



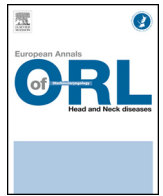
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Technical note

# Percutaneous tracheostomy simulation training for ENT physicians in the treatment of COVID-19-positive patients



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## ABSTRACT

Tracheostomy in COVID-19-related severe acute respiratory syndrome is at high risk of viral dissemination. The percutaneous dilatation technique could reduce this risk, being performed at the bedside and minimising airway opening. In the COVID-19 context, however, with precarious respiratory status, it requires specific preparation. We designed a 3-hour training module, and here provide a step-by-step schedule, including video analysis, a demonstration of the kit, the recommended precautions related to COVID-19, and several simulation scenarios of increasing difficulty, using a high-tech mannequin. A low-tech procedural simulator was also developed for practicing the steps of the procedure. Our experience (3 sessions with 14 participants) highlighted the difficult points of the procedure in the COVID-19 context, and defined a checklist for clinical practice and an assessment grid. This type of simulation helps to prepare teams for a potentially delicate technical act.

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## 1. Introduction

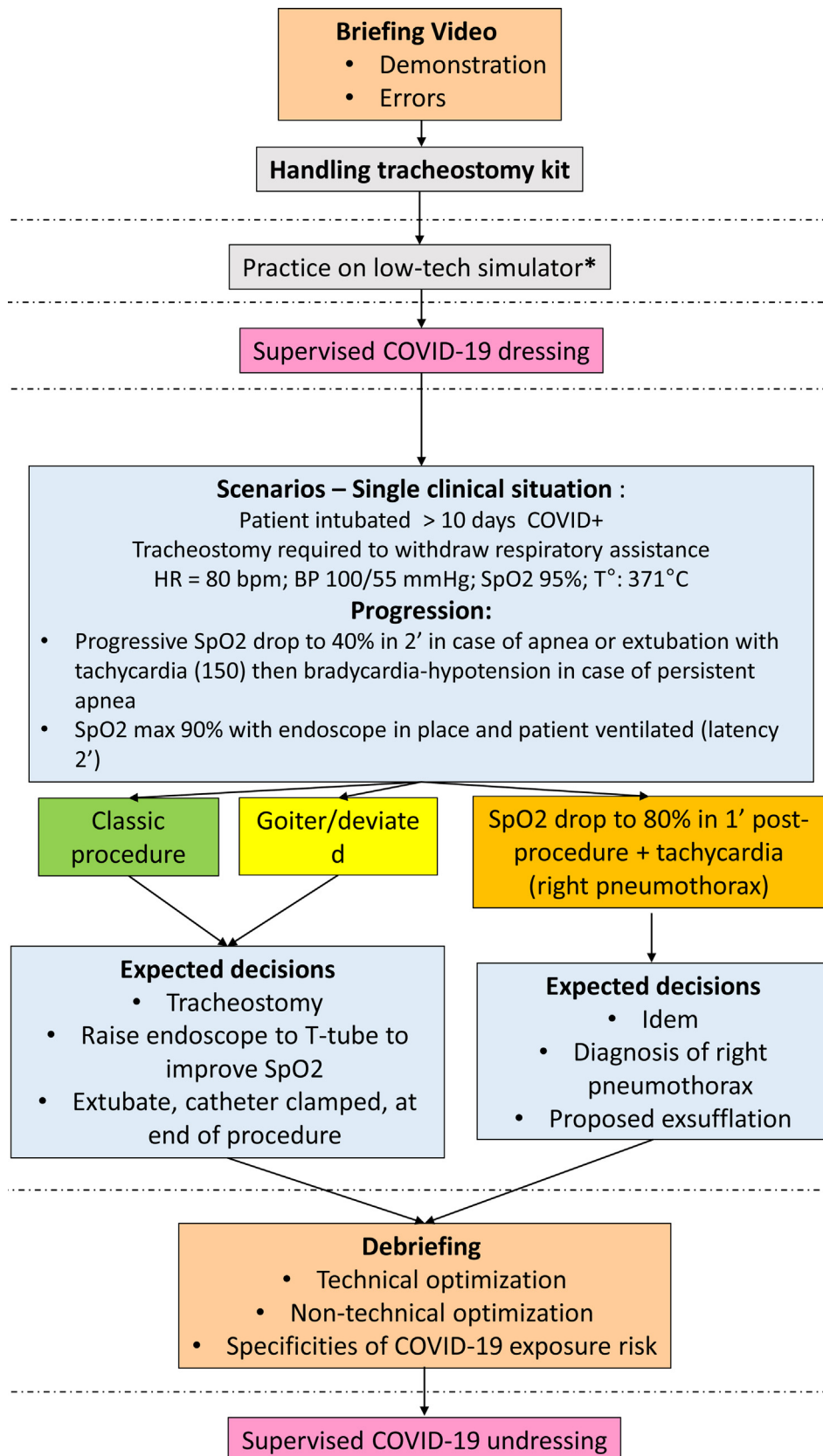
The COVID-19 pandemic requires current practice to be adapted to emerging needs and enhanced protection of patients and caregivers [1]. Patients in intensive care usually need prolonged respiratory assistance [2], blocking access for new cases when the saturation point is reached. Tracheostomy could hasten termination of respiratory assistance and reduce ICU stay [3]. However, it incurs a high risk of SARS-CoV-2 viral dissemination as it involves ventilation circuit disconnection and aerosolisation. Based on experience from Asia in 2004 [4] and 2020 [5], the American Academy (<https://www.entnet.org/content/tracheostomy-recommendations-during-covid-19-pandemic>) and the ENT-UK National Tracheostomy Safety Project (<https://www.entuk.org/tracheostomy-guidance-during-covid-19-pandemic>) drew up guidelines for surgical tracheostomy; intensive care physicians, however, seem to favour the percutaneous technique, which is quicker and does not require transfer to theatre, without more immediate complications [6,7]. Likewise, according to the recent guidelines from the French ENT

Society (SFORL) on tracheostomy under the COVID-19 pandemic (<https://www.sforl.org/wp-content/uploads/2020/04/SFCCF-SFORL-COVID-19-2i%C3%A8me-article.pdf>), the percutaneous technique is to be preferred, to limit aerosolisation-related viral contamination of care staff and avoid theatre transfer. The procedure has been well described and is used in intensive care [8,9], but usually requires 2 operators (1 at the patient's head for flexible endoscopic control, and 1 for the tracheostomy) and an anaesthesiologist to deal with the respirator and the drugs. To free up time for intensive care specialists, ENT physicians may be called upon to perform percutaneous tracheostomy, having the requisite anatomic knowledge and experience in dealing with the upper airway. This has been the case in the Nancy University Hospital and the Metz Military Hospital. However, the technique requires training, especially in the COVID-19 context. To minimise error, simulation can be of great help, and the present technical note describes a training schedule for ENT physicians in percutaneous tracheostomy in COVID-19+ patients.

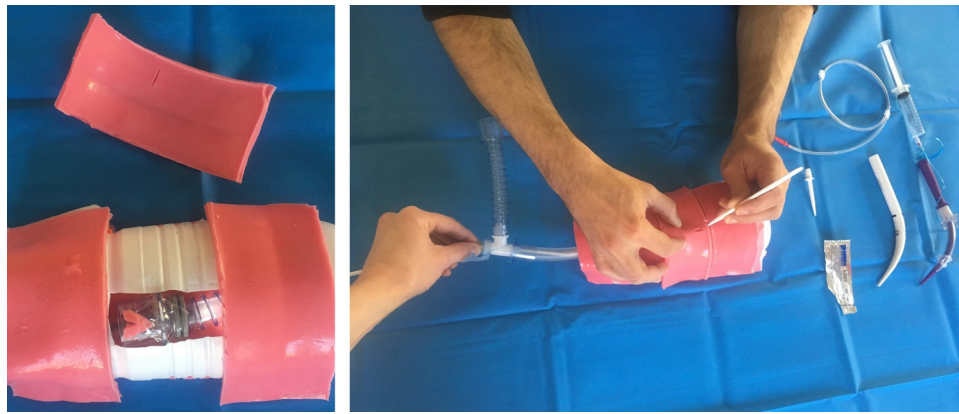
## 2. Technique

A 3-hour half-day session can include 4–6 participants working in 2–3 pairs in a simulation room equipped with a video camera and microphones. The scenario requires 1 facilitator (anaesthetist),

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**Fig. 1.** Module flowchart. Scenarios 4 and 2 appear similar, but the expected decision in #4 is to abstain; \*Step in 33 only; HR=heart rate; bpm=beats per minute; mmHg= millimetres of mercury; SpO<sub>2</sub> =partial oxygen saturation; T° = temperature.



**Fig. 2.** Low-tech simulator, made from an annealed anaesthesia ventilation circuit tube (cost, <€5). The rigid part simulates the thyroid cartilage (narrowest interior part representing the glottis); the protruding part is planed in front, with a silicone fragment attached by adhesive tape to simulate the laryngeal prominence. A piece of annealed electric sheath (20 mm; cost, <€3) is by adhesive tape to simulate the cricoid. The assembly is placed on a foam rubber or silicone support (moulded in half a plastic bottle), and the catheter is slid in at the upper part. The skin is simulated by non-woven adhesive bands (cost, <€3) coated in liquid silicone (cost, <€10 per dozen) that can be incised.

and can be supervised by 1 or 2 session leaders. Session procedure is shown in Fig. 1. A 15-min video introduction presents the kit, step-by-step breakdown of the manual procedure and error screening in a sample procedure; technical pitfalls and clinical risks are highlighted.

Trainees are then given a percutaneous tracheostomy kit (Ultra-perc kit Portex™, Smiths Medical, Minneapolis, Minnesota, USA) to handle ahead of simulation.

The second phase involves a homemade low-tech procedure simulator, costing less than €20 (Fig. 2), for practice ahead of full-scale simulation.

Trainees wear a full protective outfit: surgical clothing, FFP2 mask, protective glasses, hood, overshoes and 2 pairs of sterile gloves. An “observer” is useful, to oversee donning and doffing, as recommended in the French health authority’s methodology guide (<https://solidarites-sante.gouv.fr/IMG/pdf/guide-covid-19-phase-epidemique-v15-16032020.pdf>).

A dedicated checklist forming an acrostic from A to M enables trainees to prepare fully before entering the room, so as not to have to go out during the procedure:

- Anaesthesia: local anaesthesia. Needle and syringe with aesthetic and vasoconstrictor;
- Balloon: tracheostomy and cannula balloon to be checked and syringe for inflation to be prepared in advance;
- Curare: or at least deep sedation, to avoid coughing;
- Disinfection/drapes: Skin disinfection and sterile drapes (ideally 4 to allow wide view of landmarks);
- Extra kit: Fall-back kit, prepared in advance “just in case”;
- Flexible endoscope;
- Goitre: prior identification of any goitre, laryngeal deviation, short neck or other technical difficulty;
- Heat/humidity exchanger with antiviral filter and T-tube check-valve;
- Intubation issue: screening for intubation issues and foreseeing possible reintubation;
- Jacket: gloves and other PPE;
- Kelly clamp/Kit;
- Laminar flow: Ultra-filtered laminar airflow or mobile decontamination unit;
- Marker: Surgical Skin Marker Pen.

Using a SimMan 3G™ mannequin (Laerdal, Stavenger, Norway), 4 scenarios are implemented (standard tracheostomy, small goitre, pneumothorax, intubation difficulty) (Appendix 1), in pairs



**Fig. 3.** Example of full-scale simulation session. Each operator attempts to obtain maximal tightness.

plus 1 facilitator (anaesthesiology resident–actor, with earphones) (Fig. 3). The number of persons present is kept to an absolute minimum, to observe due COVID-19 precautions; the other trainees watch a direct retransmission on a screen in an adjacent room. A group debriefing is held after each scenario, with trainees, facilitator, spectators and training team. Trainees provide feedback, then analysis focuses on the technical steps, COVID-19 transmission risk, and a need for speedy execution due to the patient’s respiratory frailty. Scenarios are of incremental difficulty, confronting trainees with different clinical situations and corresponding options.

### 3. Discussion

Percutaneous tracheostomy is fairly easy to learn, but, in the context of a highly contagious lung disease such as COVID-19, with severely impaired respiratory capacity, it has to be performed especially efficiently and safely, adapting the steps of Ciaglia’s procedure [8] (Table 1). We therefore thought it essential to formalise training in a safe environment by means of a simulation workshop. Having conducted this training module 3 times, we are able to draw some lessons and lay out the best debriefing approach. The detailed results are presented in Appendices 2 and 3.

Although, with experience, surgeons’ self-assessments seem well correlated with their real skill [10], trainees are prone to

**Table 1**  
Percutaneous tracheostomy steps under flexible endoscopy, adapted from the description by Ciaglia [8].

Step	Expiratory pause	Detailed description
1		Skin disinfection, wide cervicotomy-type surgical draping (4 drapes)
2		Skin landmarking: thyroid cartilage, cricoid, 1st and 2nd tracheal ring, sternal fork
3		Local anaesthesia with vasoconstrictor to minimise bleeding
4		1.5 cm neck incision at 1st tracheal ring
5		Digital dissection or supraisthmus Kelly clamp
6		Positioning Kelly clamp to lower the isthmus
7	If possible	Positioning flexible endoscope in catheter
8	If possible	Careful withdrawal of catheter until the inferior edge of the cricoid cartilage appears, endoscope positioned at cricoid
9		Upward traction of larynx by operator's left hand
10	If possible	Puncture under endoscopy through the neck incision with trocar oriented obliquely toward the patient's feet; syringe connected to ensure tightness and visualisation of any bubbles. Endoscope transillumination can be used to help select puncture level
11	If possible	Visual and verbal confirmation of trocar positioning (without perforating the posterior tracheal wall)
12		Withdrawal of syringe and needle, catheter in place, with digital occlusion
13	If possible	Positioning guide-wire
14	If possible	Use of pre-dilator, with safety crest toward lateral end of the guide-wire
15		Dilator attached to stylet, extremity on the safety crest. Introduction of dilator up to skin landmark; gentle to-and-fro movement to achieve good dilatation
16	If possible	Cannula positioned on its introducer, and introduced under endoscopy
17	Mandatory	Replacement of introducer by sleeve connected to filter
18	Mandatory	Balloon inflation and circuit connection
19	Mandatory	Visual and verbal confirmation of cannula positioning
20		Resume ventilation
21		Confirm positioning with CO <sub>2</sub> detector (if available and not requiring circuit disconnection)
22		Withdrawal of intubation catheter (ideally clamped) and endoscope
23		Safety cord/suture and usual protection measures

Kit contents and tracheostomy cannula balloon status should be checked in advance. The patient is sedated and curarised under 100% FiO<sub>2</sub>. Respirator settings and alerts are adjusted to accept the extra pressure induced by the flexible endoscope within the intubation catheter. So far as possible, steps 7–8, 10–11 and 13–15 should be conducted under expiratory pause. Steps 17–20 should be conducted in < 30 sec (ideally < 15 sec).

overestimate their skills, especially in non-technical areas [11]. We therefore advise associating self-assessment to assessment by the supervisor or supervisors (Table 2 and Appendix 2).

The initial sessions highlighted technical difficulties encountered by all trainee pairs (Appendix 3), especially in managing the orotracheal intubation catheter: in half of the scenarios, the balloon got pierced or the patient was unintentionally extubated, either of which can lead to ventilation circuit leakage, impairing oxygenation for the patient and incurring viral risk for the care personnel. Errors causing extubation mainly consisted in focusing visually on the needle instead of on catheter positioning, defective control of withdrawal (the hand used should be leaning on the patient's head), and defective location of catheter position. Errors causing balloon piercing mainly consisted in focusing on the cervical part of the procedure and trying to visualise the needle as soon as the puncture was made without having first checked the position of the intubation tube. The last of these problems may be due to poor anatomy in the mannequin; the endoscopic anatomy of the mannequin should be checked in advance to avoid this bias. In the light of these findings, we introduced the low-tech pre-training step (Fig. 3), supervised use of which may shorten the learning curve by practice with the various parts of the kit and with the successive steps. The low-tech simulator provided prior identification of technical issues liable to slow down the procedure, and enhanced its safety. In the third group, which had had a short 15-min experience with the low-tech simulator, there was only 1 extubation in the 4 scenarios and no balloon piercing, and procedure time was never more than 20 minutes.

Installation also caused problems in the various scenarios. Bed height needs adjusting, and a support block can be useful. To avoid asepsis errors and equipment falling on the floor, a table bridging the patient's legs could, according to trainees, be a good solution.

The simulations and the discussions between trainees and supervisors notably highlighted the question of managing the intubation catheter, which is the most delicate point in the procedure. The recommendation was to have the more experienced ENT physician at the patient's head (endoscope), as this position requires

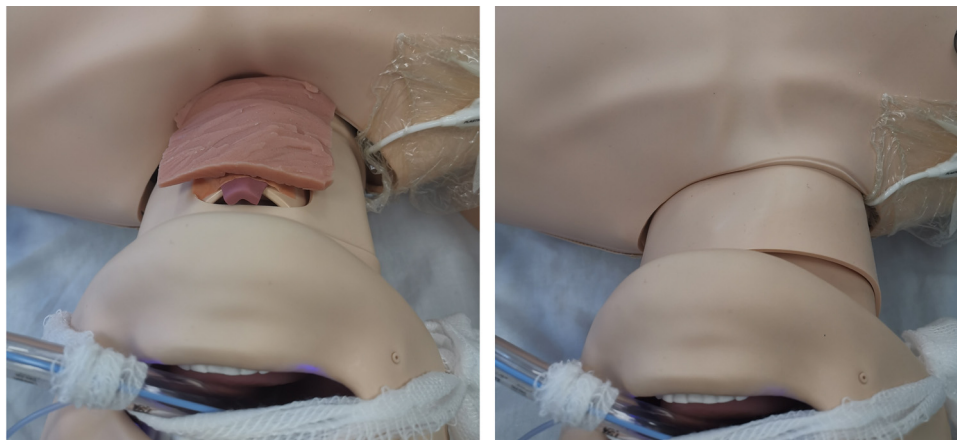
good experience of intubation and flexible endoscopy to secure optimal positioning in the airway. It also makes the leader free to synchronise ventilation with the anaesthetist and guide the trainee performing the percutaneous tracheostomy as such, which was generally agreed to be more technically straightforward. The intubation catheter should be freed from its attachments and positioned in the axis of the incisors to optimise endoscopy. When the catheter has to be moved, the movement should be slow and careful; the hand holding the catheter should lean on the patient's face to limit the risk of unintentional extubation on exposing the inferior edge of the cricoid. It is recommended to verbally call out the mark on the catheter (with respect to the dental arcades) before the catheter is raised and once it has been positioned below the glottis. In case of accidental extubation, the flexible endoscope is the best guide for reintubation, but an Eschmann stylet and a laryngoscope should also be readily available.

To minimise leakage, a finger is placed on the trocar at cervical level as soon as possible, and the physician handling the endoscope also attempts to minimise leakage at the endoscope entry point. The respirator is put on prolonged expiratory pause when leakage is most likely, if the patient can tolerate this. A further precaution against aerosolisation would be to have a portable air purifier in the room throughout the procedure, to filter out airborne viral particles before, during and after tracheostomy.

In the present case, all the scenarios were played out on the "high-tech" SimMan 3G simulator, which allows real-time adjustment of physiological constants transmitted to an intensive care screen, modelling complications (pneumothorax), modifying neck conformation (to simulate goitre, laryngeal deviation, etc.) and simulating difficult intubation (Fig. 4). A less sophisticated simulator could be used, but such full-scale simulation allows consensus to be reached on difficulties, however rare, that can be encountered in practice. In the course of the procedures and in the light of previous studies, a data collection and assessment form was designed (Table 2). The fact that the other trainees were able to watch a given pair's simulation in real time and take part in the debriefing ironed out some difficulties for the subsequent scenarios, so

**Table 2**  
Procedure assessment form.

Scenario n°:..... TIMES:.....	Date:..... Start:..... Incision:..... Cannula in place, circuit tight:.....	First operator			Assistant (endoscope)			Comments
<b>Preparation</b>								
Check equipment completeness and integrity		Yes	No	NA	Yes	No	NA	
Donning without error		Yes	No	NA	Yes	No	NA	
Checklist complete Yes No								
<b>Installation</b>								
Free work space		Yes	No	NA	Yes	No	NA	
Good installation (position, height, access to head)		Yes	No	NA	Yes	No	NA	
Good verbal confirmation		Yes	No	NA				
<b>Protection of personnel</b>								
Cut ventilation at right moment		Yes	No	NA	Yes	No	NA	
Optimal leakage prevention		Yes	No	NA	Yes	No	NA	
Protection of patient and oxygenation								
Oxygenation coordinated with anaesthetist		Yes	No	NA	Yes	No	NA	
Careful catheter raising					Yes	No	NA	
Coordinated check on needle position		Yes	No	NA	Yes	No	NA	
Reasonable force exerted on trachea		Yes	No	NA				
<b>Technical performance of tracheostomy</b>								
Right instruments at right time		Yes	No	NA				
Minimal pointless gestures		Yes	No	NA				
Good gestural ergonomics		Yes	No	NA				
<b>Major problems encountered</b>								
→ SpO <sub>2</sub> < 60% Yes No								
→ Extubation Yes No								
→ Difficult reintubation Yes No								
→ Balloon pierced Yes No								
→ Oesophageal puncture Yes No								
→ Time > 20 minutes Yes No								
<b>Non-technical issues</b>								
Coordinating team activity		Yes	No	NA	Yes	No	NA	
Dealing with pressure (and calming the team)		Yes	No	NA	Yes	No	NA	
Collecting environmental information (SpO <sub>2</sub> )		Yes	No	NA	Yes	No	NA	
Verbal expression of information		Yes	No	NA	Yes	No	NA	
Establishing joint understanding		Yes	No	NA	Yes	No	NA	
Integrating assistants' suggestions		Yes	No	NA	Yes	No	NA	
Choosing and communicating an option		Yes	No	NA	Yes	No	NA	
Adapting the initial roadmap		Yes	No	NA	Yes	No	NA	
Using secure communication		Yes	No	NA	Yes	No	NA	
Anticipating steps/desaturation/leakage		Yes	No	NA	Yes	No	NA	
Offering help – making appropriate suggestions		Yes	No	NA	Yes	No	NA	
<b>Free comments</b>								



**Fig. 4.** Examples of morphologic variants used on the simulator. Left: goitre (“skin” withdrawn); right: laryngeal deviation.

that procedure time constantly decreased despite the increasing difficulty (Appendix 2).

The present checklist, with its “A-to-M” mnemonic form, can be of great importance as, in the context of intensive care for COVID-19 patients, the room must be closed and the team needs to be completely self-sufficient, which requires having all necessary equipment to hand in sufficient quantity to ensure the safety of both patient and staff.

Supervised doffing revealed some errors: hands too close to the collar in removing the cap, the need to put all the clothing in the trash can without having to push it in, so as to avoid aerosolisation, and errors in removing the mask (need to pull the elastic bands from behind to in front of the skull to remove the mask from the face without raising it to the hairline).

In conclusion, simulation of percutaneous tracheostomy with a training module covering theory with video support, technical practice on the low-tech simulator, then clinical practice on the full-scale high-tech simulator seems suited for training ENT physicians. The module is also an opportunity to stress the specificities of protection against COVID-19 in the ICU setting. We consider the format reproducible in most simulation centres equipped with high-tech simulators, and that the low-tech simulator is easy and cheap to produce for the purely technical aspect of the training.

#### Disclosure of interest

The authors declare that they have no competing interest. Elsewhere, Valentin Favier received funding from the French College of ENT and Head and Neck Surgery for a 1-year research project on simulation in head and neck surgery.

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#### Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at <https://doi.org/10.1016/j.anorl.2020.06.002>.

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