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Acquired Tracheomegaly in Critically Ill Patients With COVID-19: A Literature Review

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ABSTRACT

Keywords:

COVID-19
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tracheal dilatation
tracheal dilation
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tracheomegaly

Tracheomegaly is defined as an abnormally dilated trachea and is seen in patients requiring long-standing mechanical ventilation and/or significant hyperinflation of their endotracheal or tracheostomy tube cuffs can occur in adults with severe COVID-19. Tracheomegaly is linked with inadequate nutrition, pneumonia, diabetes, hypotension, steroids, and protracted mechanical ventilation, which are common in COVID-19 patients. Findings include cuff leaks that necessitate cuff overinflation to maintain adequate tidal volumes. Tracheomegaly can be diagnosed with chest radiographs, chest computed tomography, bronchoscopy, or diagnostic laryngoscopy or tracheoscopy. This condition leads to a concern for obstruction, airway collapse, aspiration pneumonia, and iatrogenic tracheal injuries.

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Introduction

Tracheomegaly is a rare condition defined as an abnormally dilated trachea. It can be either congenital or acquired.¹ Tracheomegaly is commonly seen in patients who have been diagnosed with pulmonary fibrosis, those undergoing prolonged mechanical ventilation, and patients requiring long-standing hyperinflation of their endotracheal or tracheostomy tube cuffs; all of which are commonly found in patients with severe SARS-CoV-2 (COVID-19).² In critically ill adults at a large, tertiary care, academic medical center, it was noted that severe COVID-19 was correlated with an increased incidence of tracheomegaly. Given the rareness of tracheomegaly, this phenomenon triggered a literature review. It is hypothesized that adult patients who required very high-pressure ventilation for prolonged periods of time necessitated hyperinflation of endotracheal and tracheostomy tube cuffs to prevent peritubal cuff leaks. This cuff hyperinflation is suspected to lead to tracheal dilation and then a subsequent diagnosis of acute acquired tracheomegaly.

Tracheomegaly can be diagnosed radiographically through chest radiographs, computed tomography (CT) scans, endoscopically, or through bronchoscopy or tracheoscopy.¹ Tracheomegaly is particularly concerning in critically ill patients due to reduced tracheal tissue perfusion that can cause damage to tracheal mucosa. This increases the risk of complications including tracheoesophageal and tracheoinnominate fistulas, tracheal stenosis, tracheomalacia, risk of aspiration, and worsening respiratory acidosis.² This is particularly worrisome in critically ill COVID-19 patients who are already at high risk of refractory respiratory acidosis. Unfortunately, the diagnosis is frequently overlooked despite its significant negative consequences. The purpose of this literature review is to

shed light on this rare condition and to guide future research into the diagnosis and treatment of tracheomegaly found in critically ill COVID-19 patients.

Methods

Given the small quantity of literature regarding acquired tracheomegaly, the inclusion criterion for the literature review was very broad by nature. Although the focus was acute acquired tracheomegaly, literature on Mounier–Kuhn syndrome (MKS), the congenital and chronic version of tracheomegaly, was included due to the lack of publications available for acquired tracheomegaly. The search engines used were PubMed, Medline, and CINAHL. The independent concepts included tracheomegaly, acquired tracheomegaly, MKS, tracheobronchomegaly, tracheal dilation, and tracheal dilatation. These search terms were then linked to the search terms COVID-19, SARS-CoV-2, and severe acute respiratory syndrome coronavirus 2 through the use of the Boolean operator “AND.”

Initially, 61 full-text articles were identified and screened. Of these publications, 37 were excluded for not meeting the criteria for inclusion, which require use of adult samples. All pediatric samples were excluded. No clinical trials, randomized controlled trials, or meta-analyses were identified. Although preference was given to recently published studies, due to the lack of applicable and robust literature, 2 borderline studies were included from a time frame outside of 10 years. Ultimately, 3 retrospective studies, 2 reviews, and 19 case reports were included. The Joanna Briggs Institute (JBI) Criteria Appraisal Checklist for Case Reports was utilized to assess the methodological quality of the included case studies (Figure 1).³

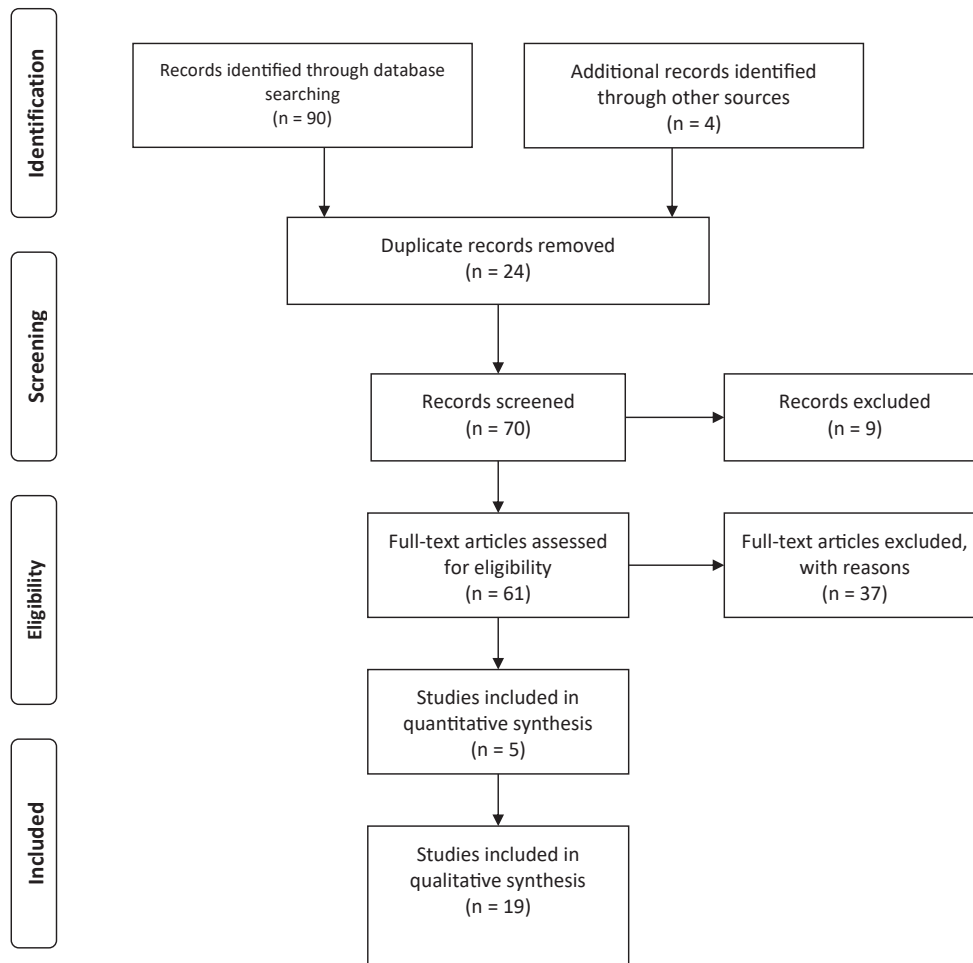


Figure 1. PRISMA flow diagram.

Results

In 1984, Seegobin and Van Hasselt published a single-center retrospective study of 40 participants looking at the effects of endotracheal cuff pressures on the blood flow of the tracheal mucosa.⁴ Although this hallmark study was published 37 years ago, it continues to have applicability today. One strength of this study is that the authors used 4 brands of endotracheal (ET) tubes, and participants were randomized to each brand of ET tube.⁴ The study confirmed findings of prior animal trials that hyperinflation of endotracheal tube cuffs is associated with a decrease in the blood flow of tracheal mucosa as measured by endoscopic photographs.⁴ This is the basis for determining appropriate endotracheal and tracheostomy tube cuff pressures today and led to the current recommendations of maintaining cuff pressures of less than 30 cm H₂O on manometry to prevent decreased tracheal mucosa circulation.⁴

Presentation

In 2016, Krustins noted a lack of epidemiological studies on the topic of MKS and performed a systematic review of 25 years of the available literature, which was almost exclusively case reports.⁵ The author performed descriptive statistics to gather more information regarding patient demographics and clinical information. Literature published between 1987 and 2013 was identified and reviewed per PRISMA guidelines.⁵ The review consisted of adults, and all studies

included tracheal measurements on chest computed tomography (CT) scans. The ratio was 8:1 male to female across 89 studies of 128 cases. Mean age was 53.19 years.⁵

Typically, tracheomegaly patients are males over age 40; this presentation becomes a bit more variable when looking at patients with the acquired version of this rare disorder.⁶ On review of the literature, the classic presentation of chronic tracheomegaly includes persistent cough,^{1,5-9} dyspnea,^{5-8,10} chronic respiratory infections,^{1,7,8,11-13} breathlessness,⁶ bronchiectasis,^{6,8,13} heavy secretions,^{6,8} hemoptysis,^{6,8} and weight loss.⁹ Physical exam findings in chronic tracheomegaly patients can include rales,^{6,7} finger clubbing,^{6,7} bronchial breathing,¹³ and hoarseness.^{6,9} Tracheal diverticulum can be seen on bronchoscopy.^{12,13}

In the acute setting, patients may have a persistent peritubal cuff leak on their endotracheal or tracheostomy tubes^{14,15-17} and may require cuff overinflation to manage this cuff leak.^{18,19} This peritubal cuff leakage may lead to difficulty maintaining the patient's tidal volume and minute ventilation.¹⁷ Some patients may have had a history of a prior cuff rupture, likely secondary to gross hyperinflation.^{15,18} When examined with tracheoscopy or bronchoscopy, there may be tracheal diverticulum^{6,7,12,13} or dynamic collapse of the trachea on forced exhalation.^{6,9,12,13}

Risk factors for tracheomegaly include a history of obesity,²⁰ diabetes,^{11,19} poor overall health,¹¹ smoking,^{6,13,16,21} environmental exposures including heavy air pollution,¹³ and prior lung transplantation.¹⁴ In critically ill patients, this also includes prolonged mechanically assisted ventilation^{2,6,11,15,21} and recurrent

lung infections while intubated.¹⁹ Other contributing factors are restlessness,¹¹ excessive endotracheal or tracheostomy tube movement,¹⁹ poor nutrition,¹¹ muscle rigidity,¹⁹ hypotension,¹¹ steroid therapy,¹¹ and the use of nasogastric tubes.^{11,19} Many of the preceding risk factors are commonly observed in acutely ill COVID-19 patient populations, but there is not an available study specifically looking at the risk factors associated with a COVID-19 diagnosis in the literature.

Tracheomegaly is associated with numerous chronic muscular, respiratory, or autoimmune illnesses including pulmonary fibrosis,^{1,2,6,7,13,21,22} cystic fibrosis,²¹ bronchiectasis,^{7,13,14} emphysema,^{7,16} chronic bronchitis,^{7,16} amyotrophic lateral sclerosis (ALS),¹⁵ sarcoidosis,⁷ chronic progressive histoplasmosis,¹ and giant cell arteritis.⁹ It has also been seen in a patient with tetany,¹⁹ Ehlers-Danlos syndrome, Marfan syndrome, and cutis laxa.⁶ Tracheomegaly is also seen in a number of conditions found in critically ill patients, including those with acute respiratory distress syndrome (ARDS)^{17,23} and respiratory failure.²² Moreover, it has been identified in patients diagnosed with various types of pneumonia including aspiration, interstitial, and multilobular.^{7,14,22,24}

Diagnosis

Tracheomegaly can be categorized based on etiology into 4 groups, including patients who have undergone prior interventions on their trachea, patients who have had recurrent infections or pulmonary fibrosis, patients with extrapulmonary elastolysis, and patients without clear predisposing factors.²² Initially, tracheomegaly may be seen on routine chest radiographs, although it can be difficult to identify given the limitations of the imaging.^{9,14,18,19,21} In fact, tracheomegaly is frequently overlooked on chest radiographs, which may, in turn, lead to underdiagnosis because tracheal dilation may not be visible on chest radiograph until the diameter of the tracheal exceeds the opacity of the vertebral column.⁶ Jaiswal et al stated that a tracheal diameter >30 mm on chest radiograph is consistent with a diagnosis of tracheomegaly.⁷

Tracheomegaly is most typically identified on chest CT scans, which is considered the gold standard diagnostic test for the condition.^{6,8-10,12,19,21} In females, tracheomegaly is often described as having a maximum tracheal diameter >21 mm in transverse planes and 25 mm in sagittal planes. In males, it is seen in tracheal diameters >25 mm in transverse planes and 27 mm in sagittal planes.¹ Krustins found that for tracheomegaly patients, the mean tracheal diameter was 36.1 mm.⁵ Some case studies listed diagnostic criteria as a tracheal diameter >30 mm.^{7,14} In intubated or posttracheostomy patients, cuff pressure, as measured by a cuff monometer, is greater than the goal cuff pressure of 22–25 cm H₂O.^{14,18,23}

Further diagnostics include tracheoscopy¹⁸ and diagnostic fiberoptic bronchoscopy.^{7,9,10,12,13,18} On bronchoscopy, tracheal diverticulum may be identified that may contain pockets of mucoid secretions.^{7,12,13} Collapse of the tracheal walls during exhalation or cough can be noted.^{6,12} Furthermore, during this bronchoscopy, punch biopsies can be taken and may show a loss of elastic fibers, atrophy of longitudinal muscles, and muscularis mucosae thinning.^{6,12} Some authors suggest that pulmonary function testing can help determine supportive care, but it is not diagnostic.^{1,13}

Risks

Tracheomegaly can cause a significant amount of risk in patients with artificial airways, which can be especially concerning when undergoing anesthesia or when critically ill. The patient's weak and enlarged airways can lead to tracheal collapse during exhalation,^{5,13,14} ineffective cough, tracheal diverticula, and possible

dislodgement of an ET or tracheostomy tube.^{5,6} Other risks include airway obstruction, iatrogenic tracheal injuries, and aspiration pneumonia.¹⁴ The marked tracheal dilation results in clinical challenges with alveolar recruitment.¹⁷

Furthermore, there is significant risk associated with peritubal cuff leak, which can lead to aspiration of oral or gastric content, tidal volume mismatch, decreases in minute ventilation, and hypercarbia leading to respiratory acidosis.⁶ To prevent a peritubal cuff leak, retention cuffs are frequently overinflated, which can lead to further tracheal trauma. In fact, this cuff hyperinflation can lead to the development of a tracheoesophageal fistula (TEF), which can be a life-threatening complication.^{11,19} The acquired version of TEF is associated with malignancies, infection, injury (i.e., post-intubation), prolonged intubation, and ruptured diverticulum.¹¹ Tracheomalacia is also seen in tracheomegaly patients and can be extremely difficult to manage.^{9,20,22} Furthermore, tracheomegaly also can contribute to further bronchiectasis and pulmonary fibrosis.¹³

Management

Unfortunately, due to the rareness of this condition, there is little evidence in the literature about successful management, and tracheomegaly is exceedingly difficult to treat. Treatment is primarily supportive. In chronic patients, treatment focuses on managing symptoms and decreasing the risk of future infections. Smoking cessation¹³ and vaccinations against respiratory infections are encouraged.^{6,12,22} In the outpatient setting, some chronic patients have seen improvement with noninvasive continuous positive airway pressure ventilation with 8–10 mm Hg pressure.⁶ In both acute and chronic patients, bronchodilators,^{12,22} mucolytic therapy,⁶ and intermittent steroid therapy^{13,22} are useful. Bacterial infections need to be treated with appropriate antibiotics.^{12,13} Other supportive care options can include mobilization of the patient and chest physiotherapy which can assist with secretion management.^{12,14} In critically ill patients, Chen et al recommended maintaining an ET or tracheostomy cuff pressure of < 25 cm H₂O when possible.¹⁹

If supportive care and medications are not successful, surgical options may need to be explored. These options may include placement of a tracheostomy tube,¹⁰ laser treatments,^{6,10,25} tracheal stent placement,^{6,7,13,14,22,25} tracheobronchoplasty,^{6,22} or, in exceedingly rare instances, lung transplantation.^{6,14,22} Unfortunately, little has been published about the success of surgical options, and there is scant evidence to guide practice.

When looking specifically at tracheostomy tube placement, Kim et al noted the typical tracheostomy tube was not long enough for the tube cuff to sit properly within the trachea and extend below the area of dilation.²¹ The normal tracheostomy tube resulted in significant peritubal cuff leak leading to hypercapnia. Unfortunately, their facility did not have longer tubes available, so the authors intubated the tracheostomy stoma with an ET tube they shortened for this purpose.²¹

In 2016, Schmitt et al discussed tracheomegaly and tracheobronchomegaly and the respiratory conditions that are associated with the diagnosis.²⁵ In this multicenter retrospective study, the authors looked at 17 subjects with tracheomegaly. Adult participants were enrolled from 9 French institutions. Demographics revealed that 53% of the patients were male with a median age of 58.²⁵ The main comorbid conditions included diffuse bronchiectasis and tracheobronchomalacia. Interventions including laser treatments (n = 2) and tracheal stenting (n = 5) via interventional bronchoscopy were performed in 41% of the participants.²⁵ Complications occurred in 80% of the patients undergoing tracheal stents.²⁵ Although the multicenter study design led to the

enrollment of 17 subjects, the sample size of this case study continues to be extremely small. Furthermore, these patients appear to be undergoing evaluation and care in an outpatient setting rather than an inpatient critical care area. Any interventions performed may not be able to be safely executed in a critically ill patient. It is challenging to use the findings to extrapolate to larger acutely ill populations and further investigations are necessary.²⁵

In 2018, Akgedik et al published a case study of 11 participants with tracheomegaly.⁸ The authors described MKS as a congenital disorder noted by a lack of elastic fibers in the trachea that results in atrophy of the smooth muscle layer, thereby creating a dead space resulting in ineffective coughing and an increase in secretions.⁸ Participants were all males from aged 38 to 80 years, with a median age of 63. The authors examined tracheal diameters on radiographs and CT scans and found a mean transverse diameter of 31.69 mm, which is larger than the normal male tracheal diameter of 25 mm.⁸ Due to the rareness of this condition, data were collected from September 2007 through November 2015. The strengths of this case study are that it clearly stated diagnostic criteria and identified common complaints, which included chronic cough, recurrent respiratory infections, hemoptysis, dyspnea, and bronchiectasis.⁸ The limitations of this study are that it examined congenital tracheomegaly in what appeared to be an outpatient setting rather than acquired tracheomegaly diagnosed in an acute/intensive care setting. A second limitation is that all subjects were male, resulting in a notable gender bias.⁸

A 2018 retrospective study looked at the relationship between endotracheal tube (ETT) size and the occurrence of leakage ventilation and tracheal dilation.¹⁷ This study found the size of the initial ETT in terms of diameter is a predictor of future ventilation leakage around the cuff (cuff leak) and tracheal dilation.¹⁷ The study initially enrolled 689 patients, and 199 patients met inclusion criteria. Of the included patients, 52 of those meeting inclusion criteria had a cuff leak, and 66 of the 199 were found to have tracheal dilation.¹⁷ The authors found that the patients diagnosed with tracheal dilation had a higher peak inspiratory pressure and a larger initial diameter of their ETT. These patients also had a higher rate of pneumonia. Of note, the authors were based in Taiwan and looked at long-term ETTs, which is not common practice in Western cultures. In Taiwan, due to cultural norms, long-term intubation with an endotracheal tube is preferable to performing a tracheostomy and the practice of placing surgical airways is uncommon.¹⁷ Another limitation is study patients were on mechanical ventilation for 6 months or longer, which describes a very chronic population. Although these limitations exist, it is reasonable that these findings can be extrapolated to COVID-19 patients who have had large-bore ETTs and tracheostomy tubes due to their prolonged high-pressure mechanical ventilation. Another strength of this study is the large sample size.

In a single-center retrospective study with 151 participants, the authors looked at tracheomalacia in COVID-19 patients over 5 months.²⁰ Tracheomalacia is defined as airway collapse during respiration. Typically, patients with tracheomalacia will have tracheal narrowing or collapse during exhalation, which can be a long-term consequence of tracheomegaly. The study found tracheomalacia was diagnosed in 5% of the participants, which is 10 times the normal average.²⁰ Marcello et al found tracheomalacia was most commonly associated with obesity, female gender, and tracheostomy status.²⁰ This was the second-largest sample size of any of the studies found in the literature review. Another strength is that this study focused specifically on the population of patients with COVID-19–related acute respiratory distress syndrome who required mechanical ventilation and tracheostomy.²⁰ Unfortunately, this study is a preprint and is still undergoing the peer review process. It is a small study performed at a single site, even

though it is one of the largest samples discovered in this review of the literature.²⁰ Lastly, the focus of this study is tracheomalacia, which is associated with tracheomegaly, but it was unclear which, if any, of the participants were diagnosed with tracheomegaly before their diagnosis of tracheomalacia.²⁰

Recommendations

As with many complications, prevention of acquired tracheomegaly is key. Maintaining the recommended ET and tracheostomy tube pressure of 20–25 cm H₂O is vital.¹⁹ Unfortunately, given the extremely high peak inspiratory pressures and positive end-expiratory pressure required to ventilate acutely ill COVID-19 patients, sometimes cuff overinflation and tracheal dilation is unavoidable.² Typically, cuff manometry should be documented once per shift by a respiratory therapist, so a standing protocol of notifying the provider for pressures that are consistently greater than 28 cm H₂O is a good idea.¹⁸ Furthermore, providers should be notified of any consistent peritubal cuff leak.

A variety of surgical interventions have been suggested; however, these are multistaged surgical procedures that would carry significant risk and are not recommended during the acute phase of COVID-19.¹⁵ Therefore, more conservative nonsurgical options are typical and appropriate. Chest physiotherapy and postural drainage can help with mobilizing secretions.^{6,12,14} Medication interventions can include treatment of any underlying bacterial infections, use of mucolytics, steroid therapy, and bronchodilators.^{12,13,22}

Furthermore, in tracheostomy patients, there is the concern is that a regular tracheostomy tube will not provide an appropriate length from the curve of the tube to the distal tip of the device to allow the tube cuff to lie in the correct position in the patient with tracheal dilation at the area of the cuff of the endotracheal tube.²¹ Typically, changing the tracheostomy tube device to an adjustable-length tracheostomy tube or an extra-long device will move the tracheostomy tube cuff below the area of dilation.²¹ This should be done as soon as it is safe to exchange the tube as to not promote even further damage to the tracheal mucosal lining. In the postacute phase, smoking cessation education programs and vaccinations against other respiratory illnesses are recommended.^{6,12,22}

Conclusion

Acquired tracheomegaly is a potentially dangerous condition that can be found in clinical situations similar to COVID-19 and can result in acute and long-term life-threatening situations.¹ This condition is associated with patients with poor nutrition, poor overall health, infections of the airway, hypotension, diabetes, long-term mechanical ventilation, steroid therapy, and use of nasogastric tubes, which are all conditions commonly found in critically ill COVID-19 patients.¹¹ Clinical findings include ET or tracheostomy cuff leaks requiring cuff hyperinflation to maintain tidal volumes on mechanical ventilation.²³ Tracheomegaly can be diagnosed with imaging, including chest radiographs, chest CT studies, bronchoscopy, or diagnostic laryngoscopy/tracheoscopy.¹⁸ There is a concern for airway collapse, airway obstruction, iatrogenic tracheal injuries, and aspiration pneumonia.¹⁴

In conclusion, tracheomegaly or tracheobronchomegaly are extremely rare conditions and a literature review revealed a dearth of available information to use in the development of evidence-based treatment guidelines. There is little available literature about acquired tracheomegaly and only 1 article about this condition in a COVID-19 population; therefore, there is scant evidence to use to guide clinical practice. A significant amount of further research is needed.

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