

Continuous Positive Airway Pressure (CPAP)

“Not being limited to what’s inside the box”

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Introduction:

CPAP therapy has been utilized in medicine for over 100 years. However, the use of CPAP in EMS is comparatively new and is not a standard of care in every system.

The introduction of CPAP to EMS ranks near the top as one of the most effective treatments introduced to the pre-hospital environment in the last fifteen years. With that said, some EMS systems have limited the use of CPAP to congestive heart failure (CHF) or for adults only; when, in fact, any patient in respiratory distress should be considered a candidate for CPAP. The goal of CPAP is to reduce the work-of-breathing and buy time for more definitive treatments to work.

The premise of this booklet is to inform EMS clinicians on the expanded use of CPAP. Only through education and experience can we improve in the medical specialty of Emergency Medicine.

Ignorance is defined as,

“The condition of being uneducated, unaware, or uninformed.”

Merriam-Webster Dictionary

“Knowledge is of no value unless you put it into practice.”

Dr. Anton Chekhov
Physician/Playwright 1860 – 1904

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How CPAP Works:

Continuous Positive Airway Pressure, (CPAP), is the maintenance of positive pressure throughout the complete respiratory cycle, (inspiration and expiration), when breathing spontaneously. CPAP is not the same as Positive End Expiratory Pressure or PEEP. PEEP only provides pressure on the expiratory side by offering resistance to exhalation using a spring-loaded valve or air flow. If a device only provides PEEP, then by definition, it is an oxygen administration device with a PEEP valve, not CPAP. The best way to determine if a device truly provides CPAP is to have a pressure manometer in-line. Having a pressure manometer in-line should be mandatory for determining pressure administered, patient safety and documentation. CPAP is measured in centimeters of water, written as cmH₂O.

Properly Applied CPAP:

1. During the inspiratory phase, patients in distress will have to create a higher flow rate of air to meet their needs, this will present as an increase in work-of-breathing (WOB). Patients in respiratory distress may need to achieve inspiratory flow rates greater than 65 liters per min (LPM). With the inspiratory support of CPAP, the patient does not have to work as hard to inhale and overcoming the auto PEEP in the lung. Auto-PEEP represents the abnormal, and usually undetected, residual pressure above atmospheric remaining in the alveoli at end-exhalation due to air trapping. Auto-PEEP is also referred to as occult PEEP, intrinsic PEEP or dynamic hyperinflation. The auto PEEP has to be overcome each time a person inhales, for a healthy person the work is minimal and goes unnoticed. However, those patients with stiff lungs, (CHF and Pulmonary Fibrosis), have to work extremely hard to overcome the increased auto PEEP on every breath.
2. The increased inspiratory pressure also increases the size, therefore the surface area of the alveoli, providing a greater opportunity for gas exchange or respiration. The process increases the Functional Residual Capacity (FRC) of the lung. The FRC is the area where gas exchange takes place.
3. Since a greater oxygen percentage is able to reach the alveoli during CPAP, the partial pressure of the oxygen molecule will be greater. The higher partial pressure will allow more oxygen to diffuse into the blood stream improving oxygenation. Oxygen under pressure should be considered oxygen therapy in its most efficient form. Increased oxygenation could result in lowered cardiac work and oxygen consumption with a reduced cardiac arrhythmia risk.
4. Fluid in the alveolar space cannot only make the lung stiff, (increasing inspiratory work-of-breathing), it also creates a barrier that can reduce gas exchange. The pressure from CPAP can reduce the fluid by forcing fluid out of the alveolar space back into the interstitium.
5. During the expiratory phase, the patient will breathe against a threshold of resistance that works as a pneumatic splint to hold the airways open. Patients with chronic lung disease have weakened airways that have a tendency to collapse on expiration, causing air trapping. Having the airways stented open during exhalation will make inspiration on the next breath less difficult.
6. The resistance during exhalation can open non-ventilated areas of the lung recruiting alveoli that have collapsed due to atelectasis, (a collapse of lung tissue affecting part, or all, of one lung effecting gas exchange).
7. CPAP decreases pre-load and after-load on the heart reducing the heart's workload. However, a reduction in pre-load and after-load will have an effect on the patient's blood pressure. Patients should have a systolic blood pressure of at least 100 mmHg before starting CPAP.

Understanding The Importance of Flow Rates:

“Flow rates have to match the patient’s need or CPAP will fail.”

The flow rate or velocity of the air/oxygen a patient breathes in has a great impact on their work-of-breathing. Most everyone has experienced the sensation of shortness-of-breath at some point. For example, anyone who has worn an SCBA, (Self-Contained Breathing Apparatus), while doing strenuous work most likely felt some shortness-of-breath, some may have opened the bypass valve to get more air. Those that have opened the bypass did not need more air, they needed it faster, to meet the demand caused by the extra work. This can also happen by simply putting on an N95 mask. The filter on the N95 mask takes extra work to inhale. For a healthy person, this extra work caused by the mask or the SCBA generally goes unnoticed.

For patients having difficulty breathing, the velocity of the air/oxygen is also of great importance. Patients in respiratory distress will have to work harder to get the air at the speed they need it and will exhibit difficulty breathing and a complaint of shortness-of-breath. Once the work-of-breathing exceeds the patient’s capability to meet that need, the patient will go into respiratory failure. Patients in respiratory failure are NOT candidates for CPAP, they need manual ventilation or a ventilator.

Most CPAP devices provide the velocity by one of two methods. The device either attaches to the high pressure side of the regulator or flowmeter, (approximately 140 LPM), or they attach to the low pressure side and use Bernoulli's Principle to increase the speed, (approximately 120 LPM), either method has been found to be effective. If the flow rate does not meet the patient's need, they will experience air hunger and will fight the treatment. Some clinicians advocate sedating patients who fight CPAP therapy, in most cases that would be counterproductive and may lead to respiratory depression. However, that does not mean the patient cannot be given an anti-anxiety medication. The first step to consider when a patient is non-compliant with CPAP is to increase the flow rate, even if it increases the pressure. Some devices are at the maximum flow rate at all times, (attached to the high pressure side), others increase the flow rate as the pressure is adjusted up, (attached to the low pressure side).

Bernoulli's Principle – As the flow is narrowed, the velocity will increase. This can be demonstrated by putting your finger over the end of a garden hose causing the water to shoot farther and faster. The maneuver does not increase the volume, just the forward velocity.

What Types of Patients Are NOT Candidates for CPAP?

Being able to assess and determine who is, and who is not, a candidate for CPAP has a great impact on whether CPAP will be effective or not. CPAP can be a very effective treatment for patients in respiratory distress but is not indicated for patients in respiratory failure. Respiratory distress patients are still compensating even though they may be working hard. It is not uncommon for respiratory distress patients to have oxygen saturations (SpO₂) and carbon dioxide, (CO₂), levels within normal range. Key determinants include; is the patient alert, (even though they are working hard), and can they follow directions. Patients that have gone into respiratory failure may exhibit a decrease in work-of-breathing, CO₂ levels climbing, oxygen saturations falling, and their level of consciousness declining, (most likely from CO₂ narcosis). CPAP is not indicated for respiratory failure patients. All respiratory distress patients, regardless of the underlying pathology, should be considered a candidate for CPAP. Some EMS systems limit their use of CPAP to Congestive Heart Failure patients, a trend that is changing as EMS systems become more comfortable and more educated on the therapy.

CPAP and Congestive Heart Failure (CHF):

The treatment of Congestive Heart Failure, (CHF), by EMS has changed significantly in the last couple of years. The mainstays of CHF in the pre-hospital setting are CPAP and nitroglycerin. The efficacy of Lasix and Morphine is under scrutiny and has been removed from many EMS protocols. Many systems that adopt CPAP start with CHF. The effects of CPAP are well suited for the physiologic issues associated with this disease. Pulmonary edema, associated with CHF, makes the lungs stiff and it is difficult for the patient to inhale; and can be observed as difficulty breathing during the inspiratory phase of ventilation or inspiratory shortness-of-breath. Since CHF is primarily a heart problem, CPAP addresses the side effects of a failing heart and its impact on the lungs. For example, pulmonary edema can cause what is called, a ventilation/perfusion mismatch often called a V/Q mismatch. What this means is anytime there is a barrier that prevents the oxygen from getting to the blood, there is a mismatch, in this case the fluid is the barrier. CHF is a process that will continue to spiral down the cardiogenic shock pathway until the cycle is broken. As the patient's heart fails, more fluid ends up in the lungs. With more fluid in the lungs, less oxygen makes it to the heart muscle, so the heart fails even more. The first step in stopping the cycle is the early use of CPAP and nitroglycerin. If the patient does not have lung disease then the airways should function normally and not collapse on exhalation. In this case, the inspiratory pressure will force the fluid out of the lungs, expand the alveoli which, in turn, will increase gas exchange (respirations) improving oxygenation. In addition, with the airways being held open by the expiratory resistance, the patient does not have to overcome the auto PEEP at the beginning of each breath. With the improvement of gas exchange and reduced impact of auto PEEP, the patient's work-of-breathing will be reduced. With the reduced work, there will be less stress on the heart.

A key factor in the initiation of CPAP, as well as nitroglycerin, is the patient's blood pressure. It is recommended that the systolic blood pressure be at least 100 mmHg before starting CPAP or nitroglycerin, due to the reduction in pre-load and after-load.

CPAP and Chronic Obstructive Pulmonary Disease (COPD):

COPD is characterized by two different disease processes, emphysema and chronic bronchitis. COPD damages the airways causing them to decrease in size or collapse on expiration. According to Poiseuille's Law, a reduction in the diameter by $\frac{1}{2}$ will increase the work-of-breathing by a multiple of four, causing most COPD patients to exhibit expiratory difficulty breathing or expiratory shortness-of-breath. Chronic lung patients also trap air because of the collapsed airways making it difficult to exhale as well as inhale. In chronic bronchitis, the airways become swollen and there is an increase in mucus production, both of which can narrow the airway. A good way to feel what it's like to have COPD is to take a deep breath and hold it, then do all of your breathing on top of the deep breath. CPAP can be very successful in the treatment of COPD. By stenting the airways open, the patient can exhale easier and more completely, resulting in less work. Since the airways, and not the alveoli, are the problem COPD patients are often treated with nebulizer treatments with bronchodilators. Since CPAP holds the airways open, breathing treatments are more effective at depositing the medications deeper in the lungs. Using continuous nebulization has been shown to be more effective than repeated treatments.

CPAP and Asthma:

Asthma is characterized by a triad of problems; bronchospasm, airway swelling, and increased mucus production. Due to the narrowing of the airway especially during exhalation by these problems, asthmatic patients will exhibit expiratory difficulty breathing. It has been shown that if bronchospasm and airway swelling are successfully treated, the patient can deal with the increased mucus production. Before CPAP was introduced to EMS, asthma was treated with bronchodilators, (Albuterol and Atrovent), for the bronchospasms and steroids, (Solu-Medrol) IV, for airway swelling. Bronchodilators and steroids are still the first-line standard of care for asthma.

CPAP can also be used in conjunction with bronchodilators and steroids in the treatment of asthma. Since asthmatics have trouble getting the air out, using CPAP to stent the airways open, will facilitate exhalation, (reducing air trapping), and reduce the work-of-breathing. CPAP will also make nebulizer treatments more effective by allowing deeper penetration of the medication.

CPAP and Pneumonia:

Pre-hospital treatment of pneumonia is supportive in nature. Historically treatment has been directed toward oxygenation and fluids to prevent dehydration. CPAP does not treat pneumonia directly, however it can reduce the work-of-breathing often seen with pneumonia. Pneumonia, in most cases, is found unilaterally, (on one side), and can interfere with gas exchange, (respiration), on the effected side. Remember, there may be additional areas of the lung that could be ventilated by using CPAP to recruit unventilated alveoli. The goal is to offset what the pneumonia is blocking with recruited alveoli or open small airways previously obstructed.

CPAP and Near Drowning:

Near drowning is the term for survival after suffocation caused by submersion in water or another fluid as compared to drowning where the patient is dead. CPAP is not the same as a Bag-Valve-Mask and is contraindicated for patients that are apneic or in cardiac arrest. Full face mask CPAP has been used with great success, in the hospital setting, for many years to avoid intubation of patients suffering from Acute Respiratory Distress secondary to near drowning. Some near drowning victims may go on to develop non-cardiogenic pulmonary edema making CPAP a viable option. Near drowning patients may also have significant hypoxia and bronchospasm, both of which can be effectively treated with CPAP. With the positive effects of CPAP on non-cardiac pulmonary edema, hypoxia, bronchospasm, along with the potential recruitment of non-ventilated alveoli, the work-of-breathing can be greatly reduced by CPAP, potentially preventing intubation.

CPAP and Pulmonary Embolism (PE):

Historically EMS has been limited to general supportive care and high flow oxygen for the treatment of pulmonary embolism. If a patient is suspected of having a pulmonary embolism and their systolic blood pressure is above 100 mmHg, CPAP may be effective in reducing the work-of-breathing. CPAP can help correct hypoxia from a PE by recruiting alveoli that are still being perfused but may not be ventilated. In addition, since CPAP increases the surface area of the alveoli with a higher FiO₂, (more partial pressure from the oxygen molecule), more gas exchange can take place. CPAP is contraindicated in patients with a low blood pressure since the positive pressure can reduce the pre-load reducing the blood pressure even further. Pre-hospital administration of CPAP to a suspected PE patient may buy the patient time for the administration of "clot-busting" drugs called, thrombolytics, at the hospital.

CPAP and Do Not Resuscitate, (DNR), Order:

In most states, a DNR is an Advanced Directive that covers some very specific procedures having to do with cardiac arrest. Most DNR's will not allow health care providers to administer chest compressions, insert an artificial airway, administer resuscitative drugs, defibrillate or cardiovert, provide respiratory assistance, (other than suctioning the airway and administering oxygen), initiate resuscitative IV or initiate cardiac monitoring. When a patient has a valid DNR, and doctors and nurses stop focusing on treatment, and begin to focus on comfort measures only, this is called Palliative Care. In some states, CPAP can be used as a form of Palliative Care, making the patient more comfortable when struggling to breathe. Follow local protocol on the use of CPAP for patients with DNR's.

CPAP and Children:

Many EMS systems place age limits on providing CPAP to children. It's not uncommon to see protocols restricting CPAP to patients over the age of 12. There are no medical contraindications to using CPAP on children of any age. For example, CPAP is routinely used in Labor and Delivery, as well as the NICU. (An example only: EMS should not be using CPAP on young infants and neonates due to the difficulty of application and the type of equipment needed). However, applying CPAP to a child can be very effective therapy if the following two rules apply. First, the patient has to be able to tolerate the treatment. If the child is fighting the treatment, it can actually make the patient worse. Secondly, does the patient interface, (mask), get a good seal? Remember, one of the goals for CPAP is to reduce work-of-breathing. If the patient is working hard-to-breathe, can tolerate the treatment and has a good mask seal, what's the downside to CPAP? There is none.

CPAP and Tracheostomy Patients:

Encountering patients with tracheostomy tubes is not uncommon in EMS. These same patients can obviously have medical problems unrelated to the cause of the tracheostomy. Is it conceivable that these patients could benefit from CPAP because of CHF or COPD? It's not only conceivable, it's likely. There are several ways to provide CPAP to a tracheostomy patient; the key is, do they have a trach tube in place? Or just a stoma or hole? For patients with a trach tube in place the first thing to determine is whether the patient is breathing through the tube or is it capped? If the tube is capped that means they are breathing normally and CPAP can be administered with a mask. The cuff on the trach tube may have to be inflated to get a good seal. A capped tube indicates that the tube has a hole at the curve of the tube for the patient to breathe through. An uncapped tube may indicate that the patient does not have an intact airway to the nose and mouth, so a mask may not be an option. Many trach tubes have an inner cannula that can be removed and will allow the patient to talk if their airway is intact. When the cannula is in place, it blocks the hole in the curve so no air passes the vocal cords. To tell the difference when the cannula is in, it resembles the connector on an endotracheal tube, (ETT), allowing a Bag-Valve-Mask, (BVM), or ventilator to be attached. If the cannula is out, the end is more flat and there is no connection for the BVM or ventilator. To apply CPAP to a patient with a trach tube, the cannula has to be in place. In most cases, the patient or a family member can assist placing the tube. If not, and protocols allow it, the cannula can be easily inserted and once in place can be locked by turning the connector to the right. With the cannula in place, some CPAP devices can be attached directly to the trach tube, once the mask is removed. By removing the mask and attaching the device directly to the trach tube, the patient's interface with the CPAP device was the only change; the device will still function as before. There are people walking around with stomas with no tube in place. The only way to place them on CPAP is to insert a trach tube, (not the standard of care for many systems), or insert an endotracheal tube into the hole and attach the CPAP device to the ETT. **Caution:** The tube should only be inserted to the point that the cuff disappears. Once the cuff disappears, the cuff should be inflated.

When Should CPAP be Discontinued and Manual Ventilation Started?

CPAP should be discontinued when a patient goes from respiratory distress to respiratory failure. It is recommended that all CPAP patients be continuously monitored using capnography/capnometry and pulse oximetry. Oxygenation is obviously very important, but the true measure of a patient's ability to move air is carbon dioxide, (CO₂). Patients in respiratory distress can have a relatively normal CO₂ because they are compensating, exhibited by the effort they are putting in to breathe. As the patient tires or their condition gets worse their ability to compensate may no longer be effective. Once the patient starts to decompensate, their CO₂ levels will start to climb. As the CO₂ climbs and converts to an acid, the pH will fall causing the patient to become acidotic and end up in respiratory failure. The patient will exhibit a reduction in their work-of-breathing or effort-to-breathe, (running out of gas), and will show signs of a decrease in their level of consciousness, (Narcosis from high levels of CO₂). These patients need to be ventilated manually or on a ventilator and are no longer candidates for CPAP.

Conclusion:

With the changes in medicine, both clinically and financially, EMS can no longer concern themselves with just the time from dispatch to the arrival at the hospital. Not only will EMS be involved with patients before they call 911, (Advance Practice Paramedics), they will also have to possess a greater understanding of how their actions, before arriving at the hospital, effect care in the hospital. Research has shown that CPAP reduces the need for intubation and that an intubated patient's stay in the hospital is twice as long as non-intubated patients. It's been reported that one day in the ICU can cost as much as \$8,000 with reimbursement being based on outcomes and not treatments. Expanded use of CPAP can be a "win," for not only the patient but the hospital as well as EMS. Some medical directors have asserted, that due to short transport times, there was no need for an aggressive CPAP protocol. In response, consider the following scenario where EMS does not carry CPAP.

EMS responds to a patient who is complaining of difficulty breathing. After assessing the patient they determine that the patient is in CHF. The crew provides general supportive care, (O₂, IV, and monitor), and administers Nitroglycerin. The patient is placed on a stretcher and taken to the ambulance. Once the patient is settled in the ambulance, the patient is transported to the hospital, about 10 minutes away. During transport, the crew called the hospital and gave a report. Upon arrival at the hospital, the patient was unloaded and taken inside where the triage nurse directed the crew to a cardiac bed. The patient was transferred to the bed and a report was given to the nurse. The ER doctor arrived at the bedside and quickly ordered the patient to be placed on CPAP. At this point, the unit secretary pages Respiratory Therapy to place the patient on CPAP. Respiratory Therapy arrives a few minutes later and starts the patient on CPAP.

This is a pretty typical call for EMS just about anywhere. EMS clinicians learn early on that patients don't call at the first sign of trouble. In this scenario, how much time would have passed from first contact with the patient to the start of CPAP by Respiratory, (assuming Respiratory and a CPAP machine are available). If the patient is on CPAP within an hour of first contact, the system does pretty well. Why should a patient continue to suffer and potentially deteriorate for another hour? (Answer: They shouldn't.) Especially when we consider the patient may have been spiraling down several hours before calling 911.

Other factors to consider:

- What if Respiratory Therapy is not available?
- What if the closest hospital is on divert?
- What if the hospital is extremely busy and does not have a CPAP machine available?
- What if you are on an ALS engine waiting for a transport unit?

CPAP is a cost-effective, life saving device . . .

. . . that should be a standard of care in every EMS system.

“Education is learning what you didn’t even know you didn’t know.”

Daniel J. Boorstin

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