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HEAD AND NECK

Elective open "Shield Tracheostomy" in patients with COVID-19

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Abstract

Purpose To prevent the consequences of long-term endotracheal intubation, patients undergo tracheostomies. However, as COVID-19 is highly contagious, its existence has made the tracheostomy a high-risk procedure. Tracheostomy procedures must, therefore, be adjusted for safety reasons. The aim is to present the adjustments that should be made to the surgical technique.

Methods Both the medical charts and surgical reports of patients with COVID-19 who were subjected to elective open tracheostomies were reviewed.

Results The retrospective study included 25 patients. Our adjustments include the timing of tracheostomies, ideally putting them at 21 days after the onset of COVID-19, the advancement of an endotracheal tube to 26–28 cm from the upper-alveolar ridge, surgery being carried out in the intensive care unit with appropriately modified positions of the patient and providers, tracheo-cutaneous sutures, and intentionally making the small tracheal flap and the tracheal window the same shape as a medieval shield.

Conclusions A tracheostomy performed in this way is now referred to as the Shield Tracheostomy. Further improvements to the surgical technique are expected in the future.

Keywords Shield · Tracheostomy · COVID-19 · Long-term endotracheal intubation · Surgical technique

Introduction

The indications for open surgical tracheostomy (TS) include medical entities demanding long-term endotracheal intubation (LETI) and mechanical ventilation. To prevent the consequences of LETI, in particular laryngotracheal stenosis, patients undergo elective TS [1]. It can be performed as either percutaneous or open surgical procedure. This article is dedicated to the latter.

The Coronavirus Disease 2019 (COVID-19) caused by SARS-CoV-2 is characterised by infamously effective spread through droplets and aerosol containing virus particles. In 3–5% of cases, the disease is of a severe type requiring endotracheal intubation, mechanical ventilation [2–5] and the application of oxygen due to respiratory insufficiency. In case of LETI, TS is indicated.

The most important strategy against the spread of the disease is the prevention of inter-human transmission. It is undeniably true that aerosol is created and spread during the surgical establishment of TS, therefore, it is considered a high-risk procedure in terms of contaminating the surgical and anaesthesia teams as well as the personnel caring for the patient in the postoperative period [6, 7].

To ensure the maximal safety of the procedure, we decided to present our experience with TS in COVID-19 patients.

Materials and methods

The present study was conducted between April 2020 and March 2021 at the Department of Otorhinolaryngology and Cervicofacial Surgery at the University Medical Centre in

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Ljubljana, Slovenia. The retrospective study included patients with COVID-19 undergoing elective open TS under general anaesthesia. The medical charts of the patients and surgeon's reports were retrospectively analysed.

Considering COVID-19, many reports in the literature have previously addressed the variations of surgical techniques of TS and related issues and were progressively employed in our Department. However, this article will not tackle the subject further. The aim here is to present the final adjustments to a surgical technique regarding TS in patients with COVID-19 that have not been discussed before in the literature.

All procedures were carried out in accordance with the ethical standards of the committee on human experimentation of the institution and also in accord with the Helsinki Declaration of 1975 as revised in 1983.

Results

In total, 25 elective open TS were performed in patients with COVID-19 (19 males, 6 females; mean age 66.5 years, range 43–79 years of age). Generally, the indications were, LETI being associated with COVID-19. In particular, the vast majority of indications (92%, 23/25) were represented by pneumonia leading to acute respiratory distress syndrome (ARDS). In the rest of the cases, the indication was surgical treatment for cervical necrotising fasciitis (4%, 1/25) and oral cavity cancer (4%, 1/25).

There were no perforations of the cuffs of the endotracheal tubes in our series. However, on two occasions (8%, 2/25), the cuff of the endotracheal tube was visualised after the retraction of the tracheal flap of the trachea due to the inadequate advancement of the tube. The anaesthesiologist immediately re-advanced it so the perforation of the cuff was prevented.

The following adaptations of TS originate in our Department and are the result of the continuous acquisition of experience from the head and neck surgeons during the year-long presence of COVID-19 in Slovenia. To the best of our knowledge, such refinements to TS have not yet been described in the pertinent literature.

Timing the tracheostomy: after 21 days

To ensure the maximal safety of the providers, surgery is postponed for at least 21 days after the onset of symptoms of COVID-19 irrespective to the results of COVID-19 testing.

Advancement of endotracheal tube by an anaesthesiologist

Prior to entering the lumen of trachea by the surgeon, the advancement of the endotracheal tube towards the carina by an anaesthesiologist is crucial. The goal is to keep the cuff beneath the level of the tracheal window to prevent it being ruptured by a scalpel. Therefore, the tube is inserted 26–28 cm from the upper-alveolar ridge. Afterwards and until the tracheostomy tube is inserted and its cuff inflated, the patient is in expiratory apnoea to prevent the potential leaking of aerosol through the unsecured tracheal window towards the faces of the surgeons.

Surgery in an intensive care unit bed with a modified positioning of the providers

TS in COVID-19 patients are performed in the bed of the intensive care units (ICU), where they are currently being tended to.

In non-COVID-19 circumstances, the position of the surgeon and the assistant is the right and left-hand-side of patient's neck, respectively. The scrub nurse stands either behind the head of the patient or at the left side of the assistant, depending on the personal preferences, while the anaesthesiologist is positioned to the right of the surgeon.

In COVID-19, there are striking differences in the positioning of the patient and the team. First, the patient lies in the extreme upper-right corner of the ICU bed (from the patient's perspective). Second, the surgeon stands on the right-hand side of the patient's neck as with a normal TS, and, as opposed to the normal circumstances, the position of the assistant is behind the patient's head. Third, the scrub nurse stands to the right of the surgeon while her working table is placed further to the right. Finally, the left-hand-side of the bed is reserved for the anaesthesiologist, nurse anaesthetist and their equipment. The suggested positioning is presented in Fig. 1.

Tracheo-cutaneous sutures

To ensure the patency of the TS canal after an inadvertent displacement of the tracheostomy tube, the tracheo-cutaneous sutures are applied. The initial part of the suture is done following minor subcutaneous preparations and before the opening of the trachea. The surgical needle enters the skin a few millimetres laterally from the incision line and comes out deep in the subcutaneous tissues. The surgical needle and the thread are maintained at their position and secured with a surgical clamp until later.

The second part of the suture is performed after the tracheal window is created and before the tracheostomy tube is inserted into the newly formed TS. The needle enters the tracheal wall from an outwards to inwards direction (from the perspective of tracheal lumen). After coming out of the lumen, the knot is tightened. As a consequence, the tracheal wall becomes laterally attached to the skin resulting in the wider opening of the TS canal. The final position of the

Fig. 1 The positioning of personnel and equipment for open elective tracheostomy in patients with COVID-19. 1 = surgeon; 2 = assistant; 3 = scrub nurse; 4 = anaesthesiologist; 5 = patient; 6 = bed of the intensive care unit; 7 = nurse anaesthetist

tracheo-cutaneous sutures is illustrated in Fig. 2. The sutures are positioned bilaterally with at least one suture per side.

Making the tracheal window

The cutting of the tracheal window is a critical point in terms of the transmission of SARS-CoV-2 from the tracheal lumen to the surgical and anaesthesia teams. At this point of the surgery, the patient is under deep anaesthesia, completely relaxed and thoroughly preoxygenated [8–16]. However, the endotracheal cuff might be inadvertently cut by the sharp surgical instruments if the tube is not pre-emptively pushed towards the carina by the anaesthesiologist.

Unfortunately, the adequacy of the advancement of the endotracheal tube cannot be visually controlled. Thus, to ensure the highest probability that the cuff will not be cut, the following steps have been suggested by our Department and are detailed in Fig. 3.

1. A horizontal incision of the intercartilaginous ligament between the 1st and 2nd tracheal rings is made (Fig. 3a)
2. A vertical incision of the 2nd tracheal ring is made on the right-hand side of the patient (Fig. 3b)
3. The small flap of the 2nd tracheal ring is retracted enabling the surgeon to inspect the lumen of the trachea and assess the position of the cuff as shown in Figs. 3c, 4. If it is observed in the lumen, the anaesthesiologist must advance the endotracheal tube further towards the carina.
4. The vertical incision is continued, turning slightly to the left through the 3rd tracheal ring on the right-hand side (Fig. 3d).
5. A vertical incision of the 2nd ring is made on the left-hand side of the patient and continues through the 3rd tracheal ring, turning slightly to the right (Fig. 3e).
6. A second horizontal incision of the intercartilaginous ligament between the 3rd and 4th tracheal rings is made and accompanied by the removal of the excised part of the anterior tracheal wall. The endotracheal tube then comes "a vue" (Fig. 3f, 3g).

As the shape of the tracheal window is that of a medieval shield as outlined in Figs. 3f, 5, we have decided to name a TS performed in this way *the Shield TS.*

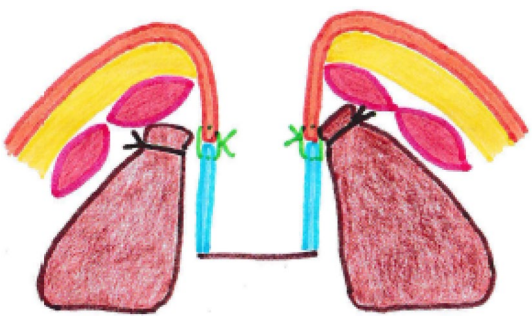

Fig. 2 The conclusion of the tracheo-cutaneous suture. Orange = skin; yellow = subcutaneous fat; red = infrahyoid muscles; brown = thyroid gland, blue = cartilaginous trachea; brown line = membranous trachea; green = tracheo-cutaneous sutures

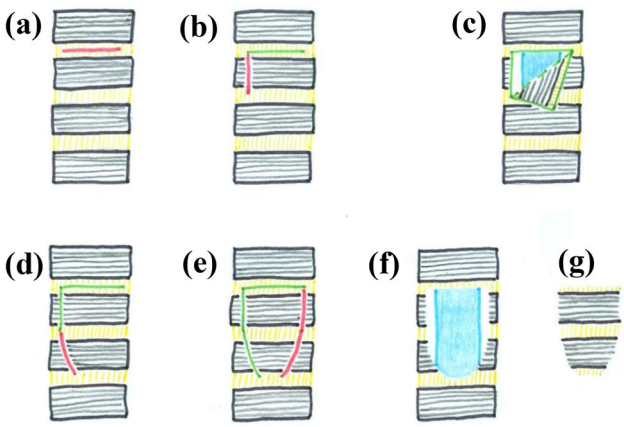

Fig. 3 The steps of the removing the tracheal window in COVID-19 Shield Tracheostomy. The anterior surface of the tracheal rings No. 2 to 5 are shown. **a** Upper horizontal incision between the 1st and 2nd tracheal rings; **b** right vertical incision of the 2nd tracheal ring; **c** tracheal flap with the endotracheal tube in the lumen (light blue); **d** continuation of the right vertical incision through the 3rd tracheal ring turning slightly to the left; **e** left vertical incision turning slightly to the right; **f** tracheal window in the shape of a medieval shield with the endotracheal tube in the lumen (light blue); **g** tracheal window removed

Fig. 4 Retraction of the tracheal flap with the endotracheal tube in the lumen

Fig. 5 The shape of the tracheal window of a medieval shield in Shield Tracheostomy

Discussion

In our series, 25 elective surgical TS were performed in patients with COVID-19. The indications (for the procedure) were LETI associated with COVID-19 pneumonia, cervical necrotising fasciitis and oral cavity cancer in 92%, 4% and 4% of cases, respectively.

During each TS, something new was discovered in the sense of how to make the TS that followed both safer and easier. This experience was the basis for the refinements and improvements of the techniques focusing on the safety of the patients and providers.

McGrath suggested that surgeons should use the techniques and equipment for TS with which they are familiar, confident and experienced [17]. However, some caution is advised here, as COVID-19 is a highly contagious and unpredictable disease demanding adjustments of the surgical techniques and equipment.

Timing the tracheostomy: after 21 days

The timing of TS in COVID-19 is one of the most controversial problems [7] with various proposals and diverse reasons appearing in the literature [18].

It is most beneficial that TS is carried out when the patient is no longer contagious. In this respect, Van Kampen's results are of fundamental importance [19]. He detected the infectious virus up to 20 days after onset of symptoms in a single patient within a group of patients on a critical course of COVID-19 and/or severe immune deficit. In light of these scientific observations, patients with COVID-19 never shed the infectious SARS-CoV-2 until after 20 days of the onset of COVID-19 [19, 20].

McGrath [17] defers TS until at least day 10 of LETI, and the mean time from intubation to TS according to Angel [21] is 10.6 days (standard deviation ± 5 days). Adding 10 days of mild COVID-19 symptoms (before the initiation of intubation and mechanical ventilation) brings us to the 20-day mark following the onset of COVID-19.

As patients with COVID-19 requiring LETI and/or TS do suffer from a critical course of COVID-19 and may even have severe immune deficits, we decided to use the findings of Van Kampen to plan our TS. We suggest performing TS 21 days after the onset of COVID-19 as does Chao [22], which exceeds Van Kampen's 20 days by exactly 1 day—the goal being to stay on the safe side. Within the framework of the herein described timing of 21 days, an additional explanation is needed.

According to Piazza, the time from symptom onset to the ICU admission for severe hypoxemia (and endotracheal intubation) is approximately 7–12 days. This leaves only 9–14 days of LETI until the day of 21, when the TS is performed. Therefore, implementing mark 21 to perform TS is safe from two aspects. First, the patient is no more contagious [19], and second, the probability for laryngotracheal stenosis after up to 14 days of LETI is low if the cuff is not excessively inflated [1].

Advancement of the endotracheal tube by an anaesthesiologist

Preventing a rupture in the endotracheal cuff during the surgical opening of the trachea is assured by the advancement of the tube towards the carina by an anaesthesiologist just before the surgeon incises through the tracheal wall,

i.e. enters the lumen. This is one of the essential modifications of the COVID-19 TS and is discussed in almost all relevant articles [15, 23–27]. The insertion should neither be too shallow nor too deep. In the first case, the rupture of the cuff by the scalpel is imminent, whereas, in the second, only the right lung is ventilated. The position of the tube could be checked by the flexible bronchoscopy, but this is an aerosol-generating procedure that poses a substantial risk to staff [28, 29], therefore, we advise against it. As a matter of fact, the advancement of the endotracheal tube is, in a way, a "blind" procedure. It would be advantageous to know, how deep the insertion should be. Hiramatsu suggests a depth of 27 cm from the mouth itself [30].

However, the length of the trachea is not constant in adults. In addition, the reference point "from the mouth" is ambiguous, as the mouth is quite a large area in terms of the head and neck. Based on our experience, we suggest that the tube be inserted to a depth of 26 cm in females and to 27–28 cm in male patients from the upper-alveolar ridge, which is a reliable anatomical landmark. Implementing these references, during the retraction of the tracheal flap, the position of the cuff was assessed as being too high in 8% only, what we regard as an acceptable rate.

Surgery in an intensive care unit bed with the modified positioning of the providers

The proper surgical setting is very important and emphasised in published guidelines [7]. TS can be done either in the ICU or in the operating room. The latter is at a disadvantage due to the transfer of the patient from the ICU to an operating room, risking the exposure of multiple staff, the requirement of two ventilation machines along with the associated logistics, which would lead to the increased risk of exposure in the inter-human transmission of the virus [7, 17].

In comparison to the surgical bed, the bedside TS in ICU has a crucial limitation. Here, surgical access is limited due to the width of the ICU bed. If the surgeon and the assistant stand on the opposite sides of the patient, they face the problem of a suboptimal overview of the surgical field and will have to lean forward. This means that both would suffer from lumbar pain after an hour of operating in this non-ergonomic position. Therefore, we suggest that the patient be placed in the extreme upper-right corner of the ICU bed with the assistant standing behind the head of the patient and the anaesthesia team positioned opposite to the surgeon (Fig. 1). Nonetheless, the described repositioning may, first, lead to an inadvertent injury of the cervical spine unless four persons are participating in the procedure. Second, spread of the SARS-CoV-2 is also possible, but from our point of view, the risk is much lower compared to transferring the patient to the operating theatre.

It is critical that the space occupied by the surgeon and the assistant is completely clear and free of equipment such as tubes, cables and intravenous lines. The rationale is that the surgeon and the assistant must be able to freely and quickly interchange their positions.

We discovered a disadvantage to the proposed position, as it can be highly demanding to rearrange a room, bed and the equipment of the ICU. Therefore, a loss of time is imminent unless upfront instructions are given so that the ICU personnel can arrange the ICU bed prior to the arrival of the surgical team.

Tracheo-cutaneous sutures

The unexpected displacement of the tracheostomy tube is a critical incident in the ICU and is, within the framework of COVID-19, a high-risk emergent situation. Such a replacement is performed under severe time constraints. The fact of the matter is that ICU personnel is often not sufficiently confident in dealing with issues concerning tracheostomy tubes.

Hence, the TS should be performed in a way that the replacement is as simple and rapid as possible and should be doable even by less experienced providers, which brings us to the point of the placing of the tracheo-cutaneous sutures (Fig. 2). From our point of view, they enable more effortless replacement of inadvertently displaced tracheostomy tube.

Making the tracheal window

The generation and spread of aerosol are to be diminished to the lowest possible level. In this aspect, cutting the cuff of the endotracheal tube during tracheal incisions must be avoided at all cost. To prevent this, the endotracheal tube should be advanced towards the carina.

The danger of entering the lumen is that the surgeon is not aware of the position of the cuff in relation to the planned tracheal window. Entering the lumen is, as discussed above, performed "blindly". To eliminate the issue of inadvertently puncturing of the cuff, the formation of a small tracheal flap consisting of the anterior part of the 2nd tracheal ring is suggested. Rather than making four "blind" incisions with a collective length of 50–60 mm on the anterior tracheal wall, a minimal 5-mm-long (vertical) cut (Fig. 3b) and a 15-mm-long (horizontal) one (Fig. 3a) are made without visual control of the cuff.

Afterwards, the tracheal flap enables the visualisation of the endotracheal tube (Figs. 3c, 4), the cuff is under control and the incisions to the trachea are safely completed.

Both vertical incisions are curved medially in their inferior parts, as shown in Fig. 3d, 3e. This is to prevent the unnecessary resection of exceedingly large portions of the tracheal rings. On one hand, we should keep as much cartilage as possible to prevent tracheal collapse after

decannulation, while, on the other, we should still enable a large tracheal window allowing for a swift tracheostomy tube replacement in the presence of dislodgment. The compromise is reached with the shape of the tracheal window that resembles a medieval shield (Figs. 3f, 5). It is for this reason that we have called a TS performed in this way (during the COVID-19 era) *the Shield TS*.

Conclusion

To conclude, there are several useful adaptations of TS for patients with COVID-19. Many of them have already been described in the current literature and widely implemented in various centres. However, some additional refinements were suggested and presented.

The major difference opposing to previously described adjustments is that before excising the shield-shaped tracheal window, a small tracheal flap is made to check the position of the endotracheal cuff in relation to the planned tracheal window.

As COVID-19 does not appear to be vanishing anytime soon, more patients will require (Shield) TS. Therefore, further improvements to the technique are expected in the near future. Until then, prudence and caution at TS in the era of COVID-19 are of utmost importance.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethics approval It was not required.

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