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# Coronavirus disease tracheostomy complications: a scoping review

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**Review Article**

Dr E Rosario takes responsibility for the integrity of the content of the paper

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## Abstract

**Background.** Coronavirus disease 2019 increased the numbers of patients requiring prolonged mechanical ventilation, with a subsequent increase in tracheostomy procedures. Coronavirus disease 2019 patients are high risk for surgical complications. This review examines open surgical and percutaneous tracheostomy complications in coronavirus disease 2019 patients.
**Methods.** Medline and Embase databases were searched (November 2021), and the abstracts of relevant articles were screened. Data were collected regarding tracheostomy technique and complications. Complication rates were compared between percutaneous and open surgical tracheostomy.
**Results.** Percutaneous tracheostomy was higher risk for bleeding, pneumothorax and false passage. Surgical tracheostomy was higher risk for peri-operative hypoxia. The most common complication for both techniques was post-operative bleeding.
**Conclusion.** Coronavirus disease 2019 patients undergoing tracheostomy are at higher risk of bleeding and peri-operative hypoxia than non-coronavirus disease patients. High doses of anti-coagulants may partially explain this. Reasons for higher bleeding risk in percutaneous over open surgical technique remain unclear. Further research is required to determine the causes of differences found and to establish mitigating strategies.

## Introduction

The coronavirus (severe acute respiratory syndrome coronavirus-2; SARS-CoV-2) pandemic has resulted in an increased incidence of acute respiratory distress syndrome in the adult population, with around a third of patients admitted to intensive care in 2020.[1] These patients often require long admissions, with high ventilatory requirements. Mean length of stay was up to 16 days in England in the early stages of the pandemic.[2] Subsequently, intensive care units have faced higher than usual demand for extended periods of mechanical ventilation.[3] Prolonged mechanical ventilation is associated with a high risk of ventilator-acquired pneumonia, a requirement for high-dose intravenous sedation, neuromuscular deconditioning, subglottic stenosis, longer intensive care stays and increased mortality.[4]

Tracheostomy can be performed to aid in ventilator weaning. This decreases airway dead space, reduces airway resistance and lessens the work of breathing, resulting in more rapid ventilator weaning.[5] Further advantages include improved tracheobronchial toilet, reduced sedative requirements and a lower frequency of subglottic stenosis, all of which contribute to a shorter intensive care unit stay.[6–9] The insertion of a tracheostomy can be performed via a percutaneous or open surgical approach. The optimal timing for tracheostomy in coronavirus disease 2019 (Covid-19) patients remains a matter of debate.[10]

The rise in numbers of critically ill Covid-19 patients requiring prolonged ventilation has resulted in a proportional increase in tracheostomy procedures.[3,11] A recent review reports an increase in the tracheostomy rate from 8–13 per cent to 16–61 per cent.[12]

Despite the benefits, tracheostomy can be a high-risk procedure. Coronavirus disease 2019 patients are often too unstable to tolerate a tracheostomy until weeks into their illness because of acute respiratory distress syndrome. Proning, along with high fraction of inspired oxygen and high positive end expiratory pressure requirements, mean that tracheostomy may be relatively contraindicated early in a patient's disease course. Thus, the procedure often may not be performed until 15 days or more following intubation, which itself may be almost 2 weeks into the patient's illness.[13]

During the first wave of the pandemic, concerns over exposing staff to aerosolised Covid-19 particles through tracheostomy insertion further delayed the procedure until viral load in secretions had decreased.[9,14] The percutaneous technique is thought to reduce aerosolisation; however, open surgical tracheostomy may be required in light of anatomical considerations, staff availability or failure of the percutaneous procedure.[15]

**Table 1.** Breakdown of literature search

| Search step | Database | Search string | Articles (*n*) |
|---|---|---|---|
| 1 | Medline | (tracheo?tom*).ti,ab | 21 765 |
| 2 | Medline | *TRACHEOSTOMY/ | 4962 |
| 3 | Medline | (1 OR 2) | 22 313 |
| 4 | Medline | (complication*).ti,ab | 990 098 |
| 5 | Medline | (hypoxi* OR infection* OR bleeding OR "subglottic stenosis" OR pneumothorax OR "cuff leak*" OR "tube obstruction" OR "tracheal injur*").ti,ab | 1 880 209 |
| 6 | Medline | exp "POSTOPERATIVE COMPLICATIONS"/ | 580 342 |
| 7 | Medline | (4 OR 5 OR 6) | 3 027 266 |
| 8 | Medline | "COVID-19"/ | 116 022 |
| 9 | Medline | "SARS-COV-2"/ | 90 962 |
| 10 | Medline | ("COVID-19" OR COVID19 OR covid OR "corona virus" OR coronavirus OR SARSCoV2 OR "SARS-CoV-2").ti,ab | 196 687 |
| 11 | Medline | (8 OR 9 OR 10) | 202 242 |
| 12 | Medline | (3 AND 7 AND 11) | 243 |
| 13 | Medline | 12 [DT 2020–2021] [Languages English] | 221 |
| 14 | Embase | (tracheo?tom*).ti,ab | 30 624 |
| 15 | Embase | *TRACHEOSTOMY/ | 7051 |
| 16 | Embase | (14 OR 15) | 31 208 |
| 17 | Embase | (complication*).ti,ab | 1 454 825 |
| 18 | Embase | (hypoxi* OR infection* OR bleeding OR "subglottic stenosis" OR pneumothorax OR "cuff leak*" OR "tube obstruction" OR "tracheal injur*").ti,ab | 2 477 416 |
| 19 | Embase | exp "POSTOPERATIVE COMPLICATION"/ | 725 721 |
| 20 | Embase | (17 OR 18 OR 19) | 3 984 065 |
| 21 | Embase | "CORONAVIRUS DISEASE 2019"/ | 159 376 |
| 22 | Embase | exp "SEVERE ACUTE RESPIRATORY SYNDROME CORONAVIRUS 2"/ | 47 754 |
| 23 | Embase | ("COVID-19" OR COVID19 OR covid OR "corona virus" OR coronavirus OR SARSCoV2 OR "SARS-CoV-2").ti,ab | 202 709 |
| 24 | Embase | (21 OR 22 OR 23) | 217 140 |
| 25 | Embase | (16 AND 20 AND 24) | 431 |
| 26 | Embase | 25 [DT 2020–2021] [English language] | 410 |

The Medical Subject Headings (used for Medline) were: 'Tracheostomy', 'Postoperative Complications', 'COVID-19' and 'SARS-CoV-2'. The Emtree headings (used for Embase) were: 'Tracheostomy', 'Postoperative Complication', 'Coronavirus Disease 2019' and 'Severe Acute Respiratory Syndrome Coronavirus 2'.

Additionally, given the increased risk of thromboembolic phenomena in Covid-19, patients often receive high doses of anti-coagulation, putting them at further risk of complications.[9] Patients have also been noted to have a high secretion burden with acute respiratory distress syndrome in Covid-19, with viscous secretions putting them at risk of 'plugging off' with subsequent tracheostomy obstruction.[9]

To the authors' knowledge, an in-depth review of tracheostomy complications in Covid-19 has not yet been conducted. This scoping review therefore aimed to summarise the existing literature surrounding complications from tracheostomy insertion in these patients.

### *Research question*

What are the complications encountered when performing tracheostomy in Covid-19 patients, and how might these differ from those in non-coronavirus patients?

### *Aims*

These are: (1) to evaluate tracheostomy complications in Covid-19 patients, through a review of existing literature; (2) to compare complication rates between percutaneous and open surgical tracheostomies, and perform meta-analysis if adequate data are collected; and (3) to assess the availability of literature comparing Covid-19 with non-coronavirus tracheostomy complications.

## Materials and methods

Medline and Embase databases were searched in November 2021. The Medical Subject Headings (used for Medline) were: 'Tracheostomy', 'Postoperative Complications', 'COVID-19' and 'SARS-CoV-2'. The Emtree headings (used for Embase) were: 'Tracheostomy', 'Postoperative Complication', 'Coronavirus Disease 2019' and 'Severe Acute Respiratory Syndrome Coronavirus 2' (Table 1).

Duplicate results and conference abstracts were removed. Results were limited to English-language papers and to articles published during the height of the Covid-19 pandemic (November 2019 to December 2021). Papers were subsequently removed by screening the abstracts; studies were excluded if they included paediatric patients, if Covid-19 was not the primary reason for admission and if tracheostomy

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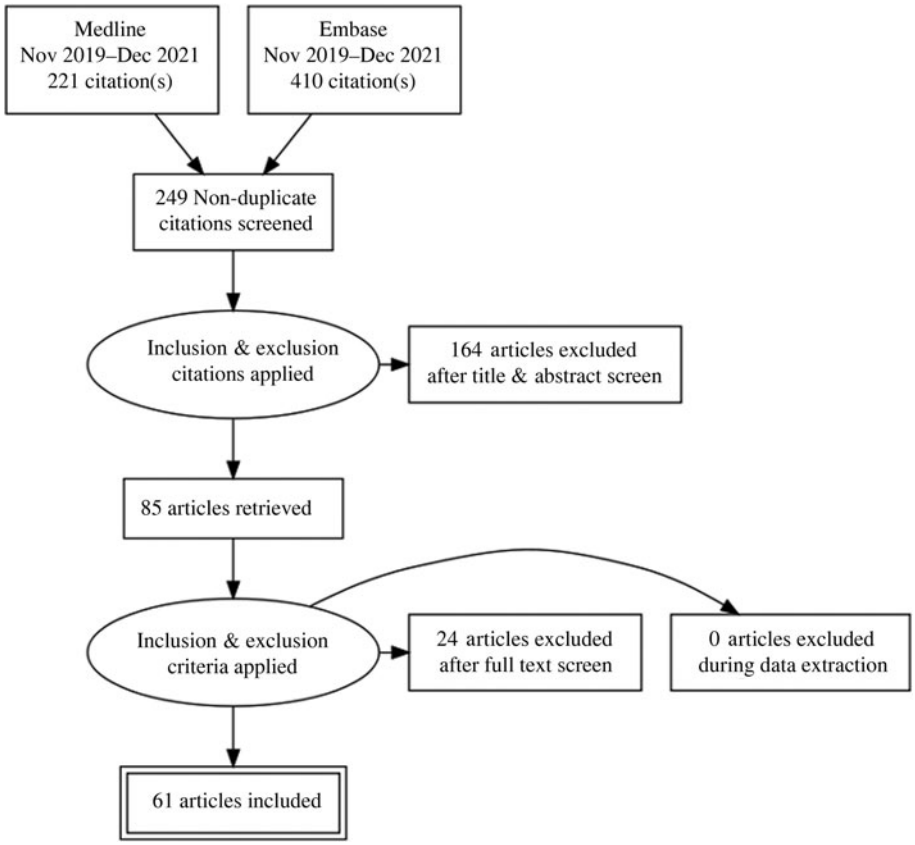


**Fig. 1.** Preferred Reporting Items for Systematic Reviews and Meta-Analyses ('PRISMA') diagram.

was performed for other indications than to facilitate ventilatory weaning (e.g. in acute airway obstruction). Case reports were excluded. The full texts of remaining papers were screened prior to analysis for the review, and were excluded if they did not comment on complications of tracheostomy procedures. Systematic reviews and guidelines were excluded from the analysis, but utilised for background information. Reference lists of included studies were used for background information. Figure 1 shows the article search breakdown.

Following full-text screening, data were extracted into a dedicated Microsoft™ Excel® spreadsheet to record: date of publication, country of publication, time from intubation to tracheostomy, type of tracheostomy performed and complications resulting from the tracheostomy procedure.

Differences in complication rates between percutaneous and open surgical tracheostomy were analysed using a significance level of 95 per cent. Data for each complication were expressed in a $2 \times 2$ contingency table, in which rows indicated percutaneous or open surgical approaches, and columns indicated whether a complication occurred or did not occur. Pearson's chi-square test of independence was performed to examine the relation between each complication and tracheostomy method for those studies that reported complications by tracheostomy type.

Reporting is in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses ('PRISMA') extension for scoping reviews 2018. A scoping review approach was selected given the novelty of this area, and the lack of randomised, controlled trials to date. An outline of the literature has been presented, to identify key areas for future research.

## Results

Of 85 papers for which full texts were screened, 61 were included in the review (Figure 1). All papers were published between April 2020 and December 2021, and were either prospective or retrospective observational studies, with a combination of single- and multi-centre studies. The majority of studies were from Europe or the USA; a breakdown is shown in Table 2. The studies included in the analysis are shown in Table 3. A meta-analysis was not performed as there were no randomised, controlled trials identified in the search.

**Table 2.** Breakdown of studies by continent

| Continent | Studies (*n*) | Tracheostomies (*n*) |
|---|---|---|
| Europe | 30 | 5670 |
| USA | 20 | 1123 |
| South America | 2 | 157 |
| Asia | 9 | 167 |

Fifty-six studies (91.8 per cent) reported the average time of intubation prior to tracheostomy, either mean or median. For the 30 papers (49.2 per cent) reporting the mean, time from intubation to tracheostomy was $18 \pm 6$ days.

In total, 7117 tracheostomies were performed. One large study did not report tracheostomy technique. In the remaining 60 studies (98.3 per cent), 2979 percutaneous or hybrid tracheostomies, and 3442 open surgical tracheostomies, were performed. From the 7117 tracheostomy procedures, a total of 1330 procedure-related complications were reported (18.7 per cent of procedures). Eleven studies (18.0 per cent) did not specify tracheostomy type when reporting complications. The summary of reported complications is shown in Table 4. Table 5 shows the rate of complications for percutaneous and open surgical tracheostomies for those studies that reported complications by tracheostomy technique.

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**Table 3.** Studies included in review

| Author | Date | Title | Tracheostomies (*n*) | Tracheostomy technique | Complications? |
|---|---|---|---|---|---|
| Bartier *et al.* | December 2021 | Tracheostomies after SARS-CoV-2 intubation, performed by academic otorhinolaryngologists in the Paris area of France: preliminary results | 59 | Both | Yes |
| Briatore *et al.* | February 2021 | Surgical tracheotomy in COVID-19 patients: an Italian single centre experience | 13 | Open surgical | Yes |
| Avalos *et al.* | May 2021 | Protocol for percutaneous tracheostomy and prevention of COVID-19 transmission | 77 | Both | Yes |
| Sood *et al.* | October 2021 | COVID-19 tracheostomy: experience in a university hospital with intermediate follow-up | 37 | Percutaneous | Yes |
| Mesalles-Ruiz *et al.* | July 2021 | Outcomes and survival of tracheostomised patients during the COVID-19 pandemic in a third level hospital | 64 | Open surgical | No |
| Goldstein *et al.* | April 2021 | Tracheostomy is safe in patients with prolonged intubation after coronavirus disease 2019 infection | 15 | Both | Yes |
| Parmigiani *et al.* | May 2021 | Suspension laryngoscopy-assisted percutaneous dilatational tracheostomy: a safe method in COVID-19 | 28 | Percutaneous | Yes |
| Prats-Uribe *et al.* | August 2021 | Timing of elective tracheotomy and duration of mechanical ventilation among patients admitted to intensive care with severe COVID-19: a multicenter prospective cohort study | 696 | Not reported | No |
| Vallejo-Díez *et al.* | June 2021 | Percutaneous tracheostomy in COVID patients. Experience in our hospital center after one year of pandemic and review of the literature | 35 | Percutaneous | Yes |
| Reis *et al.* | August 2021 | Tracheostomy in COVID-19 patients: experience at a tertiary center in the first 11 months of the pandemic | 42 | Open surgical | Yes |
| Cohen *et al.* | June 2021 | Percutaneous tracheostomy in respiratory failure due to COVID-19 | 24 | Percutaneous | Yes |
| Mahmood *et al.* | August 2021 | Tracheostomy for COVID-19 respiratory failure: multidisciplinary, multicenter data on timing, technique, and outcomes | 118 | Both | Yes |
| Tetaj *et al.* | July 2021 | Outcomes and timing of bedside percutaneous tracheostomy of COVID-19 patients over a year in the intensive care unit | 120 | Percutaneous | Yes |
| Chandran *et al.* | July 2021 | Outcomes of tracheostomy in COVID-19 patients: a single centre experience | 51 | Open surgical | Yes |
| Farlow *et al.* | April 2021 | Tracheostomy for COVID-19 respiratory failure: timing, ventilatory characteristics, and outcomes | 64 | Both | No |
| Angel *et al.* | July 2021 | Percutaneous dilational tracheostomy for coronavirus disease 2019 patients requiring mechanical ventilation | 205 | Both | Yes |
| COVIDTrach collaborative | June 2021 | COVIDTrach: a prospective cohort study of mechanically ventilated patients with COVID-19 undergoing tracheostomy in the UK | 1599 | Both | Some |
| Rossetti *et al.* | July 2021 | Apneic tracheostomy in COVID-19 patients on veno-venous extracorporeal membrane oxygenation | 32 | Percutaneous | Yes |
| Mylavarapu *et al.* | June 2021 | A study on the safety of percutaneous tracheostomy in patients with severe acute respiratory syndrome novel corona virus 2 (SARS-nCoV2) infection: a single-center observational cohort study in a CoVID intensive care unit | 24 | Percutaneous | Yes |
| Battaglini *et al.* | June 2021 | Tracheostomy timing and outcome in severe COVID-19: the WeanTrach Multicenter Study | 153 | Both | Yes |
| Rouhani *et al.* | June 2021 | A prospective study of voice, swallow, and airway outcomes following tracheostomy for COVID-19 | 62 | Both | No |
| Ahmed *et al.* | June 2021 | Tracheotomy outcomes in 64 ventilated COVID-19 patients at a high-volume center in Bronx, NY | 64 | Both | No |
| Pauli *et al.* | June 2021 | Tracheotomy in COVID-19 patients: a retrospective study on complications and timing | 55 | Both | Yes |
| Rovira *et al.* | January 2021 | Open versus percutaneous tracheostomy in COVID-19: a multicentre comparison and recommendation for future resource utilisation | 201 | Both | Yes |

| | | | | | |
|---|---|---|---|---|---|
| Nishio *et al.* | June 2021 | Surgical strategy and optimal timing of tracheostomy in patients with COVID-19: early experiences in Japan | 5 | Open surgical | Yes |
| Botti *et al.* | October 2020 | Comparison of percutaneous dilatational tracheotomy versus open surgical technique in severe COVID-19: complication rates, relative risks and benefits | 47 | Both | Yes |
| Long *et al.* | May 2021 | Percutaneous and open tracheostomy in patients with COVID-19: the Weill Cornell experience in New York City | 101 | Both | Yes |
| Martin-Villares *et al.* | August 2020 | Outcome of 1890 tracheostomies for critical COVID-19 patients: a national cohort study in Spain | 1890 | Both | No |
| Murphy *et al.* | October 2020 | Short-term outcomes for patients and providers after elective tracheostomy in COVID-19-positive patients | 11 | Percutaneous | Yes |
| Volo *et al.* | July 2020 | Elective tracheostomy during COVID-19 outbreak: to whom, when, how? Early experience from Venice, Italy | 23 | Both | Yes |
| Long *et al.* | March 2021 | Percutaneous and open tracheostomy in patients with COVID-19: comparison and outcomes of an institutional series in New York City | 67 | Both | Yes |
| Ahn *et al.* | December 2020 | Timing and clinical outcomes of tracheostomy in patients with COVID-19 | 27 | Both | Yes |
| Carmichael *et al.* | December 2020 | Early ventilator liberation and decreased sedation needs after tracheostomy in patients with COVID-19 infection | 26 | Percutaneous | Yes |
| Loube *et al.* | January 2021 | Bedside tracheostomy for a COVID-19 cohort | 12 | Percutaneous | Yes |
| Boujaoude *et al.* | January 2021 | Safety and feasibility of a novel protocol for percutaneous dilatational tracheostomy in patients with respiratory failure due to COVID-19 infection: a single center experience | 32 | Percutaneous | Yes |
| Courtney *et al.* | December 2020 | Surgical tracheostomy outcomes in COVID-19-positive patients | 20 | Open surgical | Yes |
| Erbas *et al.* | January 2021 | Efficacy and safety of an aerosol box for percutaneous tracheostomy in patients with COVID-19 in an intensive care unit | 24 | Percutaneous | Yes |
| Bertini *et al.* | August 2020 | Percutaneous tracheostomy in COVID-19 critically ill patients: experience from 30 consecutive procedures | 32 | Both | Yes |
| Matsuyoshi *et al.* | April 2021 | Optimal timing of tracheostomy in patients on veno-venous extracorporeal membrane oxygenation for coronavirus 2019: a case series | 9 | Percutaneous | Yes |
| Floyd *et al.* | June 2020 | Early data from case series of tracheostomy in patients with SARS-CoV-2 | 38 | Open surgical | Yes |
| Krishnamoorthy *et al.* | November 2020 | The safety and efficacy of tracheostomy in patients diagnosed with COVID-19: an analysis of 143 patients at a major NYC medical center | 143 | Both | Yes |
| Kim *et al.* | September 2020 | Experience of percutaneous tracheostomy in critically ill COVID-19 patients | 7 | Percutaneous | Yes |
| Avilés-Jurado *et al.* | October 2020 | Timing, complications, and safety of tracheotomy in critically ill patients with COVID-19 | 50 | Open surgical | Yes |
| Angel *et al.* | April 2020 | Novel percutaneous tracheostomy for critically ill patients with COVID-19 | 98 | Percutaneous | Yes |
| Morvan *et al.* | September 2020 | Percutaneous dilatational tracheostomy for saturating influx of COVID-19 patients: experience of military ENT physicians deployed in Mulhouse, France | 18 | Percutaneous | Yes |
| Mishra *et al.* | August 2020 | Our experience of tracheostomy in COVID-19 patients | 11 | Open surgical | Yes |
| Prabhakaran *et al.* | May 2020 | Open tracheostomy for COVID-19-positive patients: a method to minimize aerosolization and reduce risk of exposure | 18 | Open surgical | Yes |
| Betancourt-Ramirez *et al.* | August 2020 | A technique to minimize aerosolization during percutaneous tracheostomy in COVID-19 patients | 10 | Percutaneous | Yes |
| Turri-Zanoni *et al.* | April 2020 | Elective tracheostomy during mechanical ventilation in patients affected by COVID-19: preliminary case series from Lombardy, Italy | 32 | Both | Yes |

(*Continued*)

**Table 3.** (*Continued.*)

| Author | Date | Title | Tracheostomies (*n*) | Tracheostomy technique | Complications? |
|---|---|---|---|---|---|
| Zuazua-Gonzalez *et al.* | May 2020 | Surgical tracheostomies in COVID-19 patients: indications, technique, and results in a second-level Spanish hospital | 30 | Open surgical | Yes |
| Broderick *et al.* | May 2020 | Surgical tracheostomies in COVID-19 patients: a multidisciplinary approach and lessons learned | 10 | Open surgical | Yes |
| Zhang *et al.* | July 2020 | Safe and effective management of tracheostomy in COVID-19 patients | 11 | Both | Yes |
| Sun *et al.* | December 2020 | Modified percutaneous tracheostomy in patients with COVID-19 | 12 | Percutaneous | Yes |
| Picetti *et al.* | September 2020 | Safety of bedside surgical tracheostomy during COVID-19 pandemic: a retrospective observational study | 66 | Open surgical | Yes |
| Tang *et al.* | December 2020 | Tracheostomy in 80 COVID-19 patients: a multicenter, retrospective, observational study | 80 | Both | No |
| Jonckheere *et al.* | November 2020 | Percutaneous tracheostomy for long-term ventilated COVID-19-patients: rationale and first clinical-safe for all-experience | 16 | Percutaneous | Yes |
| Yeung *et al.* | August 2020 | Challenges of tracheostomy in COVID-19 patients in a tertiary centre in inner city London | 72 | Both | No |
| Weiss *et al.* | December 2020 | Controlled apneic tracheostomy in patients with coronavirus disease 2019 (COVID-19) | 28 | Both | Yes |
| Sahu *et al.* | September 2020 | Performing bedside surgical tracheostomy on covid-19 patients at intensive care unit--our experiences at a tertiary care Indian teaching hospital | 22 | Open surgical | Yes |
| Breik *et al.* | August 2020 | Safety and 30-day outcomes of tracheostomy for COVID-19: a prospective observational cohort study | 100 | Both | Yes |
| Takhar *et al.* | November 2020 | Safety and outcomes of percutaneous tracheostomy in coronavirus disease 2019 pneumonitis patients requiring prolonged mechanical ventilation | 81 | Both | No |

**Table 4.** Complications by tracheostomy type

| Complication | Total (*n* (%)) | Tracheostomy type (*n*) | | |
|---|---|---|---|---|
| | | Percutaneous or hybrid | Surgical | Unknown type |
| Post-operative bleeding | 551 (7.74) | 121 | 87 | 343 |
| Peri-operative hypoxia | 123 (1.73) | 2 | 16 | 105 |
| Tracheal injury or leak | 115 (1.62) | 39 | 62 | 14 |
| Peri-operative bleeding | 107 (1.50) | 23 | 27 | 57 |
| Local infection | 76 (1.07) | 34 | 41 | 1 |
| Displacement | 42 (0.59) | 24 | 16 | 2 |
| Surgical emphysema | 15 (0.21) | 8 | 4 | 3 |
| Pneumothorax | 14 (0.20) | 12 | 2 | 0 |
| Obstruction | 13 (0.18) | 2 | 8 | 3 |
| False passage | 6 (0.08) | 4 | 0 | 2 |
| Subglottic stenosis | 5 (0.07) | 0 | 3 | 2 |
| Fistula | 4 (0.06) | 2 | 2 | 0 |
| Granuloma | 2 (0.03) | 0 | 0 | 2 |
| Conversion to open surgery | 5 | 5 | | |

**Table 5.** Complication rates by type of procedure performed

| Complication | Percutaneous or hybrid tracheostomy (*n* (%)) | Surgical tracheostomy (*n* (%)) | Chi-square value | *P*-value* |
|---|---|---|---|---|
| Post-operative bleeding | 121 (4.06) | 87 (2.53) | 11.99 | <0.001 |
| Tracheal injury or leak | 39 (1.31) | 62 (1.80) | 2.50 | 0.114 |
| Local infection | 34 (1.14) | 41 (1.19) | 0.03 | 0.853 |
| Peri-operative bleeding | 23 (0.77) | 27 (0.78) | 0.003 | 0.955 |
| Displacement | 24 (0.81) | 16 (0.46) | 3.00 | 0.083 |
| Peri-operative hypoxia | 2 (0.07) | 16 (0.46) | 9.04 | 0.003 |
| Obstruction | 2 (0.07) | 8 (0.23) | 2.81 | 0.094 |
| Surgical emphysema | 8 (0.27) | 4 (0.12) | 1.99 | 0.159 |
| Subglottic stenosis | 0 (0.00) | 3 (0.09) | 2.60 | 0.107 |
| Pneumothorax | 12 (0.40) | 2 (0.06) | 8.72 | 0.003 |
| Fistula | 2 (0.07) | 2 (0.06) | 0.02 | 0.885 |
| False passage | 4 (0.13) | 0 (0.00) | 4.62 | 0.032 |
| Granuloma | 0 (0.00) | 0 (0.00) | n/a | n/a |
| Conversion to open surgery | 5 (0.17) | | | |

**P*-value attained following Pearson's chi-square analysis. n/a = not applicable

Analysis revealed that percutaneous tracheostomy was higher risk than open surgical tracheostomy with respect to post-operative bleeding, false passage and pneumothorax; however, open surgical tracheostomy carried a higher risk for peri-operative hypoxia. The remaining complications demonstrated no difference between percutaneous and open surgical techniques.

Three studies (4.9 per cent) compared tracheostomy in Covid-19 patients to a control group without Covid-19. One of these studies found an increased incidence of tracheal injuries in Covid-19 patients.[16] The second of these studies found a significantly increased risk of bleeding in Covid-19 patients (20.3 per cent *vs* 5.97 per cent), but with no difference in length of hospital stay.[17] The final of these studies reported an increased time from intubation to tracheostomy in Covid-19 patients (25.4 days *vs* 22.9 days).[7]

## Discussion

This review identified bleeding as the most common complication in Covid-19 tracheostomies, occurring in 9.2 per cent of all procedures. This is higher than the 6 per cent rate demonstrated prior to Covid-19, as reported in the 2014 National Confidential Enquiry into Patient Outcome and Death report on tracheostomy patient outcomes.[18] This report accounted for both surgical and percutaneous tracheostomies.

Bleeding accounted for 658 of the total complications (49.5 per cent) in this review. Post-operative bleeding was approximately

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five times more common than peri-operative bleeding. This is reasonably consistent with a 2021 systematic review of 31 studies encompassing 3479 Covid-19 tracheostomies, which found bleeding to account for 52.5 per cent of procedure-related complications.[19] This paper was not a dedicated study of complications, and therefore the complication frequency was not discussed extensively. In addition, this study did not compare bleeding risk of percutaneous versus open surgical tracheostomies, and did not compare with procedures performed in non-coronavirus groups.

It is likely that high-dose prophylactic or treatment dose anti-coagulant medications received by Covid-19 patients contributed to the higher risk of bleeding.[20] Coronavirus disease 2019 patients are at high risk of thromboembolic disease because of immobility, increased levels of clotting factors and endothelial dysfunction. The incidence of venous thromboembolism in Covid-19 intensive care patients has been reported as up to 28 per cent.[21]

Despite this, recent literature suggests that the benefits of therapeutic level anti-coagulation in hospitalised patients with severe Covid-19 are outweighed by risk of bleeding. Therefore, therapeutic dose anti-coagulation could be avoided in Covid-19 intensive care patients, which would potentially decrease the risk of tracheostomy related bleeding.[22,23] The UK's National Institute for Health and Care Excellence currently recommends above prophylactic dose low molecular weight heparin only in patients with a low oxygen requirement, unless as part of a research trial.[24]

Another potential reason for increased bleeding risk in Covid-19 patients is frequent suction due to high secretion load, which increases the risk of mucosal bleeding.[9]

Somewhat surprisingly, this review found that Covid-19 patients undergoing percutaneous tracheostomy are at higher risk of bleeding than those undergoing an open surgical procedure. Literature prior to the pandemic demonstrates no difference in bleeding rates between percutaneous and surgical tracheostomies.[25,26] This includes a 2016 Cochrane review, albeit acknowledging low quality of evidence.[26]

It is unclear why the contradiction observed in this review is demonstrated in patients with Covid-19. It is possible that the availability of electrocautery in open surgical procedures reduces the probability of bleeding in a high-risk population. Furthermore, in the preliminary months of the pandemic, open surgical tracheostomies were commonly performed by senior surgeons, given concerns about the aerosolisation risk to staff.[27] As a result, it is possible that more meticulous haemostasis was ensured, in comparison to the non-coronavirus literature, where tracheostomies are performed by operators with varied levels of experience. Finally, anti-coagulation is commonly suspended prior to surgical tracheostomy to reduce risk of bleeding.

The second most common complication identified in this review was peri-operative hypoxia, occurring in 123 out of 7117 patients (1.73 per cent). There was discrepancy in the studies in terms of hypoxia definition, with most defining it as oxygen saturations below 80 per cent or 90 per cent for a specified time period of up to 5 minutes. This is almost three times the rate found in a pre-coronavirus multi-institutional analysis from 2012,[28] and twice that found in the previously mentioned National Confidential Enquiry into Patient Outcome and Death report.[18] The higher baseline rate of complications may be partially the result of patients with higher body mass index in intensive care unit during the Covid-19 pandemic, and an increased risk of hypoxia in this cohort.[29]

Several causes of hypoxaemia have been described in Covid-19 cases. These include intrapulmonary shunting, reduced regulation of lung perfusion, pulmonary intravascular microthrombi and poor diffusion capacity, all contributing to higher oxygen requirements and the risk of peri-procedural desaturation.[30]

Furthermore, in light of the difficulty in reducing ventilatory requirements to a desirable level, some institutions were keen to perform a tracheostomy when ventilatory requirements were higher than perhaps would normally be accepted in a non-coronavirus patient. This resulted in episodes of decompensation during the apnoeic period, when the ventilator was paused to facilitate the creation of a tracheal window, and subsequent desaturation. In order to address this, some authors have suggested a trial of apnoea in the intensive care unit after pre-oxygenation with fraction of inspired oxygen of 100 per cent. In the absence of being able to tolerate such a trial, it can be argued that tracheostomy should be deferred until the patient's ventilatory requirements have reduced.[31]

This review demonstrated a higher risk of hypoxia when an open surgical technique was used. Over the course of the pandemic, various consensus guidelines have been released for the provision of safe surgical tracheostomy in Covid-19.[15,32,33] Such protocols have all shared the recommendation to pause ventilation during the creation of the tracheal window, to minimise aerosolisation during this high-risk step of the procedure. This may explain the difference found in this review, reflecting a higher risk of hypoxia during open surgical tracheostomies than during percutaneous tracheostomies. This is not consistent with the 2016 Cochrane review in non-coronavirus patients, which demonstrated no difference.[26]

Other complications found to significantly differ in rate between percutaneous and open surgical tracheostomy techniques were false passage and pneumothorax. Both of these were more common using the percutaneous technique. However, overall rates of these complications were low, at 0.08 per cent and 0.2 per cent respectively. Pneumothorax in itself appears to be high risk in Covid-19 patients, but is not necessarily linked to poor prognosis.[34] Other complications with very low numbers were subglottic stenosis and fistula. Most studies did not follow up subjects for long enough to determine the true rate of subglottic stenosis, and this is anticipated to be a phenomenon described in forthcoming studies.[35]

The expected increase in tracheostomy tube obstruction due to mucus plugging in Covid-19 patients was not demonstrated in this review, with a rate of only 0.18 per cent. This is much lower than the rate of 2.5 per cent reported in the National Confidential Enquiry into Patient Outcome and Death tracheostomy report.[18] This report included late obstruction occurring on the critical care unit or the ward in this figure, which may partially account for the discrepancy. The same is true for displacement, with a rate of 0.59 per cent here versus 4.1 per cent in the report.

This review has several limitations. Most importantly, all of the studies identified by the search are retrospective or prospective observational studies. The lack of randomised, controlled trials means that meta-analysis was not possible, and the heterogeneity of the studies makes statistical analysis difficult to interpret.

Additionally, it is difficult to comment on long-term complications of tracheostomy, as most studies did not include long-term follow up after the study period, with the total study period usually being between one and two months. Only one study specifically assessed the airway at the follow-up clinic. This means that the true numbers of long-term complications, such as subglottic stenosis and granulomas, are likely to be higher than reported here.

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A third limitation is the failure of some studies to break down complications by tracheostomy technique. This potentially skews the analysis comparing complications of percutaneous tracheostomy with those of an open surgical approach. In addition, some studies only reported specific complications, such as bleeding and hypoxia, and there may have been other complications not reported in the write-up.

Finally, there is difficulty in locating matched studies involving non-coronavirus patients, in order to compare Covid-19 and non-coronavirus complication rates. Since the start of the pandemic, the vast majority of tracheostomy research has pertained only to patients with Covid-19, with a paucity of comparative studies published.

Further research is required to fully investigate the increased risk of tracheostomy complications in Covid-19 patients, and to determine the validity of the observed differences between percutaneous and open surgical tracheostomy procedures.

An accurate meta-analysis of complications requires randomised, controlled trials. This is not necessarily practical in this cohort, as choice of tracheostomy technique is often precluded by the availability of qualified staff and other factors such as anatomical considerations. In order to obviate this, a large, multi-centre cohort study comparing matched intensive care unit patients with and without Covid-19 would be useful, that more precisely delineates factors associated with complications in patients undergoing tracheostomy.

## Conclusion

Several complications are observed following open surgical and percutaneous tracheostomy in Covid-19 patients. The overall rates of these complications appear to be increased, as compared to non-coronavirus patients, particularly with regard to post-operative bleeding and peri-operative hypoxia. There are also differences between open surgical and percutaneous complication rates that are not seen in non-coronavirus patients.

There are a paucity of high-quality, randomised, controlled trials required to draw these conclusions. Further research is needed to fully investigate the increased risk of tracheostomy complications in Covid-19 patients, in order to determine the true risk of complications. Authors should routinely report tracheostomy technique, anti-coagulation status and rates of all the complications discussed in this review. It would be helpful to include long-term follow up and airway assessment of tracheostomy patients, to accurately determine the risk of these complications.

Specific considerations must be made when considering Covid-19 patients for tracheostomy, and awareness of the commonly seen complications is an important factor in this decision.

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