PedsCases Podcast Scripts

This is a text version of a podcast from Pedscases.com on "**Non-Invasive Ventilation in Pediatric Medicine.**" These podcasts are designed to give medical students an overview of key topics in pediatrics. The audio versions are accessible on iTunes or at www.pedcases.com/podcasts.

Non-Invasive Ventilation in Pediatric Medicine

Developed by Jenner Lakusta, Dr. Jonathan Duff and Dr. Chris Novak for PedsCases.com.
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Introduction:

Hello everyone, my name is Jenner Lakusta and I am a Medical Student at the University of Alberta, in the class of 2020! This podcast was produced for PedsCases.com with the help of doctors Jonathan Duff and Chris Novak. Dr. Duff is a pediatric intensivist at the Stollery Children's hospital in Edmonton as well as an associate professor in the University of Alberta's Faculty of Medicine and Dentistry. Dr. Novak is a second-year resident at the Stollery Children's Hospital. This podcast will review the usage of non-invasive ventilation (NIV) in pediatrics. The use of NIV in acute care and the home care setting has been rising since the 1980's. NIV has now become a valuable tool in treating both acute and chronic respiratory failure in both pediatric patients and adults.

Clinical Case

Let's use a case study to put this discussion in context. You are just starting your pediatric rotation and working in the Pediatric emergency department for a night. One of your patients is John, a previously healthy 12-month-old boy. He was brought in twenty minutes ago because his parents noticed he was having some trouble breathing. From a detailed history, you learn that about 3 days ago he came down with what looked like a normal cold. He was irritable had a runny nose, fever and a cough but otherwise seemed OK. Over the last two days though they say his cough seemed to get progressively worse and then last night he began to have increased work of breathing. John's parents say that he seemed to be breathing much faster than normal and started wheezing, they were worried so they brought him into the emergency room. The nursing staff report Johns vitals to you, heart rate 190 bpm, resp. rate 65brpm, temperature 39.5°C via rectum, blood pressure 100/54, and a worrying oxygen saturation of 85% on room air. On exam, you note severe work of breathing with intercostal in-drawing and tracheal tug. Listening to the chest you hear diffuse expiratory wheeze, and upper airway congestion. Nursing places John on some oxygen by nasal cannula, however his oxygen saturation only increase to 90% on 2L and his severe work of breathing persists. After consulting your attending physician, you both agree that it's likely that John has some kind of viral lower respiratory tract infection like

RSV (Respiratory Syncytial Virus), that has led to bronchiolitis. The attending asks what you would like to do next? You explain that you would like to give this patient some respiratory assistance, but how do you proceed? Should you secure his airway and intubate? Should you consider non-invasive ventilation? These are all questions that we will be able to answer by the end of this podcast. With this in mind let's move to the learning objectives:

The learning objectives of this podcast are to:

1. Review basic principles of non-invasive ventilation
2. Discuss the different types of non-invasive ventilation including high-flow nasal cannula, CPAP and BiPAP.
3. Review common indications for NIV in pediatric medicine today.

Definitions

To start our podcast let's review some basic definitions. Invasive ventilation refers to, forms of ventilatory support that use an artificial airway such as an endotracheal tube or tracheostomy tube. Non-invasive ventilation refers to any form of ventilatory support that does not make use of an invasive airway.

To provide ventilation, a pressure gradient between the mouth and lungs must be created to drive air in to the chest. There are 2 ways to generate this pressure gradient: positive pressure ventilation and negative pressure ventilation.

Negative pressure ventilation mimics our natural physiology of respiration. Negative pressure ventilation creates a pressure less than that of atmospheric pressure inside the airways to suck air into the lungs. In normal physiology, our respiratory muscles including the diaphragm, expand the thoracic cavity to create this pressure. In the old days of polio epidemics, the "iron lung" was an example of non-invasive negative pressure ventilation. The thorax was incased in a full body tube or a smaller shell around just the thorax and the pressure within this vessel is decreased until it is less than that of the atmosphere. This creates a negative pressure system that pulls air into the lungs to inflate them. Expiration occurs with the passive recoil of the chest wall and thorax. Negative pressure ventilation is rarely used today primarily due to better options being available.

Positive pressure ventilation (PPV) refers to methods of ventilation in which respiratory assistance is provided by using pressure greater than atmospheric pressure to drive air into the lungs. There are a number of different interfaces to provide positive pressure and air delivery. Examples of positive pressure ventilation include high-flow nasal cannula, continuous positive airway pressure or CPAP and Bilevel positive airway pressure or BiPAP. Positive pressure can be delivered using specially designed nasal cannula (high-flow nasal cannula) or, more commonly, through a mask. Different masks can be used including a full-face mask (covering both the nose and mouth), a nasal mask (which covers just the nose), or a total face- mask (which covers the mouth nose and eyes sealing on the forehead). Non-invasive positive pressure ventilation has been shown to be effective in

reducing respiratory rate, increasing tidal volumes and decreasing dyspnea in patients with varying respiratory conditions.

Types of Non-Invasive Ventilation

Let's now discuss the three most common types of non-invasive ventilation: CPAP, BiPAP and High-Flow Nasal Cannula.

As we learned earlier CPAP stands for continuous positive airway pressure. So CPAP as the name implies maintains a continuous supply of positive or greater than atmospheric pressure air to the patient's airway. It can be thought of as sticking ones head out of a fast moving car with your mouth open minus all the bugs you would swallow. This positive pressure works to keep the airways open and therefore to assist in breathing, by using an air "stent". CPAP proves the most beneficial to patients who need help keeping their lungs open.

BiPAP on the other hand stands for Bi-Level Positive Airway Pressure. As the name implies this means that the ventilator delivers two pressures. It maintains a level of constant positive pressure known as expiratory positive airway pressure or EPAP. EPAP is identical to CPAP. The difference between BiPAP and CPAP comes during patient inspiration. In BiPAP, the ventilator detects the patient's ventilatory effort and provides an increased level of pressure to aid their inspiration – known as inspiratory positive airway pressure or IPAP. BiPAP pressures are recorded as IPAP over or on EPAP – for example 16 on 8. This means the patient is receiving 8 cm of water pressure CPAP and an additional 8 cm of water pressure (for a total of 16) during inspiration. BiPAP is more complex to setup than CPAP as it needs to detect the patient's inspiratory effort, which can be difficult in small pediatric patients. It is most helpful when patients have difficulty with inspiratory effort such as in muscle weakness or parenchymal lung disease.

Another interface for delivering non-invasive ventilation that we will touch on is high flow nasal cannula. High flow nasal cannula or HFNC delivers humidified oxygen through a specialized nasal cannula at high flow rates. Modern systems add both heat and humidity to the oxygen to make it more comfortable and viable for delivering high flows. This large amount of flow acts to create continuous positive pressure in the lungs – in essence, delivering CPAP through nasal cannula. In fact HFNC has been referred to as a poor-man's CPAP. Modern systems were originally developed for neonates but have since been refined and brought to the world of adult medicine. A typical dose of high flow oxygen is 1-2cc/kg/min up to a maximum of 60lpm. HFNC helps to flush out any dead space in the child's lungs with oxygen rich air, and the pressure can act as a positive pressure stent helping to keep the child's airway patent, especially with small patients. An important consideration is that patients must have intact respiratory drives in order to benefit from a high flow nasal cannula. The research is still very much in progress with HFNC and with more research we will have a more concrete set of guidelines.

CPAP, BiPAP and high flow nasal cannula represent three of the most useful and popular options for Non-invasive ventilation, now that we know a little bit more about them lets move on to figuring out when exactly we should utilize them!

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Indications for NIV

The use of NIV has been on the rise as the technology and our understanding of how to use it increases. When successful, it avoids some of the potential complications of invasive ventilation such as airway injury and increased sedation requirements. We need to understand the best ways in which we can use NIV to get the most benefit for our patients. When should we consider NIV as a treatment option and when should we avoid it?

The indications for NIV can be roughly divided into acute and chronic. Acute indications include a variety of causes of respiratory distress. Chronic indications include obstructive sleep apnea, and neuromuscular disorders.

Let's start with acute indications for NIV. When using NIV in acute care settings it's important to first consider contraindications. NIV is NOT a substitute for an artificial airway. The patient must have a patent airway for NIV to be successful. Other absolute contra-indications for NIV include cardiopulmonary arrest, multi-organ failure, and facial deformities that impair mask seal. Poor secretion control is a relative contra-indication to NIV as it can sometimes lead to secretion impaction and airway obstruction. Hemodynamic instability is a relative contra-indication as well. In general, if your patient needs to be intubated, then you should intubate them.

So when should we use NIV is the acute setting? It is suggested that a trial of NIV be used for most hemodynamically stable pediatric patients who are experiencing mild to moderate hypoxemic or hypercapnic respiratory failure but do not require intubation. Again it is important to confirm that your patient does not have any contraindications to NIV as discussed earlier. Evidence exists for the use of NIV in acute cases such as:[2]

- Bronchiolitis
- Status asthmaticus (severe acute exacerbation of asthma not responding to therapy)
- Pneumonia, especially in patients with neuromuscular disease
- Pulmonary edema
- Cystic fibrosis
- Acute chest syndrome in Sickle Cell Disease
- Dynamic upper airway obstruction caused by tracheomalacia, laryngomalacia

In any of these situations, where no contraindications are present it would be appropriate to start NIV in the acute care setting. Using NIV in the acute care setting can decrease the severity of a presenting illness and help to avoid the need for intubation.
Now let's take a look at some uses for NIV in the more chronic care setting:

NIV has been successfully utilized in both adult and pediatric obstructive sleep apnea or OSA. OSA is more common in adults for various reasons but it is also seen in pediatric patients from time to time with the most common cause being enlarged tonsils or adenoids. Children with Downs' syndrome are also at increased risk for OSA[4]. OSA is caused by abnormal upper airway patency while children sleep, this causes the airway to collapse and become obstructed, leading to apneic events. NIV and CPAP specifically helps to keep the upper airways patent by providing a continuous airflow "stent"[4]. Cessation of the apneic

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events allows for sleep throughout the night, which is essential for the growth and development of children (and the sanity of parents). To learn more, you can listen to our PedsCases podcast on OSA in children.

NIV has also found great use with the treatment of neuromuscular lung disease including genetic progressive neuromuscular diseases such as muscular dystrophy or spinal muscular atrophy. Studies suggest that NIV improves outcomes in restrictive lung diseases in 3 ways: 1. Improving ventilatory mechanics, 2. Resting fatigued respiratory muscles and 3. Enhancing ventilatory sensitivity to carbon dioxide[5,6]. Respiratory failure is one of the leading causes of death for children with neuromuscular diseases, and NIV can help extend the life expectancy of many of these children.

The last modality we would like to touch on for indications is that of heated/humidified High Flow Nasal Canal or HFNC. High flow nasal cannulas seem to be best suited to those with mild to moderate hypoxemic respiratory distress. Because it does not require a tightly fitting mask, it is more comfortable than CPAP or BiPAP, However, it cannot generate the same amount of pressure as CPAP and can only be used in patients with milder disease. The setup of HFNC is also considerably simpler than that of CPAP and BiPAP. Many patients experience claustrophobia while using CPAP facemasks, HFNC avoids this by use of nasal prongs. There is good evidence that the use of HFNC in bronchiolitis can reduce trips to PICU and decrease the need for intubation. In summary, HFNC works well for patients in respiratory distress that cannot tolerate CPAP/BiPAP, for respiratory assistance during transportation, and there is increasing evidence for it's use in bronchiolitis[7].

On top of all this information it is important to remember that NIV is still a young science. Many small studies have been published noting the possible benefits of NIV in other areas of medicine but until more research is done in these areas especially on the pediatric side of things we cannot yet say how effective NIV will be. What should be apparent though is the use of NIV is on the rise and its indications will likely only increase in time.

Starting NIV

So now that I know when to consider NIV how do I get started? What do I have to consider?

When choosing a method of delivery for positive pressure ventilation there are a few things we should consider. The seal is the most important variable, if the mask does not seal then the therapy will not work to its fullest capacity or intent. It's important to remember that when it comes to positive pressure ventilation with a mask interface, the method of delivery that we choose must make a good seal with the patients face to minimize air leak. An airtight seal is not required and not recommended, but adequate sealing to minimize leak is essential. Next, we should examine the patient's breathing pattern, if our patient breaths a lot through their mouth then a mask that supplies air through the nose only will not be suitable as any positive pressure applied through the nose with the mouth open will simply flow out the mouth defeating the purpose of the respiratory therapy. Next, we should try to pick the best delivery method with regards to patient comfort and wellbeing. A lot of considerations should go into this. How long will our pediatric patient have to wear the mask? Will it be on essentially 24/7, only at night or during episodes of desaturation? Do we

have masks small enough to fit the patient comfortably? Fitting a facemask can be tricky and often requires specialized services such as occupational therapy. Lastly we should consider claustrophobia and fear. Is our patient old enough to understand why they need the mask, if they are agitated and constantly trying to remove the mask this is a problem. Many adult patients have reported claustrophobia and anxiety with the use of the full-face positive pressure mask. This anxiety and fear can further complicate a situation with a pediatric patient who is desaturating and can lead to decreased well-being for patients who are using these masks for long periods of time. The total facemask is an option for patients who feel claustrophobic, as it allows a fuller field of vision and is more comfortable for many patients.

Masks can be difficult to fit so it's a good idea to also ask yourself, can I do the same thing with HFNC instead of CPAP. If the answer is yes it does not hurt to trial a HFNC before CPAP. In most patients, if the non-invasive ventilation improves the patient's symptoms, they will tolerate it well. If a patient cannot tolerate non-invasive ventilation as it is currently setup, it is very possible that it is not setup correctly or not the best ventilator strategy for that patient. All of these factors should be considered when choosing a delivery method for positive pressure ventilation.

Conclusion

That wraps up this podcast- but before we go let's do a quick case review!

Remember our patient is a 12-month-old boy named John, who presented with bronchiolitis with severe work of breathing and low O_2 sats on low-flow nasal cannula support. Thinking back to your newfound knowledge in NIV you suggest the use of a high flow nasal cannula. The attending agrees and the nurses immediately set up John with high flow nasal cannula, at a rate 12l/min of body temperature humidified oxygen. John's O_2 sat quickly rises to 96% and his work of breathing significantly decreases. John is brought to the PICU for supportive care, and within 2 days is weaned down to low-flow nasal cannula O_2. A nasopharyngeal swab comes back positive for Respiratory Syncytial Virus, a common infection in children. Thanks to NIV, John was able to avoid intubation, have excellent respiratory support and make a full recovery.

That just about does it for this podcast but before we wrap up, let's quickly go over a few key take-home points:

1. Non-Invasive Ventilation provides positive pressure ventilation through either special nasal cannula or a facemask.
2. NIV can be used for acute presentations of respiratory distress, or for chronic conditions like obstructive sleep apnea or neuromuscular disorders.
3. When initiating NIV we should consider contraindications, if the available masks can seal with our patients face and patient comfort and compliance.

For further updates and information always refer to the appropriate clinical guidelines, with any luck some will be published soon for NIV in pediatric medicine. Thanks for listening!

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