Management of ventilator associated respiratory infections in children on home invasive mechanical ventilation

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Abstract

Ventilator associated respiratory tract infections (VARTI) are among the most common indications for hospitalization among children with chronic respiratory failure requiring at-home ventilation. This review aims to provide an overview of the key clinical features, diagnostic approaches, and management strategies for home VARTIs while highlighting the challenges in diagnosis and management.

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Abstract

Ventilator associated respiratory tract infections (VARTI) are among the most common indications for hospitalization among children with chronic respiratory failure requiring at-home ventilation. This review aims to provide an overview of the key clinical features, diagnostic approaches, and management strategies for home VARTIs while highlighting the challenges in diagnosis and management.

Ventilator associated respiratory tract infections (VARTI) including tracheitis and lower respiratory tract infections are among the most common indications for hospitalization among children with chronic respiratory failure requiring at-home ventilation [1]. Ventilator associated tracheitis is an infection of the trachea that can result from bacterial colonization of the endotracheal tube, the tracheostomy site or from aspiration

of respiratory pathogens. Altered upper airway defenses in these patients further increase the likelihood of pathogen transmission to the lower airways resulting in lower respiratory tract infections (LRTI). LRTI is an infection of the bronchi or the lungs that can be caused by viruses, bacteria, or fungi.

Bacterial pneumonia is the most common reasons for hospital admission in children with tracheostomy, accounting for over 2,000 admissions and $100 million in U.S. hospital charges in 2009 [1]. These numbers are likely increased with advances in biotechnology and care of patients needing long-term mechanical ventilation. The prevalence rates of VARTI or individual tracheitis and LRTI rates are unknown as the definitions of these disease processes are not standardized in children receiving home ventilation. Ongoing limitations of diagnostic tools, as well as patients' access for evaluation and diagnostic testing add to the challenges of diagnosing VARTI. The Center for Disease Control (CDC) criteria for diagnosing tracheobronchitis are primarily designed for national surveillance rather than individual patient diagnosis and does not provide clarity for LRTIs (CDC). Chest radiographs, auscultation, and sputum production are unreliable indicators, and tracheal aspirate cultures may not reliably distinguish between colonization and infection [2,3]. These uncertainties and lack of standardized protocols in a patient population with high risk of clinical deterioration understandably result in variable clinical practices.

Families of children with medical complexities, who are chronically ventilated, may call their clinician rather than bring their child to the clinic or hospital, because of the large transportation burden on these families [4]. These calls to the physicians may result in over diagnosis and unnecessary antibiotic treatments. This is reported to be common occurrence in pulmonology, complex-care patient clinics and may contribute to increased diagnosis and treatment of VARTI[4]. Physicians may also elect to admit patients to avoid additional outpatient evaluation to ease the hardship for the patients and caregivers. It is therefore crucial to have timely identification and accurate diagnosis of these infections to provide appropriate therapy and prevention of further complications and morbidity. This review aims to provide an overview of the key clinical features, diagnostic approaches, and management strategies for home VARTIs while highlighting the challenges in diagnosis and management.

Several factors contribute to the increased risk of respiratory tract infections in children with tracheostomy tubes. The upper airway's defense mechanisms, including nasal filtration, warming, and humidification of inspired air, are compromised [5]. Tracheostomy tubes bypass the nasal cavity and reduce the effectiveness of these defense functions, leading to increased susceptibility to infections. Additionally, tracheostomy tubes can cause damage to the tracheal mucosa, impair cough effectiveness and mucus clearance, and create an environment conducive to the formation of biofilms, which protect bacteria and contribute to antibiotic resistance[6]. Other risk factors for respiratory infections in tracheostomy-dependent children include underlying medical conditions, difficulty swallowing and aspiration, and the use of certain medications such as proton pump inhibitors [7]. Children with tracheostomy tubes often develop a diverse range of bacterial colonization in the trachea, including multi-drug resistant pathogens. Viral respiratory infections, although less studied, are also common in this population, with the same viral pathogens that are present in children without tracheostomy.

With the varied consensus of VARTI, most clinicians consider a combination of symptoms that indicate a possible infection in the respiratory tract including the following [8]:

- Systemic findings including fever, chills, malaise, fatigue

- Change in ventilator settings, oxygen requirement from baseline and respiratory symptoms such as increased respiratory rate, dyspnea, or hypoxemia

- Increased secretions, sputum production, sputum color or consistency, purulent or foul-smelling discharge, hemoptysis, or blood-streaked sputum

- Increased cough, wheezing, chest pain, concern for aspiration

- Localized pain or tenderness over the tracheostomy site

- Altered mental status, confusion, or agitation

A retrospective single center review of encounters found that bacterial tracheostomy associated respiratory tract infections was significantly associated with a chest radiograph consistent with bacterial pneumonia, a positive tracheal aspirate culture, higher white blood cell count, and change in oxygen requirement. Patients diagnosed with VARTI did have more total abnormal studies documented suggesting a combination of above listed factors played a role in their diagnoses [4]. Additional factors generally considered by physicians include: history of exposure to a sick household contact, recent infections, vaccination status and other comorbidities. Recently, artificial intelligence modeling has been used in few adult studies to identify patients at risk of developing infection and with advances in the analysis of patient data can be considered in the future and may help with accurate definition of VARTI.

Despite the obvious practical difficulties, a thorough clinical evaluation, including a detailed history, physical examination, and assessment of respiratory parameters, are still essential for identifying possible tracheitis and LRTIs. Laboratory diagnostics can include complete blood count (CBC), erythrocyte sedimentation rate (ESR), C-reactive protein (CRP), procalcitonin, blood gas analysis. Tracheal cultures (collecting tracheal secretions or sputum samples for microbial culture and sensitivity testing and viral panel testing can help identify the causative organisms and guide appropriate antimicrobial therapy. Imaging studies may include chest X-ray (CXR), which can show signs of pneumonia or atelectasis, or other modalities such as ultrasound or computed tomography (CT) scan, depending on the availability and indication. These tests have utility to help identify the likely causative agent and the extent of inflammation and respiratory changes in the child.

There is significant variability in the way tracheal cultures are obtained, processed and in the interpretation of results. Currently there is no gold standard for when microbiologic work up is needed. There is a lack of epidemiologic understanding of organisms expected to be isolated during true VARTI or during the periods of wellness[2]. Culturing tracheal aspirates does not effectively distinguish between infection and colonization but can still be helpful[3,9]. Review of recent and previous tracheal aspirate cultures identifying the same microorganisms may suggest ongoing colonization rather than active infection. Although it is non-invasive, obtaining a culture still poses significant hardship for the caregivers, at times requiring patient to be evaluated in multiple facilities increasing their risk of infection [2].

The prevention of VARTI involves strict adherence to infection control measures, such as hand hygiene, aseptic technique, and proper care of the ventilator circuit and humidifier [10]. Providing age-appropriate vaccinations including but not limited to pneumococcal, COVID-19 and influenza vaccination is also crucial for prevention of infections. There has been also significant debate on the best treatment and management options of VARTI in this population group. It is hard to decide when to start antimicrobial treatment especially when there is any growth of bacteria from these cultures. The longer the exposure to healthcare environments and ventilation the higher the likelihood for patients to have colonization, and colonization with multi-drug resistant microorganisms. Repeated excessive or unnecessary antibiotic treatment courses can create more resistance and side effects.

Most physicians agree that in bacterial tracheitis patients may have change and increase in secretions with no significant changes in their oxygen requirement or ventilation parameters. They may have fevers, and these are usually not persistent and if a chest radiograph is obtained it does not show a new pulmonary infiltrate. If feasible, a tracheoscopy will also help with the diagnosis [5]. These patients may have viral infections as well. In addition to evaluation of sick household contacts and viral testing, especially for RSV, influenza and SARS-CoV-2 should be considered. Bacterial infections could follow these viral infections and may cause secondary fevers and further changes in tracheal secretions and respiratory parameters.

Antimicrobial treatment is ideally guided by prior cultures while a new one is obtained. If a culture is not obtained amoxicillin treatment can be considered. A typical treatment for tracheitis can be limited to five days and for LRTIs this duration could be extended to seven days. If patient is clinically worsening and cultures and radiographs were not obtained tracheal aspirate cultures and chest radiographs should be

obtained. Blood cultures should be considered especially in patients with systemic inflammatory symptoms who are not improving on initial empiric treatment. Treatment should be reevaluated weighing previously identified pathogens, history of exposure and overall clinical status. Treatment should not be started or continued without appropriate assessment of the patient.

Available previous cultures could be again used to guide the clinician for possible colonization and if treatment is needed to understand the antimicrobial susceptibility patterns of the detected microorganisms. Targeted treatments should start as soon as culture results are available. Any additional risk factors including the possibility of aspiration or pulmonary toilet changes need to be addressed as these may be causing the infection.

There are several local management guidelines for patients with home-care ventilation addressing supply needs and required education for caregivers but the diagnostic criteria and required laboratory and radiographic evaluation to guide therapy, including duration, are mainly based on expert opinion or extrapolated from data for ventilator-associated infections in inpatient settings. More research is needed to further characterize the specific nuances (and its range of variation) of pediatric patients with at-home ventilation.

With the advent of quality improvement science, implementation of standardized criteria for testing and treatment guidelines have shown that decrease in antibiotic use and resource utilization can be safely achieved among children requiring mechanical ventilation. More widespread use of these novel approaches are needed.

Home mechanical ventilation is increasingly used in children with chronic respiratory insufficiency, but data on adverse events are limited[17]. A small study has shown that incidence of emergencies is low[17] but nonetheless life-threatening, and most could be handled at home (including VARTIs) if both caregivers and providers are adequately prepared.

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