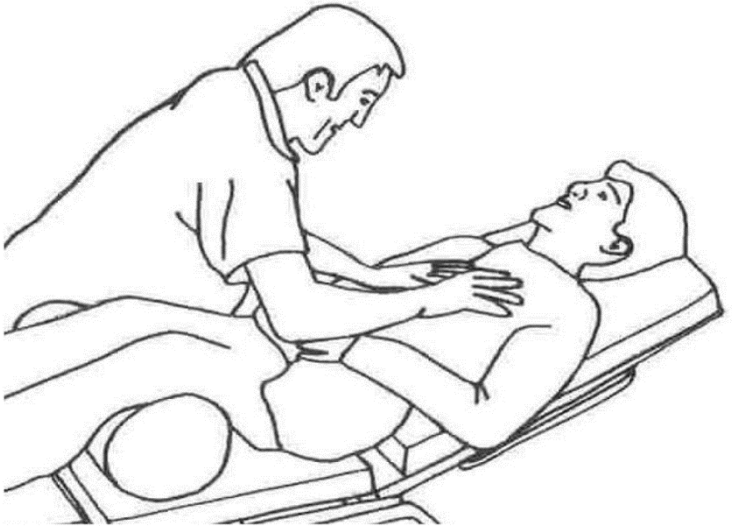
Manually assisted coughing

- significantly increases peak cough flow by a well timed thrust from an assistant during the expiratory cycle.

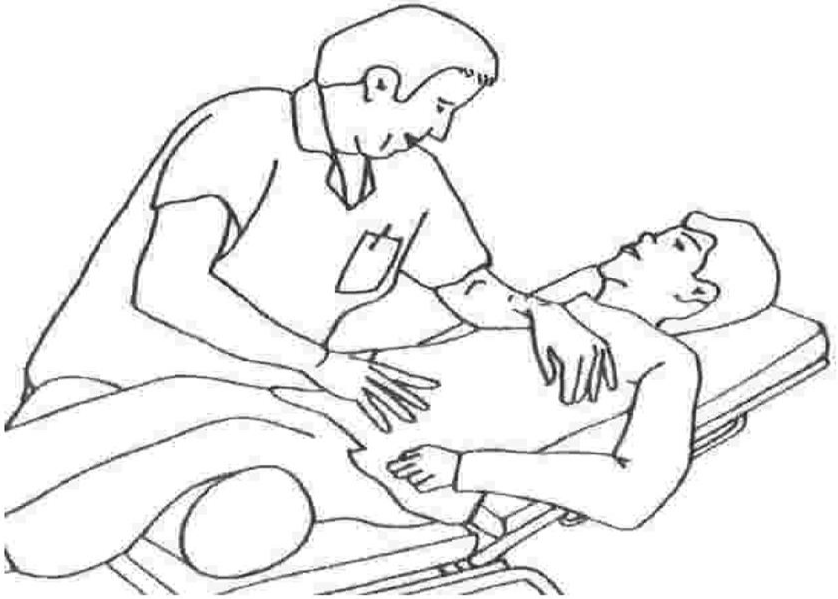
- MIC in inspiration

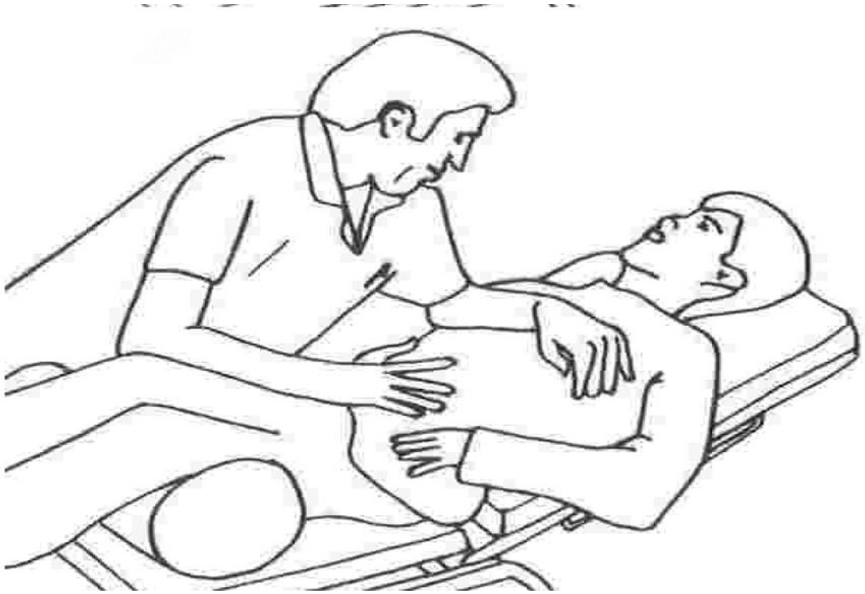
Hand placement can be on:

- the abdomen (Heimlich-style thrust)
- anterior chest wall or costophrenic angles (thoracic compression)



Manually assisted cough via thoracic compression





Manually assisted cough via abdominal–thoracic compression

Self assisted coughing technique

MECHANICAL INSUFFLATION-EXSUFFLATION

gradual application of positive pressure to the airway followed by a rapid shift to negative pressure. The slow inhale/rapid exhale airflow simulates the natural coughing process

What is MI-E?

- The MI-E applies positive pressure by mask, mouth-piece, or tracheostomy connector inflating both lungs evenly. Positive pressure is followed by a rapid shift to a negative pressure to generate a consistent Peak Cough Flow (PCF) of 300-600 L/min

Mi-E Oider Model

When do you perform MI-E?

- MI-E is best performed before meals and at bedtime if combined with MAC to minimize risk of refluxed gastric contents
- MI-E with MAC usually results an improved PCF of up to 20%

Combined

BTS recommendation

- Consider mechanical insufflation–exsufflation as a treatment option in patients with bulbar muscle involvement who are unable to breath stack.
- Consider mechanical insufflation–exsufflation for any patient who remains unable to increase peak cough flow to effective levels with other strategies.
- Where cough effectiveness remains inadequate with mechanical insufflation–exsufflation alone, combine it with manually assisted coughing.

Who benefits from MI-E?

- Individuals with weak inspiratory and expiratory muscles unable to achieve an effective PCF of 270 L/min using lung volume recruitment (LVR) with or without manually assisted cough (MAC) usually benefit from routine use of the MI-E. Weak inspiratory and expiratory muscles are associated with neuromuscular diseases (e.g., amyotrophic lateral sclerosis (ALS), muscular dystrophy, post polio), spinal cord injury or muscular skeletal conditions (e.g., kyphoscoliosis).
- The individual must be alert, cooperative and able to communicate

When do you NOT perform MI-E?

- The use of the MI-E is NOT recommended in the presence of hemoptysis, pneumothorax, recent or current barotrauma, bullous emphysema, nausea or vomiting or previous adverse effects with MI-E
- Traditional suctioning techniques should be used for individuals with impaired consciousness or inability to communicate

Invasive mechanical ventilation

SUCTION

Suctioning is the mechanical aspiration of pulmonary secretions from a patient with an artificial airway in place.

Suggested Procedure for Ventilator Hyperinflation

Use volume control continuous mandatory ventilation with square wave flow and inspiratory flow of 20–40 L/min.

Increase tidal volume to reach peak inspiratory pressure of 35 cm H_2O and certify that plateau pressure is $\leq$ 30 cm H_2O.*

Set optimal PEEP to maintain airway patency.

Ensure that PEF-PIF difference $>$ 33 L/min; if it is not, consider reducing the inspiratory flow or the rise time.

In patients without respiratory drive, reduce breathing frequency to keep the baseline minute ventilation.

Monitor hemodynamics, oxygen saturation, and ventilator curves throughout the procedure.

Use PSV with cycling off of 10% and set the lowest rise time that do nc cause flow asynchrony (ie, flow starvation).

Increase PSV to reach peak inspiratory pressure of 30 cm H_2O.

Set optimal PEEP to maintain airway patency.

Certify that the PEF-PIF difference is $>$ 33 L/min; if it is not, consider reducing the rise time.

Monitor hemodynamics, oxygen saturation and ventilator curves throughout the procedure.

Take home message

Bronchial hygiene techniques

* Postural drainage
* Percussion & vibration
* Directed cough
* Forced expiratory technique (
* Active cycle of breathing
* Autogenic drainage
* Positive expiratory pressure