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CORRESPONDENCE

Modern cuirass ventilation for airway surgery: unlimited access to the larynx and trachea in anaesthetised patients

Michael S. Kristensen*, Rasmus Hesselfeldt and Jakob F. Schmidt

Department of Anaesthesia, Centre of Head and Orthopaedics, Rigshospitalet, University of Copenhagen, Copenhagen, Denmark

*Corresponding author. E-mail: michael.seltz.kristensen@regionh.dk

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Editor—Cuirass ventilation works by placing a shell (the cuirass) with an airtight seal on the anterior chest and upper abdomen. Ventilation is achieved by applying alternating negative and positive pressure inside the cuirass.[1] Ventilation can thus be achieved without a tracheal tube, a supraglottic airway, or a jet ventilation device in the airway. A major advantage of cuirass ventilation is that it allows unlimited access for surgery in the larynx and the trachea without time restraints[2] or development of hypercapnia[3] associated with apnoeic techniques. The disadvantage of tracheal intubation for this kind of surgery is that it partially or completely obscures access to the surgical field. Thus with tracheal intubation, it might be necessary to perform repeated extubations in order to complete the surgery during short apnoea periods. Repeated extubation makes the surgery difficult and carries the risk of oedema of the airway. The advantages and disadvantages are discussed in more detail in the accompanying editorial.[4]

Cuirass ventilation has been used previously for airway surgery, but the equipment formerly consisted of a bulky oscillator with the cuirass held in contact with the body by being clamped to a plate placed underneath the patient.[5,6] Thus, the technique never became widely used clinically. We describe the first use of *modern* cuirass ventilation for airway surgery using a versatile, mobile, flexible, transparent, and lightweight[7] device (see video of the technique at: (http://airwaymanagement.dk/attaching_cuirass_and_ventilating) (Hayek RTX Biphasic Cuirass Ventilator; United Hayek Industries, London, UK). The cuirass ventilator system is approved for clinical use by Conformite Europeenne and the United States Food and Drug Administration, and has been implemented as part of our standard techniques for difficult airway management. Data were only obtained from the patient file and only as part of delivering the standard of care. Thus no formal ethics committee approval was sought for this report because it is not a study or investigation. Patients subsequently provided oral and written consent to have their data and photos/videos from the patient file used for publication.

We implemented cuirass ventilation for laryngotracheal surgery in April 2022, and now report on the first 14 patients (Table 1) treated until April 2023 with case reports of two patients described in more detail.

Cases were selected for cuirass ventilation when the surgeon suspected that owing to the nature of the anatomy and pathology, it would be difficult to get sufficient access to the lesion to perform the planned laser treatment, resection, or dilatation. Additionally, cuirass ventilation was chosen when a prolonged duration of surgery was predicted, and for patients who previously had complications because of repeated tracheal intubations resulting in post-surgery stenosis. All patients had total intravenous anaesthesia, neuromuscular block with rocuronium and face mask ventilation, followed by cuirass ventilation. The airway was kept open with a suspension laryngoscope for the duration of the surgical procedure. Oxygen–air mixture was delivered either from the anaesthesia machine via a nasal mask (SuperNO$_2$VA™; Vyaire Medical, Mettawa, IL, USA) or by high-flow warmed and humidified nasal oxygen (HFNO) (Optiflow™; Fisher & Paykel Healthcare, Auckland, New Zealand). After termination of cuirass ventilation, neuromuscular block was reversed with sugammadex (Merck & Co., Inc., Rahway, NJ, USA).

Pa_{CO_2} was initially (patient #1–5) measured by frequent blood gas analysis. After continuous transcutaneous CO_2 ($TcCO_2$) monitoring during such procedures proved to be reliable and precise,[8] we applied continuous $TcCO_2$ monitoring

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Table 1 Retrospective case reports of the first 14 patients ventilated using biphasic cuirass ventilation during airway surgery. A-line, intra-arterial cannula; M, male; F, female; BCV, biphasic cuirass ventilation (cuirass ventilation with an inspiratory and an expiratory phase); End-BCV-PCO_2, P_{CO_2} (Pa_{CO_2} or $TcCO_2$) measured at termination of biphasic cuirass ventilation; N/A, not available; SGA, supraglottic airway device; TBD, tracheal balloon dilatation; $TcCO_2$, transcutaneous carbon dioxide; $TcCO_2-Pa_{CO_2}$, difference between simultaneously measured $TcCO_2-Pa_{CO_2}$ in kPa; 'Unsurpassed surgical conditions', access to the surgical field perceived as better than with any other known method including jet ventilation.

Patient characteristics						Surgery and airway management			P_{CO_2} monitoring			Outcome	
Pt #	M/F	Weight, kg	Age, yr	Pathology	Surgery	Airway during initial BCV optimisation	Duration of BCV, min	Gas delivery during BCV	A-line	$TcCO_2$	End-BCV P_{CO_2}, kPa	$TcCO_2$ -Pa_{CO_2}, kPa	Surgeon's evaluation
1	M	81	26	Tumour vocal cord	Laser evaporation	Tracheal tube	32	Nasopharyngeal tube	Y	N	6.0	N/A	'Unsurpassed surgical conditions'
2	M	85	44	Laryngeal papilloma	Laser evaporation	Tracheal tube	24	Nasopharyngeal tube	Y	N	7.0	N/A	'Unsurpassed surgical conditions'
3	F	76	75	Tracheal chondrosarcoma	Resection, shaving	Nasal mask with jaw thrust	53	Nasal mask	Y	Y	5.5	−0.4	'Unsurpassed surgical conditions'
4	F	44	61	Tracheal stenosis	Incision, biopsy, TBD, corticoid injection	Face mask	28	Nasal mask	Y	Y	4.8	N/A	'Unsurpassed surgical conditions'
5	F	69	54	Tracheal granuloma	Incision, biopsy, laser, corticoid injection	Face mask	24	Nasal mask	Y	Y	5.1	−0.3	'Unsurpassed surgical conditions'
6	F	65	72	Tracheal stenosis	TBD	Tracheal tube	22	Nasal mask	N	Y	5.7	N/A	'Unsurpassed surgical conditions'
7	F	63	36	Tracheal stenosis	Incision, TBD, corticoid injection	Face mask	33	Nasal mask	N	Y	5.4	0.05	'Unsurpassed surgical conditions'
8	F	79	35	Tracheal stenosis	Incision, TBD, corticoid injection	Face mask	34	Nasal mask	N	Y	7.3	N/A	'Unsurpassed surgical conditions'
9	F	70	43	Tracheal stenosis	Incision, TBD, corticoid injection	SGA	29	Nasal mask, $+O_2$ via suspension laryngoscope	N	Y	4.5	−0.5	'Unsurpassed surgical conditions'
10	F	60	26	Tracheal stenose	Incision, TBD, corticoid injection	SGA	20	Nasal mask, $+ O_2$ via suspension laryngoscope	N	Y	4.2	−0.1	'Unsurpassed surgical conditions'
11	F	52	49	Papilloma masses in larynx	Laser evaporation	Suspension laryngoscope	44	Nasal mask, $+ O_2$ via suspension laryngoscope	N	Y	5.6	N/A	'Unsurpassed surgical conditions'
12	F	67	28	Papillomas in larynx and trachea	Surgical shaving, laser evaporation	SGA	56	Nasal mask	N	Y	5.1	N/A	'Unsurpassed surgical conditions'
13	F	58	49	Synechia in glottis and tracheal stenosis	Balloon dilatation, corticoid injection	Suspension laryngoscope	17	Nasal mask	N	Y	5.5	0.4	'Unsurpassed surgical conditions'
14	F	55	40	Idiopathic subglottic stenosis	Incision, TBD, corticoid injection	Face mask	24	Nasal mask	N	Y	4.5	−0.1	'Unsurpassed surgical conditions'

(Sentec; SenTec Inc. CH-4106, Therwil, Switzerland) from patient #3 onwards. Detailed procedural setup and guidance is provided in Supplementary Table S1.

Patient #3 (Table 1): One month before, the patient had undergone a diagnostic direct laryngoscopy with biopsies under brief general anaesthesia with oxygenation maintained by HFNO. The patient was referred for further diagnosis and treatment, and because of planned extensive surgery and predicted difficult access to the surgical site, cuirass ventilation was chosen. Subsequently, application of the cuirass ventilation was initiated and adjusted to an adequate minute volume. Examination revealed both chondrosarcoma at the level of the cricoid cartilage and several elements of osteochondroplastic tracheobronchopathy dispersed in the trachea that was resected with a surgical shaver (see video at: http://airwaymanagement.dk/cuirass_for_airway_surgery).[9] The duration of cuirass ventilation was 53 min, Pa_{CO_2} and $TcCO_2$ remained in the normal range during the entire procedure, and the patient had an uneventful recovery.

Patient #8 (Table 1): The patient had progressive tracheal stenosis and was previously treated five times over the previous 3 yr. Nine months prior to the present surgery, the patient had laser treatment and dilatation of the stenosis. On that occasion, the airway was managed by intermittent tracheal intubation with a 4-mm internal diameter (ID) tube alternating with extubation and apnoea for the surgical treatment. During this procedure increasing resistance to the intermittent intubation was noted, and at termination of surgery, the trachea was intubated with a 4.5-mm ID tube and the patient transferred to the ICU for treatment with dexamethasone for 2 days before the trachea was successfully extubated. Because of the serious previous complication, cuirass ventilation was chosen for the procedure. During ongoing cuirass ventilation, the patient had incision, dilatation with a non-occlusive dilatation balloon (Trachealator; DISA Medinotec, Cape Town, South Africa), and injection of corticosteroid to prevent scar formation. After completion of the surgery, the airway was maintained with jaw thrust and face mask ventilation, and the patient was discharged to home after a few hours.

In all cases, surgery was conducted without the need to switch ventilation mode. Severe hypoxaemia, defined as $SpO_2<90\%$ for >60 s,[10] was not observed and all patients denied having any adverse effects attributable to the cuirass exerting pressure on the upper body. Surgical conditions were routinely discussed with the surgeons, and they reported that the method provided ‘unsurpassed surgical conditions’ in each patient (Table 1).

When switching from face mask positive pressure ventilation to cuirass ventilation, the airway *must* be kept patent without interruption. This was achieved by face mask with jaw thrust, by placement of a supraglottic airway device, or by temporary placement of a tracheal tube until replaced by the surgical suspension laryngoscope (Table 1). Direct placement of the suspension laryngoscope was used in cases of extreme and floppy masses of papilloma (patient #11 Table 1) in order to stent the airway open.

Several other techniques exist for obtaining surgical access to the glottis without devices in the airway. These include maintenance of spontaneous breathing, apnoea with HFNO, or surgery during periods of apnoea interrupted by intermittent tracheal intubation with a small bore tube or supraglottic jet ventilation, but each of them have important limitations.[4,11]

There are some possible disadvantages to using cuirass ventilation in conjunction with airway surgery. During the surgery, the ventilatory minute volume cannot be measured directly, either frequent arterial blood gas samples or, as in our case, transcutaneous CO_2 measurement must be used. It is possible to make a baseline measurement of the minute volume of cuirass ventilation with a face mask or a supraglottic airway device *before* placement of the suspension laryngoscope. The challenge in monitoring ventilation is common for all open-airway techniques. Owing to the position of the cuirass above the front surface of the thorax, placing the suspension laryngoscope requires special preparation and this should be rehearsed beforehand.[4] It is unknown how cuirass ventilation will work in connection with airway surgery in morbidly obese patients.

Use of modern cuirass ventilation combined with transcutaneous CO_2 monitoring provided good conditions for perioperative anaesthesia management, unsurpassed surgical access, and helped avoid serious complications (patient #8) and time restraints (patients #3, 11, and 12 Table 1). The technique has become an important part of our armamentarium for managing these patients.

Declaration of interests

The authors declare that they have no conflicts of interest and no funding was received.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.bja.2023.07.010.

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