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The surgical airway in the COVID-19 era

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The aim is to summarize the guidelines for tracheostomy management during the COVID-19 pandemic. This is a comparative study analysis and literature review using articles found in the PubMed/MEDLINE database. Here we summarize published work on tracheostomy timing, technique, outcomes, mortality, and decannulation rates during the COVID-19 pandemic, with a focus on expertise from our own institution. Among 12 studies, 2,692 tracheostomies were performed at an average of 17.5 days from intubation. 66.4% were performed open, and 33.6% percutaneously. A total of 85.6% were performed bedside, and 14.4% in the operating room. 19.5% experienced all-cause mortality, and 43.4% were decannulated. In these studies, only 1 proceduralist became infected with COVID-19. Early COVID-19 recommendations advocated for tracheostomy a minimum of 14 days from intubation. Currently, tracheostomy is performed more closely to prepandemic criteria. Bedside tracheostomy comprised most procedures during the pandemic. Tracheostomy in COVID-19 patients, when performed with techniques to minimize aerosolization, is safe and poses minimal risk of infection to providers performing the procedure.

Introduction

Safe airway management has become a target for innovation, quality improvement, and widespread discussion internationally since the start of the novel Coronavirus disease 2019 (COVID-19) pandemic, caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Many COVID-19 positive patients become affected with acute respiratory distress syndrome (ARDS), which was an early hallmark of infection. Safe airway management continues to be a topic of evolving recommendations as more information regarding viral variants, infectivity rates, and vaccination become available. Tracheostomy is an important step in the airway algorithm for patients infected with COVID-19 who require prolonged intubation and a need for continued ventilation. This article will focus primarily on the surgical management of the airway in COVID-19 patients.

At the start of the pandemic, as many as 10%-12% of patients hospitalized with early COVID-19 infection required intubation and mechanical ventilation, and 58% of those required Intensive Care Unit (ICU) level care.[1] As the rates of prolonged mechanical ventilation rose at the start of the pandemic, so did the need for tracheostomy. Management of the surgical airway focused on adaptation to an increased demand with minimization of viral exposure to the healthcare workers and providers involved. A variety of consensus statements, such as from the American Academy of Otolaryngology-Head and Neck Society (AAO-HNS)[2], the ENT UK and British Laryngological Society,[3] and the New York Head and Neck Society[4] were

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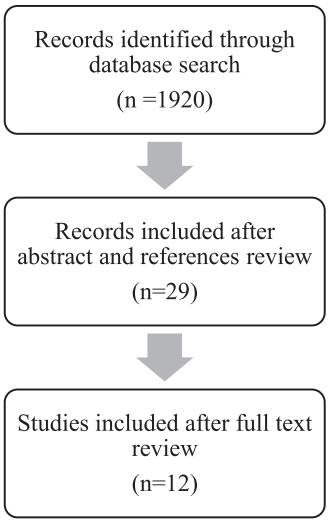

Figure 1 Literature search results. (Color version of figure is available online.)

released, with the objective of standardizing recommendations. Here, we summarize the guidelines for tracheostomy management during the COVID-19 pandemic, with a focus on the methods and management utilized in our institution.

Methods

This was a literature review and comparative study analysis. We searched the PubMed/MEDLINE database for relevant publications using the search terms *tracheostomy, tracheotomy, surgical airway, COVID-19*, and *SARS-CoV-2* (Figure 1). This was supplemented by reference review. Data from our institution that is referenced in this analysis was previously queried and published by the senior author from 2 tertiary care hospitals (Moses and Weiler campuses of Montefiore Medical Center) in Bronx, New York.[5,6] 12 studies in our literature review included patient data regarding timing, technique, and outcomes of tracheostomy (Table 1).

Results

Across twelve studies, the overall mean time to tracheostomy from time of intubation was 17.5 days (Table 1). Mean pre-tracheostomy ventilator settings were PEEP of 11.7 cm H2O, and FiO2 of 0.6. The majority of COVID tracheostomies (85.6%) were performed bedside within the intensive care unit. Of the 14.4% performed in the OR, 70% of those were performed in an OR that was converted into ICU rooms during the pandemic. If performed in the ICU, tracheostomy ideally should be performed in a negative pressure room with a portable HEPA filter to reduce aerosolized exposure.[1,2,6-9] In 2 studies, tracheostomies were not always performed in negative pressure rooms, but none of the proceduralists became infected with COVID-19 or had positive COVID-19 serology.[1,10] A total of 66.4% of the tracheostomies were performed open, and 33.6% were performed percutaneously. There were no significant differences in complications, mortality, outcomes or time to decannulation based on technique (open versus percutaneous) across studies. 19.5% of patients suffered from all-cause mortality. There were no deaths attributable to tracheostomy except for 2 patients from Spain, one of which suffered intraoperative mortality, and one who died of postoperative bleeding from the tracheostomy site.[11] An average of 43.4% of patients were decannulated. Across 12 studies, none of the healthcare providers performing tracheostomy tested positive for COVID-19 infections or had positive serology, except for one otolaryngologist in the study published by Kwak et al.[12]

Discussion

The role of tracheostomy in COVID-19 patients has been extensively examined, but obtaining meaningful data is difficult. COVID-19 is a recent disease making large studies and long term follow up difficult. Additionally, it is an ever-changing disease. Differences in variants of the virus, the development of vaccines, the increase in host immunity, and improvements in care complicate summarizing data. In this review, we highlight the literature detailing tracheostomies during the COVID-19 pandemic and discuss current best practices, and how these practices were developed.

Indications and timing

The benefits of tracheostomy in any critically ill patient include the ability to wean sedation and mechanical ventilation and decrease total intensive care unit (ICU) stay, rates of ventilator-associated pneumonia (VAP), and length of hospital stay.[13,14] The ability to wean sedation and mechanical ventilation may also reduce ICU delirium, ICU-associated dementia, and post-ICU syndrome.[1] While the timing of tracheostomy continues to be refined, many people recommend tracheostomy for patients who are estimated to need more than 10 days of mechanical ventilation. Before the COVID-19 pandemic, the mean time to tracheostomy among critically ill patients was about 10 days with an overall mortality rate of 14.7%.[15]

Early in the pandemic, recommendations advocated against early tracheostomy in order to mitigate the risk of exposure to aerosolizing viral particles, accidental tracheostomy tube dislodgement during proning, and to avoid tracheostomy in those for whom there was a high risk of mortality.[4,7,8,16,17] Reports suggested as many as 40-68% of patients requiring prolonged ventilation experienced mortality in the beginning of the pandemic.[1,7] This number has been quoted as high as 88% in some studies.[16] The American Academy of Otolaryngology-Head and Neck Society (AAO-HNS),[2] the ENT UK and British

Table 1 Literature review and summary of management of the surgical airway in COVID-19 patients

	N	Mean time to tracheostomy*, days	Technique, open/percutaneous, no.	Location, bedside/OR, no.	Criteria, or mean ventilator settings	Mortality† (%)	Decannulation (%)
Long et al[1]	101	24	48/53	29/71‡	N/A	11	71
Ahmed et al[5]	64	20	48/16	40/24	PEEP <15 FiO2 <0.6	33	28
Botti et al[9]	44	7§	29/15	44/0	PEEP 13.5 FiO2 0.6	34.1	N/A
Picetti et al[10]	66	N/A	19/47	66/0	PEEP 11.5 FiO2 0.66	13.6	18
Martin-Villares et al[11]	1890	12§	1461/429	N/A	N/A	23.7	36.1
Kwak et al[12]	148	12.2	N/A	148/0	PEEP <12 FiO2 <0.6	20	64
Chao et al[16]	53	19.7	24/29	52/1	N/A	11.3	13.2
Angel et al[18]	98	10.6	0/98	98/0	N/A	7	8
Farlow et al[19]	64	22	26/38	60/4	PEEP <10 FiO2 0.55	19	64
Queen Elizabeth Airway Team[22]	100	13.9	25/75	N/A	PEEP <8 FiO2 <0.4	15	84
Riestra-Ayora et al[24]	27	13	10/17	27/0	N/A	41	N/A
Sood et al[26]	37	22	0/37	36/1	N/A	5	48
Total	2692	**17.5**	**66.4% / 33.6%**	**85.6% / 14.4%**	**PEEP 11.7 FiO2 0.6**	**19.5**	**43.4**

* From time of intubation.
† All cause mortality.
‡ Operating rooms converted to ICU.
§ Median time to tracheostomy.

Laryngological Society,[3] and the New York Head and Neck Society,[4] as well as, the majority of the studies reviewed, recommend waiting a minimum of 14 days to tracheostomy, to avoid aerosolizing procedures and the associated risk to providers, in patients who have a high risk of mortality.

However, there were some who advocated for early tracheostomy. Angel et al performed 98 percutaneous tracheostomies at a mean time of 10.6 days with a low mortality rate.[18] Kwak et al found that while there was no survival difference between early and late tracheostomy, tracheostomy within 14 days of intubation was associated with shorter duration of ventilation and ICU stay, and late tracheostomy was associated with longer time to ventilator weaning.[12] Farlow et al found each additional day of intubation to be significantly associated with an additional 1.2 days to liberation from the ventilator.[19] After adjusting for demographics, every 1 day increase in time of intubation was also associated with a 3% decreased chance of discharge from the ICU, and 2.8% decreased chance in discharge from the hospital, although this was not statistically significant.[1]

Another reason for supporting early tracheostomy was to address the increased demand for ventilators and ICU beds. Because of this, Botti et al (Italy) performed tracheostomy at 7 days and reported that early tracheostomy decreased the length of ICU stay by about 14 days per patient.[9] Providers in Europe, with the exception of England, were more aggressive regarding early tracheostomy, whereas British, North American, Singaporean, and South African providers were more likely to perform tracheostomy 14 days or more after intubation.[20] In a published comparative analysis including 59 protocols, 25 of which were from the United States, timing of tracheostomy varied widely from 3 to 28 days, and 91% of the protocols recommended a minimum of 14 days from time of intubation to tracheostomy.[21] However, the data on the ideal timing of tracheostomy is inconclusive, and a study from the Queen Elizabeth Hospital COVID-19 airway team (Birmingham, UK) found no survival difference between patients who underwent tracheostomy before 10 days or after 14 days.[22]

The factors that support early tracheostomy in pre-covid patients, including decreased duration of translaryngeal intubation, decreasing sedation, improved weaning, and faster mobilization of patients from the ICU, all provide the same benefits to COVID-19 patients as they do to non-COVID patients. Some of the benefits of late tracheostomy in COVID-positive patients, specifically minimizing procedures in patients who will not sur-

vive and minimizing risk to health care workers, were more pertinent at the start of the pandemic than they are now. Early in the pandemic the unknown risk to health care workers, coupled with very high initial mortality rate in ventilated COVID-positive patients, led many to recommend late tracheotomy. Over time, as survival among COVID-19 patients increased, the rates of mechanical ventilation decreased,[23] the risk to health care workers was established as low, and vaccines became prevalent, many institutions relaxed their guidelines on tracheostomy in COVID-19 patients to match those of non-COVID patients.

At our institution, tracheostomies were performed at least 14 days from intubation at the start of the pandemic, with an average time of 21 days.[5] To be a candidate for tracheostomy, we require patients to have stable ventilator settings of PEEP <15 cm H2O and FiO2 <0.6. Although these numbers are not validated, they served as rough guidelines, and were weighed against the patient's clinical condition. A previous study at our institution did not find a significant difference in ventilator settings between survivors and nonsurvivors.[5] Currently at our institution, and many other institutions in New York, tracheostomies in COVID-19 patients are handled similarly to those of non-COVID patients in terms of both indications and timing, including 5-10 days of intubation without the ability to wean, the anticipated need for prolonged ventilation, or need for tracheostomy for post-ICU placement.

Personal protective equipment

Initially, the type of Personal Protective Equipment (PPE) needed for performing tracheostomy safely in COVID-positive patients was debated, with some institutions recommending Powered Air Purifying Respirators (PAPR), and others recommending PPE with N95 masks. Regardless of COVID-19 status, for example– if repeat testing pre-procedurally revealed negative COVID-19 testing– full PPE should always be donned.[20] Appropriate PPE includes surgical cap, eye protection/face shield, N95 surgical mask, surgical gown, and gloves. Many subsequent studies have shown that with proper PPE, and standardized doffing and donning procedures, tracheostomy in COVID-positive patients presents minimal risk to providers. A study at our institution looked at patients treated in April and May of 2020, during which there were 65 surgeon exposures, but no surgeon tested positive or developed symptoms of COVID.[6] Across 12 studies, none of the healthcare providers performing tracheostomy tested positive for COVID-19 infections or had positive serology except for 1 otolaryngologist in the study published by Kwak et al.[12] Tracheostomy may theoretically create less aerosolization of viral particles overall in comparison to the aerosolization produced during extubation trials, postextubation positive pressure ventilation, and reintubation.[7]

Technique

At the start of the pandemic, there was considerable debate about the benefits of open versus percutaneous tracheostomy. Initially, some reports favored a percutaneous approach, given the theoretical reduction of aerosolized viral particles by virtue of being performed in a closed system.[4,8,18,20,24] Others favored an open approach to minimize airway manipulation and bronchoscopy. If expertise is available, percutaneous tracheostomy can be performed under minimal airway manipulation (i.e. minimal suctioning, disconnection from circuit, etc), or under ultrasound guidance rather than bronchoscopy.[4,8,18] Since neither method has been shown to be superior in COVID-19 patients, providers should use whichever method they have the most comfort or expertise in. At our institution, 75% of tracheostomies were performed open, but at other institutions in New York City, there was an almost equal split of open versus percutaneous tracheostomy.[1,2] To date, no data has supported the use of 1 method over the other in COVID-19 positive patients.

The physical location in which the tracheostomy was performed, operating room (OR) versus bedside, was also a significant source of debate. The safety of bedside tracheostomy is well established in non-COVID patients.[25] Because of the potential environmental risk of contamination and aerosolization during transport, the possible contamination of OR rooms, and the high volume and urgency of tracheostomies, the majority of COVID tracheostomies have been performed bedside within the intensive care unit. Most institutions recommended that tracheostomy should be performed in negative pressure rooms with portable HEPA filters to reduce aerosolized exposure.[1,4,6-9] The 2 studies for which procedures were not performed in negative pressure rooms and had no COVID infections, raise the question of the true need for this precaution.[1,10] These studies did not specify if the PPE worn by providers differed to compensate for the lack of negative pressure. Since the goal of a negative pressure room is to contain aerosolized particles and protect those outside of the room, and none of these studies address this issue, the recommendation to use a negative pressure room is more theory than data driven.

There is a general consensus regarding tracheostomy technique for COVID-positive patients, with the majority of studies reviewed echoing the techniques used at our institution. The procedure is very similar to that in non-COVID patients with some slight modifications to minimize particle aerosolization and risk to providers. Patients should be paralyzed prior to the start of the procedure to eliminate coughing, and anticholinergics may be used as needed to decrease secretions.[4,6,8] Since many patients with COVID-19 infection develop poor pulmonary reserve, patients should be preoxygenated with 100% oxygen. As is the case in all tracheostomies, FiO2 levels should then be decreased to less than 50% when cautery is used directly on the trachea. Initially, many suggested

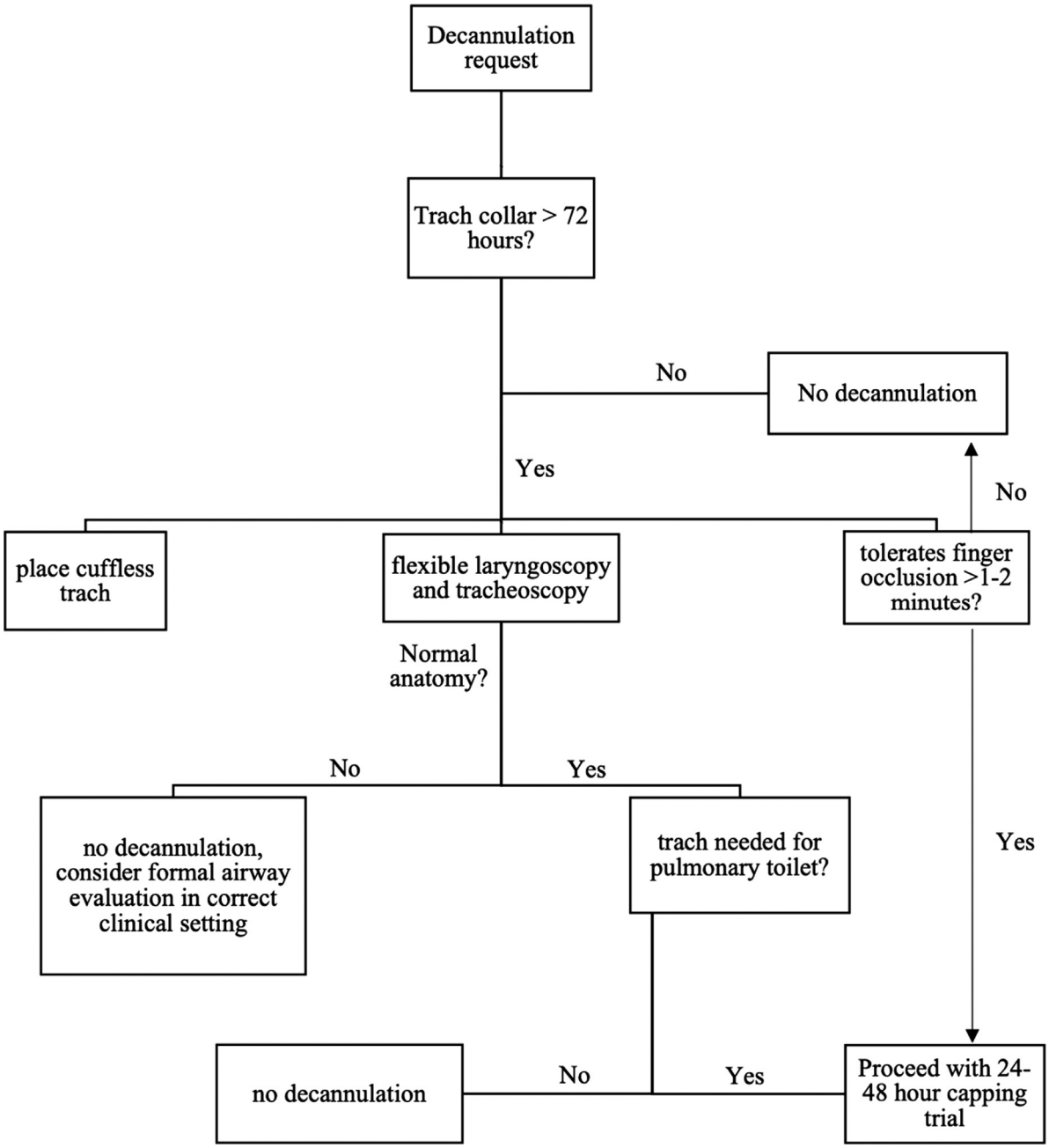

Figure 2 Montefiore Medical Center Department of Otolaryngology decannulation criteria. (Color version of figure is available online.)

that cautery and suction should be minimized, as these can aerosolize particles.[4,6] However, there is no data to suggest either cautery or suction increases the risk of exposure to healthcare workers, and these can be used judiciously as needed. When the airway is ready to be incised and the tracheostomy tube inserted, the ventilator should be placed on standby to prevent positive pressure aerosolization. The ventilator should be resumed when the tracheostomy tube is in place, the cuff is inflated, and there is a closed system.[4-6,8]

Although the cessation of ventilation for tube exchange lasts a mere few seconds, providers must be prepared for a patient's inability to tolerate this cessation due to the severity of lung disease. Although not frequently needed, we have found it useful to have a bronchoscope readily available after positive pressure is reinitiated. If there are issues with ventilation after insertion of the tracheostomy tube, this can help confirm proper placement of the tube, and can occasionally be useful in directing suctioning of post-surgical tracheal blood clots and secretions. Many of the patients who require immediate bronchoscopy have high pre-tracheostomy PEEP (>15cm H_2O) or FiO2 (>0.6), making it difficult to tolerate the period of apnea. When performing tracheostomy in the pre-pandemic era, apnea immediately before incision into the airway was not a common practice, and so this was not a common issue.

Decannulation

The rate of decannulation ranged widely across studies (8-84%), likely due to differences in tracheostomy indications, follow up time, or institutional criteria for decannulation. In our institution, patients with a history of COVID-19 ARDS who are off mechanical ventilation for at least 72 hours, without anticipated need for mechanical ventilation, are downsized to a number 4 or 6 cuffless tracheostomy tube, capped for 24-48 hours on continuous pulse oximetry, and decannulated if they have no desaturation events, subjective difficulty breathing, or need to remove the cap for pulmonary toilet (Figure 2). Sood et al required patients to be 6 days off mechanical ventilation before decannulation.[26] Although previous studies have found no difference in the rates of laryngotracheal stenosis (LTS) with early versus late tracheostomy (after 7 days),[27] many COVID-19 patients underwent tracheostomy at day 21 or later, which is a longer duration then the standard definition of late tracheostomy. The rate of COVID-19-related laryngotracheal stenosis, ranging from granulomas, stenosis, tracheomalacia, webs, or fistulae, may be currently underreported as tracheal stenosis can take time to develop and therefore is not yet well established.[17] More time and further studies are needed to determine if COVID-19 is an independent risk factor for laryngotracheal stenosis, and as this is better understood, institutions may alter their criteria for decannulation for these patients in comparison to patients who underwent tracheostomy for different reasons.

Conclusions

Early COVID-19 pandemic recommendations advocated for tracheostomy at least 14 days from intubation to minimize infection to providers. However, many studies have demonstrated that with proper precautions providers performing tracheostomy on COVID-positive patients are at minimal risk. Currently tracheostomy is performed more closely to timing and criteria utilized before the pandemic. Bedside tracheostomy comprised most procedures performed, as opposed to tracheostomy in the OR, and both open and percutaneous tracheostomy have the same outcomes. Tracheostomy in COVID-19 patients, when performed with techniques to minimize aerosolization, such as wearing appropriate PPE, paralytics, preoxygenation, cessation of ventilation upon entering the airway, and resumption of ventilation after cuff inflation have proved to be safe methods which pose minimal risk of infection to providers performing the procedure. Further studies are needed to help establish the ideal timing of tracheostomy in COVID-positive patients.

Disclosures

The authors have no financial disclosures or conflicts of interest.

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