BROCHURE

CPAP in ambulance service

Introductory course

UNIVERSITETSSYKEHUSET NORD-NORGE
DAVVI-NORGGA UNIVERSITEHTABUOHCCEVIESSU

HELSE NORD

This brochure was written in connection with the introduction of CPAP into the ambulance service at University Hospital Northern Norway. The authors of the brochure are *Lars-Jøran Andersson, Morten Lyngås Føyen* and *Johannes Strand*.

As authors we wish to give special thanks to *Ole Magnus Filseth,* who made his compendium on respiratory physiology available to us. Portions of this brochure quote directly from it.

In addition to this, we have used Knut Dybwik's book on respiratory treatment as a source for the brochure.

Johannes Strand did the layout and design.

Introduction

It has been decided to introduce CPAP into the ambulances at the University Hospital of Northern Norway.

This brochure has been written as part of this introduction. The brochure will be an introduction about what CPAP is and will provide the necessary basics for using the tool in an ambulance.

In addition to this, all personnel will receive a day of training in the CPAP before it is put into service.

Within emergency medicine, CPAP has traditionally been a procedure that was only available inside the hospital.

The reason we wish to start using CPAP in the ambulance service is that early treatment contributes to shorter hospital stays and better care for the patient.

CPAP is an advanced form of care. Knowledge of the indications and contraindications is therefore important. Successful CPAP treatment demands good cooperation between the provider and the patient, and alertness by the provider. Serious complications with CPAP are rare and the treatment can, when necessary, be quickly stopped. We believe that CPAP treatment will be used relatively seldom, but for the individual patient the treatment can offer a significant health advantage. It is important that one knows the equipment well so that the threshold for using it will be low.

In the ambulance service, CPAP treatment will be prescribed by the doctor in the same way as medicinal treatment.

What is CPAP and how does it work?

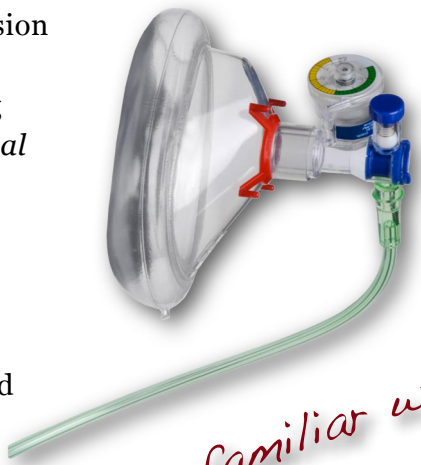
CPAP treatment requires that the patient breathes in a closed tubal system that registers a continuous positive airway pressure. In our case, this will be a CPAP mask that is driven by the oxygen we have in the vehicles.

In the ambulance service, CPAP is used for patients with serious respiratory failure. The indications will be: ***Pulmonary edema, asthma*** and ***COPD***.

CPAP improves oxygenation for these patients in three ways:

1. By causing the patient to breathe with a higher lung volume, which will increase the diffusion surface (*reducing shunting*). The resting lung volume (*functional residual capacity - FRC)* increases and atelectatic tissue (collapsed lung tissue) is inflated and atelectasis is prevented from reforming.
2. By displacing pulmonary fluid in lung congestion. Positive airway pressure reduces venous return to the heart (*lowers "preload"*). In left ventricle failure, the heart's per minute volume will increase as a consequence of reduced "preload".
3. By better *lung compliance* (respiration becomes easier and the quantity of CO_2 in the blood is thereby reduced). It is easier for the patient to breathe with a lung that is inflated than when the resting volume of the lung is reduced.

In other words, CPAP works in several ways to improve the patient's oxygenation. In order to have a good understanding of how this works, we must delve a little deeper into respiratory physiology...



Some unfamiliar words and expressions?

Don't worry, the explanation is coming ;-)

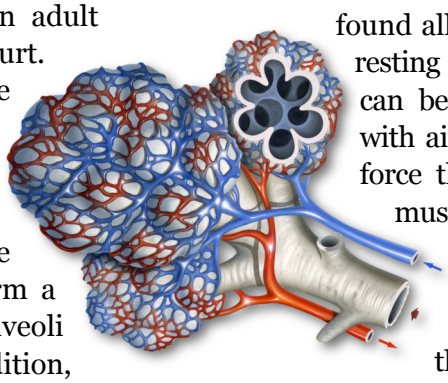
Airways

The upper and lower airways have the task of conducting air to and from the lungs. In addition, they take care of ***filtering***, ***warming*** and ***humidifying the air***.

Lungs

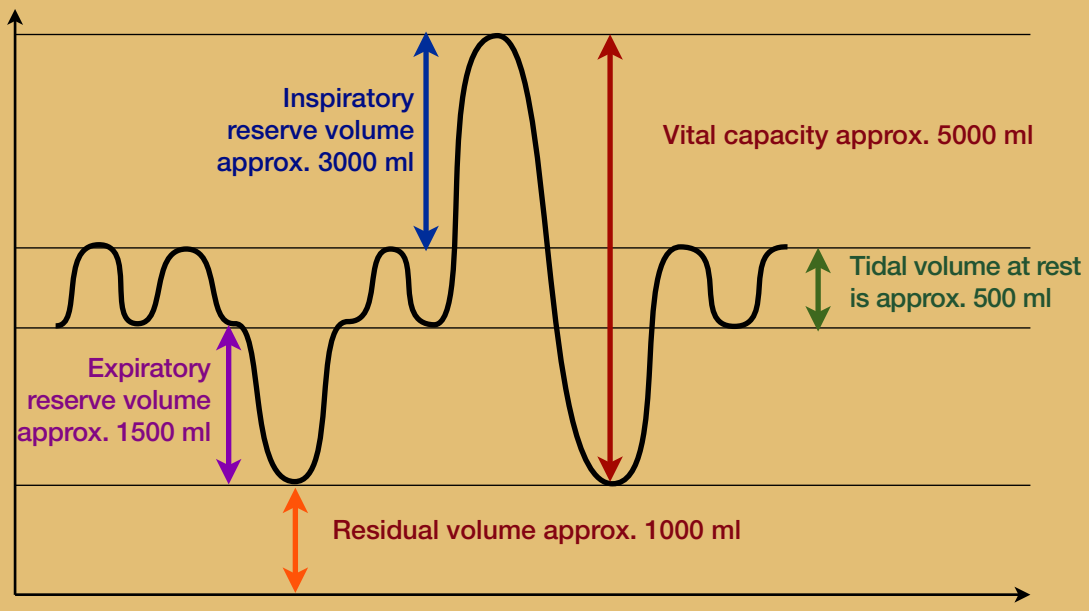
The inner surface of the lungs of an adult person has an area the size of a tennis court. The primary tasks of the lungs can be divided into three main functions; ***oxygen uptake***, ***carbon dioxide elimination*** and ***pH regulation***.

The alveoli are covered with a single layer of flat epithelial cells which form a thin membrane between the air in the alveoli and the blood in the capillaries. In addition, the alveoli are covered with a lipoprotein (*surfactant*), which reduces the surface tension and thereby prevents the alveoli from closing at the same time that it ensures that they don't also over-distend.



The lungs are very elastic and can be compared to a rubber band. A network of elastic fibers is found all over the lungs. From the resting position of the lungs, this can be stretched out and filled with air. For this to happen, the force that will expand the lung must overcome the elastic forces of the lung tissue. In addition, there is the elastic resistance found in the chest wall.

Lung capacity and volume



A healthy adult male has a *total lung capacity* (***TLC***) of approx. 6 liters, that is, the quantity of air found in the lungs after maximal inspiration.

The tidal volume (***TV***) is the volume that is inspired in normal respiration and is approx. 0.5 liter.

After normal expiration, a healthy adult male could expire approx. 1.5 liter. This is called *expiratory reserve volume* (***ERV***).

What is left in the lungs is called *residual volume* (***RV***).

If you add ***ERV*** and ***RV*** you get *functional residual capacity* (***FRC***), which is the normal resting volume of the lungs. (During CPAP treatment, ***FRC*** is increased.) If after normal inspiration you continue to breathe in as much as you can, you obtain an *inspiratory reserve volume* (***IRV***), that is approx. 3 liters.

The elastic forces in the lungs and chest wall during expiration (breathing out) contract the lung back into the resting position. Expiration is therefore normally a passive act. In technical literature, the term ***compliance*** is used for the lungs' elasticity.

The body's oxygen supply

The organism's oxygen supply depends upon its ability to take up oxygen and the ability to transport it out of the body. Under normal circumstances, the oxygen supply depends upon the following factors.

1. Hemoglobin level
2. Oxygen saturation
3. Cardiac minute volume

In order to obtain an adequate supply of oxygen, it is often possible to influence these three factors even by simple means outside of the hospital.

Words and Expressions...

Hypoxia:

Reduction of the oxygen supply in the tissues, despite adequate blood supply, is usually due to hypoxemia.

Hypoxemia:

Reduced oxygenation of the blood causes hypoxia. In practice, hypoxemia and hypoxia are often used interchangeably.

Ischemia:

Lack of oxygen in tissue, which is due to reduced blood supply in the tissue, as for example in angina pectoris.

Asphyxia:

Lack of oxygen in the inspired air, or absence of air to breath, synonymous with asphyxiation.

Hypercapnia:

Increased quantity of CO_2 in the blood, synonymous with hypercapnia. Hypercapnia is a strong stimulus to increase respiration. Attempt to hold your breath while you measure oxygen saturation and you will experience a strong need to inhale before oxygen saturation falls.

Hypocapnia:

Reduced quantity of CO_2in the blood, for example, a hyperventilating episode.

Hemoglobin (Hb):

Oxygen-bearing molecules in erythrocytes. Every hemoglobin molecule can bind to four O_2 molecules. Each gram of hemoglobin can bind to 1.34 ml of oxygen. If we want to indicate whether hemoglobin is bound to oxygen or not, we can distinguish between oxyhemoglobin (oxygen is bound) and deoxyhemoglobin. The quantity of hemoglobin in the body is normally 11.5 - 17 g/dl.

SaO_2:

Oxygen saturation in arterial blood. When all hemoglobin in the blood is saturated with oxygen, SaO_2 is 100%. If SaO_2 is, for example, 60%, this means that 60% of the binding sites for oxygen are bound to oxygen.

SpO_2:

The designation for arterial oxygen saturation when it is measured in the peripheral arterial blood using a pulse oximeter. The pulse oximeter distinguishes between oxygenated and deoxygenated hemoglobin using light with different wave lengths.

With correct use and interpretation, SpO_2 will correspond to SaO_2.

Functional residual capacity (FRC) is the quantity of air that is left in the lungs after normal expiration. When you breathe out and reach FRC, you are doing fine. You can then begin to breathe in, which will be both easy and natural. You can also choose to continue to breathe out until you reach residual volume, which is the amount of air which is left in the lungs after maximum expiration; it will feel heavier. Ordinarily we do not think about when we should stop breathing out and begin to breathe in, this is controlled by the respiratory center in the brainstem.

Thus we choose unconsciously when we should begin to inhale. Even though the choice is unconscious, it is sensible and oriented toward ensuring good ventilation with the least possible effort.

The functional residual capacity **is determined therefore by the equilibrium between the forces that work in opposite directions**.

Some forces contribute to pulling the lungs out (filling the lungs), such as the elastic forces in the chest wall and muscle tone in the diaphragm, while the elastic forces of the lung tissue work oppositely (empty the lungs). In order to empty the lungs further once we have reached FRC, we must use the muscles to force expiration. FRC varies significantly, also within an individual patient. FRC is greater when standing then when lying down. FRC is reduced in collapse (atelectasis) of the lung tissue and in all of the processes that reduce the area of the lungs (pleural fluid, obesity and distended abdomen). FRC is reduced also by general anesthesia (narcosis) because of the loss of muscle tone in the diaphragm.

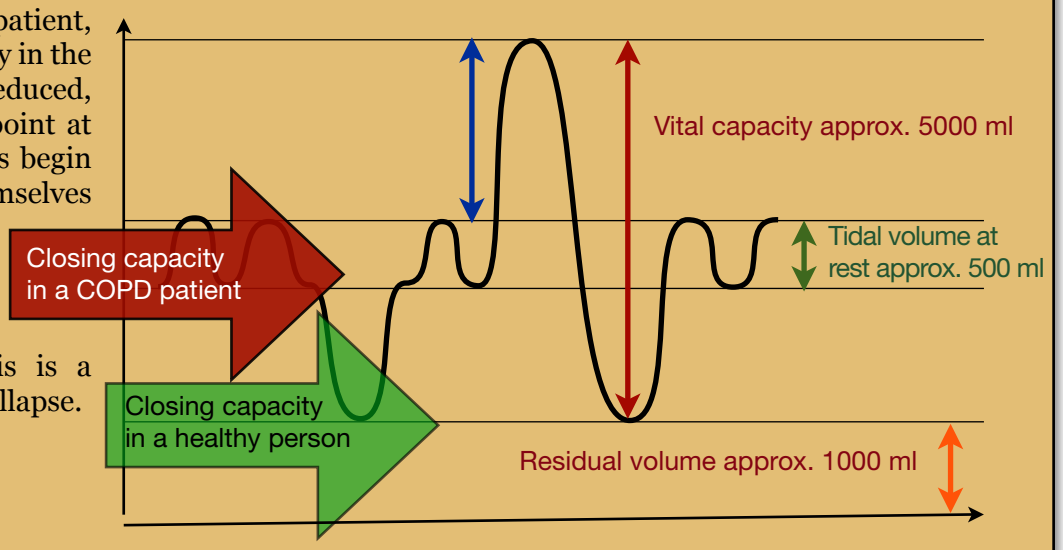
In a normal healthy young adult all of the lung's segments will be open at the end of a normal expiration. But when we breathe out to the maximum, the small airways that exist farthest down in the lungs are closed. This is called static airway collapse. The lung volume at which this occurs is called closing capacity. We do not need to worry about this as long as it occurs after we have reached the functional residual capacity in expiration.

Closing capacity is determined by the lung tissue's elastic properties. *Closing capacity* can be highly elevated in COPD. When *closing capacity* is higher than FRC, it means that portions of the airways collapse during normal breathing. This leads to an improper relationship between ventilation and circulation in the lungs. Circulated lung segments are not ventilated (shunt). The result will be poorer oxygenation of the blood.

Closing capacity is an innate property of lung tissue and is independent of other processes. The functional residual capacity, on the other hand, can be influenced. A patient with an elevated closing capacity and worsening of COPD will thus benefit from measures that increase functional residual capacity. To raise into an upright position in order to get atelectatic (collapsed) lung tissue to open is an example of a measure that will increase FRC. CPAP is able to contribute to the opening of atelectatic tissue and will also make it easier to breathe with greater volume.

Static airway collapse

In a COPD patient, resting elasticity in the lung tissue is reduced, such that the point at which the lungs begin to close by themselves (closing capacity) is reached during normal expiration. This is a static airway collapse.



Dynamic airway collapse

When we breathe out hard (forced expiration), the diaphragm, stomach and chest wall muscle is used to press together the chest cavity. Instead of negative pressure (as with ordinary expiration) we now have a positive pressure both in the chest cavity and around the lungs.

We obtain a large pressure differential and we should expect a large expulsion of air from the airway. Along the airways a gradual fall in pressure from 85 to 0 cm H2O will occur. The pressure in the airways will be lower than the pressure around the lungs. If the airways were rigid tubes this would not mean much, but the alveolar passages and bronchioles are held distended by the surrounding elastic tissue and the bronchioles have cartilage that can only resist a certain outer pressure. In this case, we have a total or partial collapse of the airways that lasts until the forced expiration ceases.

One has then a *dynamic airway collapse*, because it is related to the air expelled out of the lungs. If a person exhales with less force, the airway will remain open during expiration. In normal people, the dynamic airway collapse will show itself to be the upper limit of how fast the lungs take to empty of air (approx. 600 to 700 l/min, far above what we have need for under all physiological circumstances).

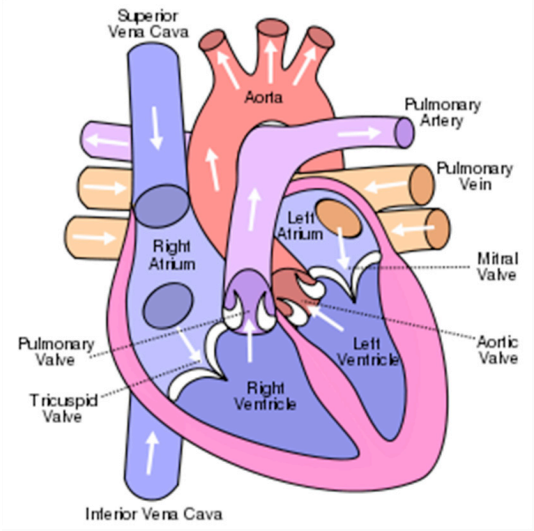
The tendency to dynamic collapse increases when the airways are narrowed down, as in the case of pulmonary edema or asthma. It means that large portions of the airways will have collapsed before one has reached FRC. This means also that the lungs contain trapped air that does not come out. This air is under pressure and will form a resistance that must be overcome in the next inspiration. This phenomenon is called auto-PEEP or air trapping.

The tendency to dynamic collapse increases when airways are narrowed, as with pulmonary edema or asthma...

CPAP reduces the pressure differential and therefore combats auto-PEEP.

Blood flow and pressure in lung circulation

The circulatory system consists of the greater (systemic) circulation and the lesser (lung) circulation. The greater and the lesser circulations are joined in a series. This does not apply to the fetus or persons with simple congenital heart failure. Flow through the pulmonary vascular bed varies as does systemic circulation between 5 l/min at rest to 25 l/min with high activity (in the well-trained).



Blood flow in the pulmonary circulation will therefore be equal to the blood flow in the systemic circulation.

The pressure in the pulmonary arteries is only 1/6 of the pressure in the aorta. This means that if we measure systolic blood pressure at 120 mmHg, the pressure in the pulmonary arteries will be approx. 20 mmHg. A consequence of the lower pressure in the pulmonary arteries is that the blood flow to the lungs is more dependent upon gravity, such that at any time the lowest lying portions of the lungs have the best blood flow.

Blood flow in the lungs will change with the patient's position. In lower-lying areas, there will be a tendency to poor ventilation, in the higher-lying areas the tendency will be to poor perfusion. For the lungs overall, the relationship between ventilation and perfusion is good, nearly 1:1. Normally the "driving pressure" in lung circulation is determined by the difference between the pulmonary artery pressure and the pulmonary venous pressure.

Clinical points: If a person has positive pressure in the airways (for example, CPAP or respiratory treatment), we can get a situation in which the driving pressure (blood pressure) is determined by the difference between the pulmonary arterial pressure and airway pressure. With a combination of high airway pressure and low pulmonary artery pressure, we can get a situation where the airway pressure is greater than the pulmonary arterial pressure in all or part of the lung. In a situation such as this, we will not get any blood flow to the actual area and the entire circulation could be affected.

Indications

The indication for CPAP treatment in the ambulance service must be serious respiratory failure. In practice this will be ***asthma, COPD and heart failure/pulmonary edema.***

Respiratory failure

We have respiratory failure when the gas exchange in the lungs leads to reduced oxygen saturation in the blood. If the respiratory failure is serious, we often see also an increase in carbon dioxide in the blood (hypercapnia).

A series of conditions can cause respiratory failure, such as injuries, pneumonia, collapse of lung tissue (atelectasis), airway obstruction, drug reactions (for example, opiates) and sepsis.

Patients with COPD can go about with chronic respiratory failure, but with gradual worsening as a consequence of airway infections.

When assessing a patient with respiratory failure, it is necessary, in addition to oxygen saturation, to evaluate respiratory rate and depth, respiratory pattern, withdrawals, use of accessory muscles, psychic condition and whether the labor of breathing is tiring the patient.

When we use CPAP in the ambulance, the patient must have a serious respiratory failure and one of the following conditions must also be suspected: pulmonary edema, COPD or asthma.

Pulmonary edema

The most frequent cause of pulmonary edema is heart failure. Certain toxins and various forms of overhydration can also cause pulmonary edema. Heart failure means that the heart's function as a pump is failing. Heart failure is a condition that can have different causes, for example, infarction, arrhythmia, valvular disease, infection, sepsis and cardiomyopathy. When the heart (left side) fails, the blood pressure in the pulmonary circulation is higher. Because of the elevated pressure, fluid leaks out into the space between the capillaries and the alveoli, then into the alveoli and leads to pulmonary edema.

A patient with pulmonary edema will appear to be very affected. It can often be difficult to distinguish pulmonary edema from worsening of COPD or pneumonia.

The treatment of heart failure depends upon the cause. For example, it might be PCI or valve surgery. Pre-hospital, the possibilities are medicinal treatment, positioning, oxygen and CPAP. In coronary disease (infarct) thrombolysis will also be a treatment option.

In order to relieve the heart, the patient is positioned with the upper body high and is treated with nitro preparations (nitrolingual every 5 to 10 minutes), morphine (start dose of 2.5 to 5 mg) and diuretics (Furosemide 10 to 40 mg). CPAP has an effect on heart failure because the increase in airway pressure that CPAP provides leads to fluid being pushed back into the bloodstream.

CPAP gives results also because it helps the patient to breathe at a higher lung volume, opens the lungs and reduces atelectasis formation. All these measures lead to lower blood flow in the heart and this is exactly the point. The heart receives less blood that must be pumped further, and is relieved. This means also that the patient must be monitored because the treatment can work so strongly that it leads the patient over into circulatory shock. Treatment of acute heart failure is a balancing art.

Symptoms and signs:

- Agitation or anxiety
- Confusion and disorientation because of hypoxia
- Poor general condition, weakness
- Chest pain
- Cough - frothy, possible bloody expectorate
- Increasing shortness-of-breath and air hunger
- Increased respiratory rate
- Gurgling respiration and crackling sounds over the lungs
- Skin: Gray and cold sweats
- Cyanosis
- Jugular vein stasis
- Edema in the ankles and legs
- Drop in blood pressure
- Tachycardia and arrhythmia

Asthma / COPD

Chronic obstructive pulmonary disease is a composite designation for emphysema and chronic bronchitis, often caused by smoking.

Some patients need home oxygen.

Medicinal treatment includes inhalations, for example, salbutamol (ventoline) and ipratropium bromide (ipraxa) and steroids (for example pulmicort). With worsening, steroids may be given by I.V. or peroral, extra treatment with inhalations, theophylline (aminophylline) and oxygen.

If a patient with worsening COPD needs intubation, it will often be a long respiratory handling. Early CPAP treatment can reduce the need for intubation. CPAP makes it easier for the patient to breathe at a higher lung volume (higher FRC), which allows more parts of the lungs to be ventilated. In other words, the tendency to static collapse of alveoli is reduced. Furthermore, CPAP reduces the tendency to dynamic airway collapse because the pressure differential is less. Many COPD patients try to obtain this effect by breathing out through pursed lips.

Symptoms and signs:

- Known primary disease
- Agitation/anxiety
- Problems speaking entire sentences
- Lowering consciousness, possible coma
- Dyspnea at rest
- Wheezing
- Exhales through pursed lips
- Cough, coughs up mucus
- Fever
- Increased respiratory rate
- Shallow breathing
- Use of accessory muscles
- Reduced respiratory sounds, wheezes
- Tachycardia, rise in blood pressure, fall in blood pressure, arrhythmia, cardiac arrest

Contra-indications

Risk of aspiration – If the patient vomits, the mask can fill up with vomit and the patient can aspirate. It is important to assess this risk before securing the mask with the straps.

Lowered consciousness – If the patient's consciousness is reduced, such that the patient risks not being able to maintain a free airway, the patient should not receive CPAP.

Increased intracranial pressure – CPAP can contribute to increased intracranial pressure because of increased intrathoracic pressure. It should not be used when there is a suspicion of head injury or brain hemorrhage.

Pneumothorax – CPAP, like intubation, causes higher airway pressure which can lead to worsening of pneumothorax.

Systolic blood pressure <90 mmHg – CPAP leads to higher intrathoracic pressure, something that can reduce blood flow to the heart. If the patient is about to go into circulatory shock, establishing CPAP can lead to circulatory collapse.

Major bleeding – Risk that the patient can develop circulatory shock which can worsen with the use of CPAP.

Epiglottitus – All manipulation with airways can lead to worsening of the condition.

Equipment

There are a number of types of CPAP systems. From CPAP functions in advanced respirators to simple systems that connect to an ordinary flow meter.

The system we have chosen for the ambulance division of UNN is of the simple type. The system consists of a "CPAP generator" with integrated PEEP manometer and safety valve, mask and hood. This is coupled with ordinary oxygen tubing directly with the oxygen outlet in the vehicle or the portable O_2 cylinder.

Flow/PEEP resistance

Flow liter/minute	CPAP/PEEP (cm H_2O)
10 liter/min	1.5 - 2.0
15 liter/min	3.0 - 4.0
20 liter/min	6.0 - 7.0
25 liter/min	8.5 - 10

The equipment is for one-time use and is disposed of after use.

Assembly/start-up

- Have all equipment available before starting, ensure safety and inform the patient.
- Choose the correct mask size.
- Connect the tube to the flow meter.
- Start the flow at 15 l/minute.
- Put the mask on the patient so that it fits snugly.
- Secure the mask using the accompanying straps (when the patient accepts the mask).
- Adjust the flow to the PEEP pressure desired. Flow of 25 l/min is required to reach the highest PEEP resistance.
- SpO2 and blood pressure will be measured during the CPAP treatment.
- Maximum air or O2 flow - 30 l/minute.

Oxygen consumption

Our CPAP system will normally use 15 to 25 liters of oxygen/minute. This means that the treatment is very oxygen-demanding and we must keep watch on how much oxygen we have available in the ambulance and how long a time we can continue the treatment.

For long transport, a replacement of oxygen bottles underway must be planned for with pauses in the treatment.

Patient experience/communication, requirements for success

An indication for CPAP treatment is respiratory failure in connection with COPD and heart failure/pulmonary edema.

Shortness-of-breath often leads to significant agitation and anxiety. In CPAP treatment, the mask is placed snugly over the patient's face and the patient experiences having to breath out against a resistance.

Calculating oxygen

Volume x pressure = available oxygen

5 liters x 200 bar = 1000 liters

$$\frac{\text{available oxygen}}{\text{liter per min}} = \text{MAX treatment time}$$

$$\frac{1000 \text{ liters}}{20 \text{ liter/minute}} = 50 \text{ minutes}$$

It is not unusual for patients to accept the treatment poorly and try to remove the mask.

For the treatment to succeed it is important for the patient to cooperate.

Be calm and inform the patient of what is taking place. Sit together with the patient. Let the patient himself hold the mask snugly over the nose and mouth. Do not secure the mask before the patient is cooperating well and accepts the treatment.

Observation and documentation

Good patient examination and good observation are crucial in deciding that CPAP treatment should be started. During actual treatment, good observation is crucial for evaluating whether the patient is getting a result from the treatment, but also to prevent complications from arising that force us to break off or whether there is a failure in the equipment which requires fixing (leaks, lack of oxygen etc.)

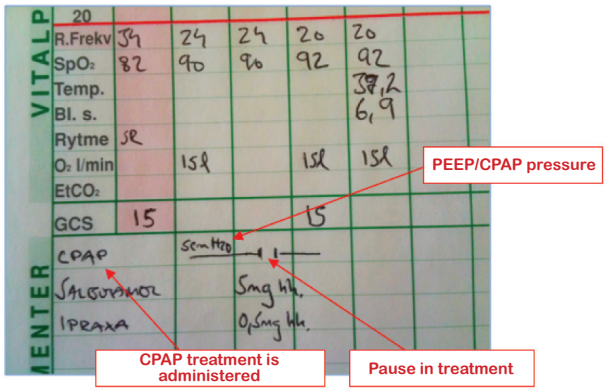
Note

- Consciousness, GCS should be scored, but it is a crude tool in this situation, assess also whether the patient is beginning to be sleepy and worn out. (CPAP treatment requires that the patient is awake and can keep the airways free.)
- Respiratory rate (RR), Respiratory pattern (superficial, accessory muscles etc.), Spo2.
- Pulse (rate, amplitude and regularity), skin (warm, cold, dry, clammy). Blood pressure.
- Temperature

Documentation

All observations and measures that are performed should be documented, also CPAP treatment. In addition to the usual vital parameters, it is important in CPAP treatment to document PEEP/CPAP pressure. Pressure is given in cm H2O, also document O2 l/min, also document how long the patient receives CPAP treatment. Also, be careful to document the changes in respiration of the patient (RR. SpO2).

CPAP can be looked up in the ambulance reference under the category of medications. Put in the PEEP/CPAP pressure and draw a line through the boxes for it and show when the treatment occurred, show with "gaps" in the line when there were pauses in the treatment, or when the treatment ended. (see table)



NOTE:

Watch to see that the patient is exhaling through the port in the mask/CPAP generator. In order for the patient to be able to exhale it is important that it does not become blocked!

Also, be watchful with regard to the risk of aspiration in CPAP treatment. **Never leave the patient** during CPAP treatment!

Sources of error

The Flow-Safe CPAP system is very simple and easy to assemble. Nevertheless errors can arise in the system.

The most frequent is leaks, most frequently around the mask. If the mask does not fit tightly, there will not be the desired pressure in the system and consequently not the desired effect.

It is also important that the CPAP generator is properly connected to the mask so that there is no harm to the O2 tubing, and that the O2 tubing is firmly connected to the flow meter. The system also requires adequate flow to reach the desired pressure.

REFERENCE HANDBOOK

CPAP treatment

(Continuous Positive Airway Pressure)

CPAP provides positive airway pressure both with inhalation and exhalation. Pre-hospital CPAP care means that we can avoid intubation and long intensive care for some patients. For pulmonary edema, good results are obtained by starting CPAP treatment before beginning medicinal treatment. For COPD/asthma, inhalation treatment with salbutamol and ipratropium bromide should be attempted before beginning CPAP.

Indications

Serious respiratory failure and suspicion of at least one of these conditions:

Pulmonary edema
COPD
Asthma

Contra-indications

Risk of aspiration
Lowered consciousness
Increased intracranial pressure
Pneumothorax
Hypotension (systolic BT <95 mmHg)
Major hemorrhaging
Epiglottitis

Before beginning, the following should be performed:

Listen to the patient
Check that we have enough oxygen, and possibly make a plan to order more.

Start-up

- Have all equipment available for start-up, check for safety and inform the patient.
- Chose the correct mask size.
- Start CPAP system at a moderate setting (flow at 15 liters)
- Place the mask on the patient so that it fits snugly.
- When/if the patient accepts the mask, secure the mask using the accompanying straps.
- Adjust to the desired PEEP pressure. Usually a pressure between 5 and 10 cm H_2O
- It is not unusual that patients accept the treatment poorly and attempt to remove the mask. In order for the treatment to succeed, it is important that the patient cooperate.
- Be calm and inform the patient about what is happening. Sit together with the patient. Let the patient himself hold the mask tightly over the nose and mouth and do not fasten the mask on the patient before the patient cooperates well and accepts the treatment.

Monitoring/Evaluation

Monitoring of SaO_2, BP and pulse at least every five minutes to begin with. Evaluate the treatment result continually. Pause or termination of the CPAP-treatment should be evaluated when other measures have had time to work; when the patient is improving significantly; if contra-indications arise during treatment; if the patient will not accept the mask or if the patient gets worse from the treatment.