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Case Report

Tracheal Stent Buckling and In-stent Stenosis: A Proposed Airway Management Algorithm for Airway Obstruction for Patients With Tracheal Stents

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EMERGENCY AIRWAY management strategies for patients with complications due to tracheobronchial stents are of growing interest to anesthesiologists. Although tracheal stenting increasingly is used to manage tracheobronchial stenosis of both benign and malignant conditions,[1-3] official guidelines for the perioperative airway management of patients with tracheobronchial stents in situ are lacking.[3] Here, the authors discuss the management of airway obstruction from a tracheal stent strut protrusion and in-stent stenosis in a patient with a self-expanding nitinol tracheal stent in situ. They discuss the airway management strategy employed and outline a pragmatic airway management algorithm for patients with tracheal stents presenting with airway obstruction.

Key Words: tracheobronchial stents; airway obstruction; bronchoscopy; crisis management; thoracic; surgery

Case Presentation

A 57-year-old male patient with morbid obesity (body mass index = 42.6 kg/m^2, weight = 126 kg, height = 172 cm) presented to a regional hospital with acute airway obstruction and respiratory failure. The patient had a history of tracheal stenosis and tracheomalacia following a tracheostomy and prolonged intubation 18 years prior for an unrelated critical illness. At that time, a SILMET (Novatech, La Ciotat, France) self-expanding nitinol stent (diameter 18 mm, length 60 mm) was implanted for definitive airway management. Over the subsequent 8 years, because of recurrent in-stent stenosis from granulation tissue overgrowth, the patient had required multiple tracheal dilations and laser treatments to maintain tracheal patency. In 2015, an uncovered metal stent (Boston Scientific Ultraflex, diameter 16 mm, length 40 mm) was placed within the first stent to overcome midstent stricture. In total, the patient had undergone 58 bronchoscopic procedures over an 18-year period to maintain tracheal patency.

The patient's respiratory comorbidities included obstructive sleep apnea requiring nocturnal continuous positive airway pressure, bronchiectasis causing mild chronic obstructive pulmonary disease (FEV$_1$: 72%), and chronic pulmonary thromboembolic disease, with a prophylactic inferior vena cava filter in situ.

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Cardiac risk factors included heart failure with a reduced ejection fraction of 46%, stable coronary artery disease, hemorrhagic cerebrovascular accident with residual left-sided hemiparesis, atrial fibrillation, mixed aortic valve disease, hypertension, and hypercholesterolemia. The patient was a current smoker and reported regular high alcohol consumption.

The patient presented to the general practitioner with a 7-day history of worsening dyspnea and a productive cough. He was treated with oral antibiotics for community-acquired pneumonia; however, 4 hours later, after progressively worsening dyspnea, he then presented to the emergency department of a regional hospital with acute severe type-2 (hypercapnic) respiratory failure. A venous blood gas analysis on high-flow oxygen therapy revealed a $PaCO_2$ of 125 mmHg and a PaO_2 65 mmHg (with a pH of 7.04). The patient was diaphoretic and had inspiratory stridor with prominent accessory muscle use and increased work of breathing. He was hypotensive (blood pressure 80/40 mmHg), tachycardic (heart rate 124 beats/minute), tachypneic (respiratory rate 32 breaths/minute), and hypoxic (oxygen saturation of 80% on room air). He was afebrile. A 12-lead electrocardiogram did not reveal any ischemic changes or features of pulmonary embolism. While in the emergency department, the patient rapidly deteriorated, with an acute respiratory arrest that required urgent tracheal intubation. Transnasal humidified rapid-insufflation ventilatory exchange immediately was applied to prolong the apnea time available for intubation.

During resuscitation, a surgical airway via the “front-of-neck access” route was discussed as part of an airway management plan; however, this was considered technically difficult given the patient’s history of previous tracheostomy and an upper tracheal metal stent in situ. There was no extracorporeal membrane oxygenation (ECMO) support services at the regional hospital. Therefore, given the time-critical nature of the respiratory arrest and impending cardiovascular collapse, ketamine (40 mg intravenously [IV]) was administered, and an IV ketamine infusion was initiated at 2 mg/kg/h to maintain spontaneous breathing. Then, direct laryngoscopy was performed by an anesthesiologist using a standard laryngoscope blade (Macintosh, Size 4). This revealed a Grade 2a Cormack-Lehane classification view of the airway (partial view of the glottis). Neither a 7.0- mm nor 8.0- mm cuffed endotracheal tube (ETT) would advance below the laryngeal inlet due to a fixed resistance. An 8.0- mm ETT was positioned below the level of the laryngeal inlet, with the cuff inflated, and the patient was initiated on pressure- support ventilation mode (8 cmH_2O positive end-expiratory pressure and 20 cmH_2O pressure support) with the ETT in this position. Then, a fiberoptic bronchoscope was passed through the ETT, which revealed that the cause of the obstruction was a protruding strut of the tracheal stent. This displaced strut was occluding the airway and preventing the advancement of the 8.0- mm ETT (Fig 1). A pediatric tracheal tube introducer (bougie) was placed through the 8.0- mm ETT and advanced without resistance. The 8.0- mm ETT was exchanged over the bougie for a 6.0-mm cuffed ETT, with the distal end positioned 2 cm above the carina and confirmed using a pediatric bronchoscope. Rocuronium (100 mg) was administered for neuromuscular paralysis, and the ventilation mode changed to volume-control ventilation (tidal volume 550 mL, 8 cmH_2O positive end-expiratory pressure, 12 breaths/min, inspiratory:expiratory ratio of 1:3 to allow complete expiration). The ketamine infusion was continued, and blood pressure was supported with intermittent boluses of metaraminol. Arterial blood gases were significantly improved and revealed a $PaCO_2$ of 75 mmHg and a PaO_2 of 155 mmHg, with a pH of 7.22.

A computed tomography (CT) pulmonary angiogram revealed bilateral lower lobe consolidation and no evidence of pulmonary embolism. A CT scan of the airway and chest confirmed that the 6.0- mm ETT had traversed the stent and

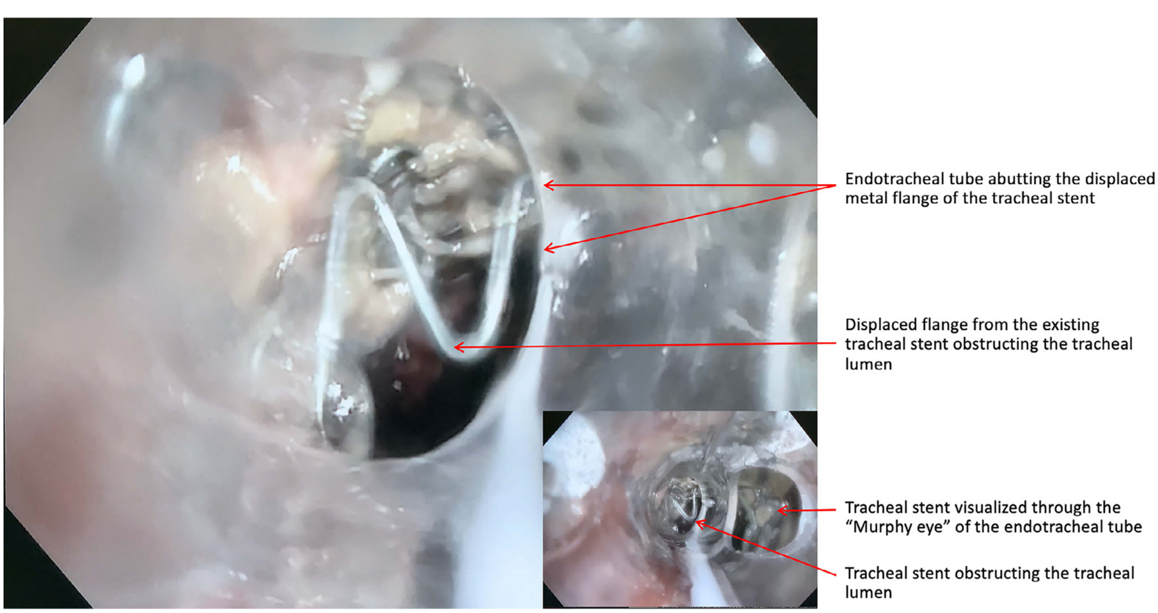

Fig 1. A flexible bronchoscope-directed view of the SILMET-covered self-expanding nitinol stent showing the displaced strut obstructing the trachea.

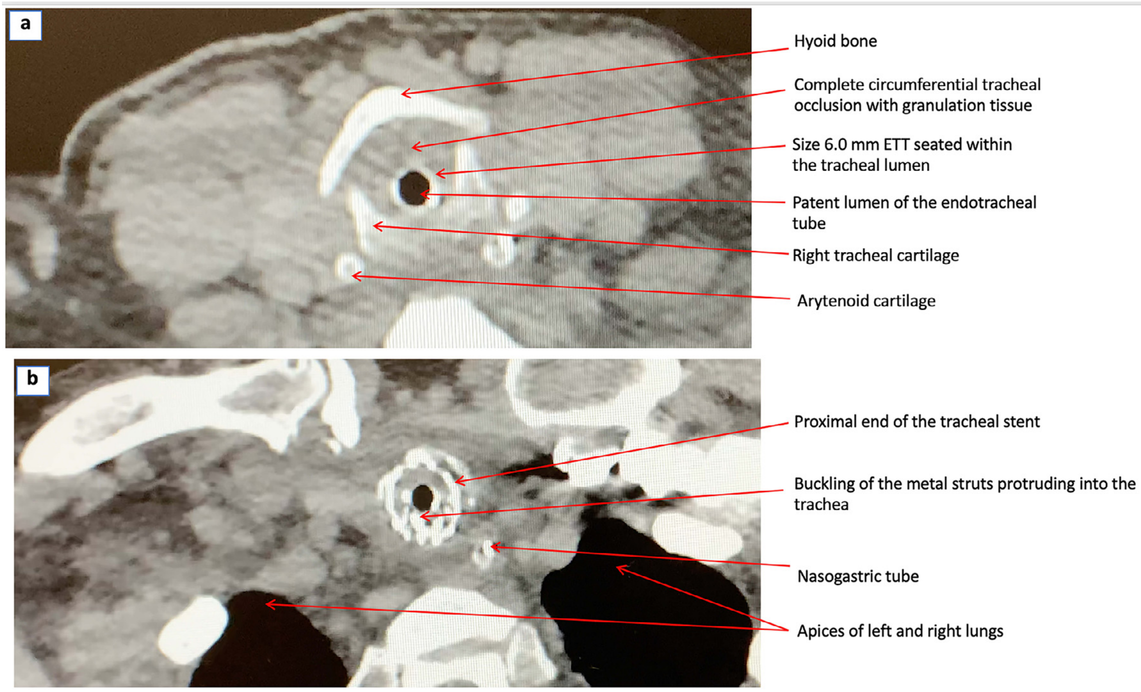

Fig 2. A computed tomography axial view of the neck demonstrating granulation tissue formation in the (A) trachea and (B) stent buckling with in-stent stenosis. ETT, endotracheal tube.

further confirmed severe in-stent stenosis, with obstructing metalware protruding into the airway (Fig 2; Video 1). The patient immediately was transferred to the authors' institution, which is a tertiary level university hospital specializing in complex thoracic surgeries, for further airway management.

The patient proceeded urgently to the operating room, with a cardiothoracic anesthesiologist and surgeon in attendance. With both venovenous and venoarterial ECMO support available, a fiberoptic bronchoscope was advanced through the ETT, which confirmed tube patency and revealed normal tracheobronchial anatomy distal to the stent without any obstruction. A pediatric tracheal tube introducer (bougie) then placed was through the 6.0- mm ETT, and the ETT was removed. A Storz 7.5- mm rigid bronchoscope (Karl Storz; Tuttlingen, Germany) was advanced over the bougie through the stenotic segment of the tracheal stent. The tracheal stent was dilated by changing the rigid bronchoscope from a 7.5- mm to 8.5- mm scope. The removal of the granulation tissue that had formed circumferentially around the proximal aspect of the stent was removed using a flexible electrocautery probe; this resulted in airway stent patency.

Upon completing the above procedure, a size 8.0- mm ETT was placed through the stent using a conventional airway exchange technique. Intravenous dexamethasone was administered, and the patient was nursed in a 45-degree position in the intensive care unit to minimize airway edema. A positive cuff-leak test was present on postoperative day 2, and the patient was extubated 24 hours later and subsequently discharged home on postoperative day 14. The patient remained asymptomatic at 6 weeks and 3 months postdischarge follow-ups. Written informed consent was obtained from the patient for publication of this case report and accompanying images.

Discussion

Airway stenting is used to manage tracheobronchial obstruction for which more definitive or less- invasive treatment is not appropriate or feasible.[1-4] Difficult tracheal intubation secondary to airway stent buckling and in-stent stenosis has not been described previously in a patient presenting with acute airway obstruction. A summary of the different types of tracheal stents that have been developed for clinical use, including technical factors (design, size, and material) and potential complications, is presented in Table 1.

As highlighted in this case, patients with a tracheal stent in situ who present with breathing difficulties are likely to have a complication related to the stent; however, alternative causes always should be considered.[3,5] The patient in this report presented initially with an obstructing airway, which deteriorated rapidly to complete airway obstruction. The likely cause of the airway obstruction was in-stent stenosis caused by an overgrowth of granulation tissue, which, in turn, was further complicated by the buckling or fracture of the stent, making passage of an ETT through the stent difficult. The authors here postulated that the cause of the stent buckling was due to granulation tissue hyperplasia causing a fibrotic stent stricture, which may, in turn, have overcome the radial force of the stent on the trachea, thereby increasing the stent's critical buckling pressure. Given that many stents become oval and eccentric in cross-section over time, granulation tissue overgrowth may have increased the critical buckling pressure of the stent, resulting in the elliptical lumen and outer wall deforming toward the circular shape with increasing lumen pressure. While the bucking of tracheal stents also may be the result of the stent being too long or oversized, the authors think this was a less likely mechanism in the present patient.

Table 1
An Overview of the Types, Properties, and Limitations of Tracheal Stents

	Silicone Stents	Covered and Uncovered Metal Stents	Hybrid Stents	Investigational Stents
Stent properties	• Most commonly used stent worldwide • Consists of smooth wall stents made in varying lengths and shapes, or cylindrical tygon plastic tube stents molded into a screw-thread shape	• Consists of self-expanding tubular meshes of crocheted filaments • Often compressed prior to employment, requiring special loading equipment or manipulation, such as suture removal to allow the expansion of the stent to its target size. • May consist of flanges that prevent migration; however, most metal stents do not have this feature as migration is less common when compared with silicone stents • Self-expanding tubular meshes of crocheted filaments (also known as self-expanding metal stents)	• Consist of expandable metal frame, which resists compression • Often covered by a silicone membrane that limits the ingrowth of tumor or granulation tissue	• Numerous investigations stents in developmentThese include: I Biodegradable stents that maintain their biomechanical strength for 6 weeks and dissolve completely after 3 to 4 months II Drug-eluting stents that prevent granulation tissue by inhibiting fibroblast growth III Bioengineered airway stents: custom-made IV Three-dimensional−-printed airway stents • Biodegradable stents are constructed from a knitted polymer fiber (eg, polydioxanone) that degrades when placed inside the airway, making bronchoscopic extraction unnecessary
Placement technique	• May require specially designed loading devices • Most require rigid bronchoscopy, but some can be placed using a flexible bronchoscope	• Flexible bronchoscopy, which requires only topical airway anesthesia and moderate sedation	• Most require rigid bronchoscopy, but flexible bronchoscopy with direct visualization or flexible bronchoscopy with wire-guided fluoroscopy can be used	• Flexible bronchoscopy with direct visualization or flexible bronchoscopy with wire-guided fluoroscopy or rigid bronchoscopy with direct visualization
Sizes available	Shapes include L, Y, and straight	• Larger internal to external diameter ratio compared to silicone stents	• Available in different shapes, lengths, and sizes • Consists of small loops at the proximal and/or distal ends to aid with removal and repositioning	• Purposely designed in different shapes, lengths, and sizes
Indications	• Disease at main and secondary carina • Often considered for nonmalignant stenotic lesions • Considered for benign tracheoesophageal fistulas when longer term use is indicated	• Malignant stenotic lesions • Covered metallic stents can be used if only short-term use is planned • Uncovered metal stents often considered in patients with nonmalignant stenosis after other options have been attempted • Covered self-expanding metal stents preferred for short-term palliation for malignant tracheal-esophageal fistulas • Self-expanding uncovered metallic stents indicated for bronchial necrosis and dehiscence following lung transplantation as these may promote neo-epithelization and help close the airway defect	• Preferred choice for nonmalignant stenotic lesions	• Biodegradable stents used for airway strictures secondary to lung transplant-related anastomotic complications, healing airway fistulas, and benign strictures

(continued)

Table 1 (*continued*)

	Silicone Stents	Covered and Uncovered Metal Stents	Hybrid Stents	Investigational Stents
Advantages	• Durable • Stent fracture is less common • Comparatively less expensive and well-tolerated • Firm in structure therefore resistant to extrinsic compression • May have small studs or flanges on external surface to prevent migration • Easily modified by cutting a portion of the stent, allowing customization to the airway anatomy prior to deployment	• Radio-opaque and easily visible on chest x-ray • Compared to silicone stents metallic stents have a better internal-to-external diameter ratio resulting in a larger airway lumen • Most resistant to extrinsic airway compression • Uncovered stents minimize obstruction across bronchial lobar orifices, therefore impacting less on muco-ciliary clearance • Excellent adherence properties—lower migration risk compared to silicone • Less likely to impair muco-ciliary clearance	• May have atraumatic extremities designed for placement in the bronchus and the carina • Given hybrid design, can be manufactured in several lengths and suitable for patients with significant trachea-bronchomalacia or long strictures involving the trachea and/or mainstem bronchi	• Biodegradable stents may be useful for airway conditions that need a temporary stent • Biodegradable stents can be used in pediatric patients with trachea-bronchomalacia
Disadvantages	• Increased risk of migration	• Increased risk of difficulty with removal due to epithelization or granulation tissue ingrowth • Higher risk of airway and vascular perforation due to higher expansile force • Less durable than silicone stents and more prone to stent fracture (at 500-1,000 days)	• Uncovered hybrid stents prone to epithelialization making extraction more difficult	• Biodegradable stents may result in stent fragmentation with airway obstructions toxicity from degradation products • Biodegradable stents at higher risk of premature failure
Granulation tissue growth risks	• Epithelization or granulation tissue ingrowth common at proximal and distal ends	• Highest risks of granulation tissue or tumor growth through the spaces between the uncovered metal struts • Uncovered metal stents at highest risk of stent obstruction	• Uncovered hybrid stents prone to epithelialization • Epithelization or granulation tissue ingrowth common at proximal and distal ends	• Epithelization or granulation tissue ingrowth common at proximal and distal ends
Mucus plugging	• Most prone to mucus plugging	• Less prone to mucus plugging	• Less prone to mucus plugging	• Less prone to mucus plugging
Migration risks	• Most prone to migration	• Less prone to migration • Self-expanding characteristics generate sufficient force to distend even the firmest of strictures, which is helpful if the airway cannot be dilated before stent insertion	• Less prone to migration	• Prone to migration
Stent fracture	• Least prone to stent fracture	• More prone to stent fracture compared to silicone stents	• More prone to stent fracture compared to silicone stents	• More prone to stent fracture compared to silicone stents
Expense	• Least expensive	• More expensive than silicone stents	• More expensive than silicone stents	• Most expensive

NOTE. Modified and adapted from Folch and Keyes[1] and Colt.[2]

The airway challenges in patients presenting with midtracheal obstruction and, specifically, with a tracheal stent in situ, are significantly different from those in patients with upper airway obstruction.[6] While direct laryngoscopy may demonstrate clear visualization of the laryngeal inlet and vocal cords,[7] the introduction of an ETT has the possibility of damaging or dislodging the stent, creating a false lumen, or perforating the trachea.[4,8-10] It is recommended that if ETT placement is required, it is guided with a flexible or rigid bronchoscope into the stent or above a distally placed stent.[4,8]

If immediate tracheal intubation is required, it has been recommended that a bougie gently be inserted, and then the ETT railroaded over it.[8] The tube and stent position then should be checked with a flexible bronchoscope.[8,10] A patent upper airway may be obtained with bag-mask ventilation or supraglottic airway placement, but ventilation may not be effective because of the severe tracheal obstruction.[10] Importantly, an emergency surgical airway may not be possible and could damage the stent. Moreover, an emergency surgical airway may not provide airway rescue, as the tube may not be able to be advanced beyond the obstruction.[6,8-10] The insertion of a rigid bronchoscope by a skilled operator can rescue the situation if complete obstruction occurs. The rigid bronchoscope also provides the necessary access to further evaluate and manage the stent complication.

There are 4 important questions to consider when a patient with a tracheal stent presents with tracheal obstruction. First, how urgent is airway management? Second, what was the indication for the stent? Third, what is the location of the stent in the airway? Finally, what is the cause of airway obstruction?[9] Patients can develop advanced airway obstruction with minimal symptoms; therefore, they must be monitored continually in a high-dependency area, as they rapidly can deteriorate. The clinical pathway will be guided by the symptoms and examination findings, such as dyspnea, stridor, and upright posture, and radiologic studies of the airway such as CT or magnetic resonance imaging, of the airway, if these studies safely and promptly can be performed.[9] It also is important to consider whether only the trachea is affected or whether there is associated vascular and cardiac compression.[7,9,10] It is not uncommon for such patients with severe airway obstruction to develop significant hemodynamic instability as a consequence of hypercarbia and hypoxia, which can be compounded by the cardiosuppressant effects of anesthesia medications.

Patients with airway obstruction and a tracheal stent in situ can be broadly categorized into 3 groups: (1) those who require immediate airway management (ie, the *obstructed* airway); (2) those who require urgent airway management (ie, the *obstructing* airway); and (3) those who have very minor symptoms, who can be investigated thoroughly before intervention (ie, the *elective emergency* airway).

The *obstructed* airway group should be managed with a Vortex Approach[11,12] (see Supplementary Figure 1) by the clinicians immediately available, but with a modified intubation approach and potentially without the possibility of surgical airway rescue, especially if a metal tracheal stent is in situ. In the *obstructing* airway group, airway management is directed at securing the airway before complete obstruction occurs.[11,13] If it is safe to do so, one of the primary goals of management is to use temporary measures to maintain airway patency while these patients are transferred rapidly to the operating room. Temporizing measures,[14-17] which are detailed in Table 2, will enable the team and location to be prepared for a patient with an obstructing airway.

The management of airway obstruction in a patient with a tracheal stent in situ is a shared airway emergency,[4,6] and teamwork is vitally important. In addition to an expert anesthesia team, a fully prepared surgeon and operating room team, who can immediately perform rigid bronchoscopy, are crucial.[7,13] There is increasing recognition of the value of a team able to establish patients on ECMO.[18] High-volume centers that perform ECMO on a regular basis may not face the logistic and pragmatic challenges that can be germane to low-volume ECMO centers. As evident by this case, the importance of referring such patients to a well-equipped center, with an experienced team to efficiently institute ECMO, if required, is imperative. The timely initiation of urgent ECMO in the event of catastrophic collapse of oxygenation and ventilation is critical. Hospitals that provide ECMO support for life-threatening airway situations should have a "Code ECMO" action plan, highlighting the pragmatic, logistic, and ergonomic tasks required for effective ECMO initiation, in addition to the operational and technical considerations. Consideration for the immediate availability of all ECMO personnel and equipment is essential. Likewise, radiologic support with the use of image intensification for screening should be available immediately and planned for, particularly if line placement is expected to be difficult. For example, in obese patients, radiology may be required, as the transthoracic echocardiography window for the bicaval view often is not achievable to guide the positioning of the ECMO cannula in the right atrium. For obese patients, the placement of guidewires before airway manipulation is ideal, and the ECMO proceduralist or surgeon should be prepared, in the scrubbed position, with image intensification positioned in such a way that it promptly can be used. In essence, the use of emergency ECMO for the management of the obstructive airway should be protocolled beforehand.

Table 2
Temporary Measures in the Management of an Obstructing Airway

Patient positioning: sit the patient upright
Positive reassurance: provide reassurance to reduce anxiety overlay, possibly help reduce work of breathing
Oxygen therapy: use high-flow humidified nasal oxygen to optimize oxygenation, reduce patient distress, and work of breathing[15]
Nebulized adrenaline: use 1 to 4 mg for bronchospasm reduction[16]
Bag and mask circuit: connect with positive pressure or continuous positive airway pressure
Intravenous steroids: for example, dexamethasone (8 mg)[17]
Helium-oxygen mixture (helium 60%-80%): use helium to reduce work of breathing by reducing obstruction-related turbulent flow; this requires a lowered F_IO_2[18]

An airway strategy with a series of plans needs to be developed, agreed upon, and fully prepared to enable team members to prompt timely progression. In the *obstructing* airway and *elective emergency* airway groups, the initial anesthesia plan should be directed at the safe insertion of the rigid bronchoscope or ETT distal to the obstruction to enable management of the problem.

The authors here advocate for a four-option checklist in which the following options can be sequentially considered. In turn, these should inform the anesthesia approach chosen to reach this endpoint (options 3 or 4 would be chosen on almost all occasions). The following are options for anesthesia:

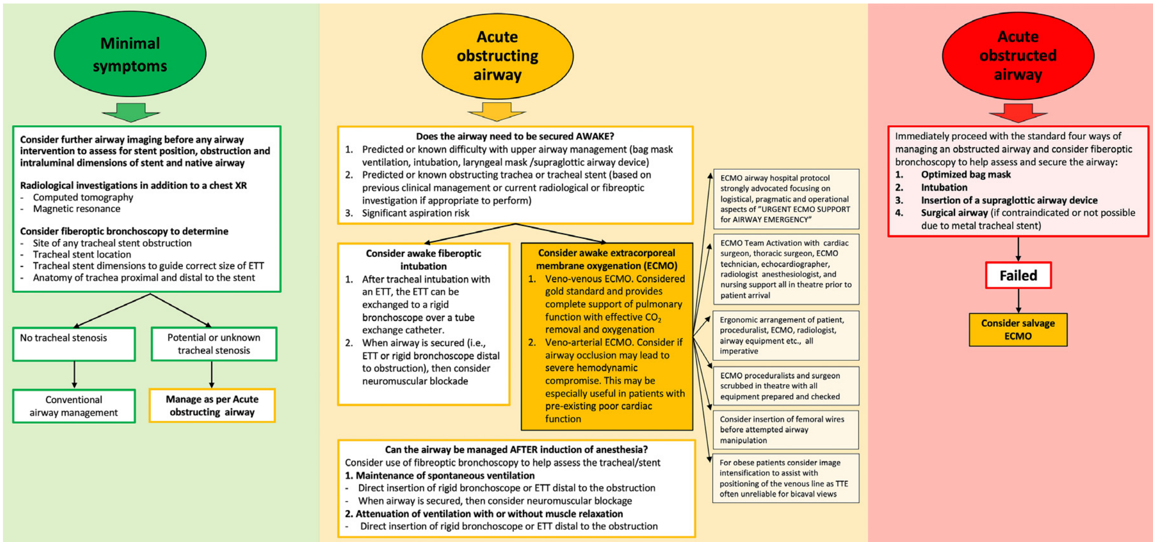

Fig 3. The proposed airway management algorithm of airway obstruction for a patient with a tracheal stent. ECMO, extracorporeal membrane oxygenation; ETT: Endotracheal tube; TTE, transthoracic echocardiogram; XR, x-ray.

1. ECMO under local anesthesia. If the obstruction is severe, this option always should be considered, as it successfully has been used.[18-21] Outcomes are poor when ECMO is used as a rescue for failed airway management.[20]
2. Fiberoptic intubation under local anesthesia before anesthesia is induced and the tube exchanged for a rigid bronchoscope over a tube exchange catheter. There is significant concern that this exchange might not reliably be completed.
3. Spontaneous-ventilation general anesthesia using total intravenous general anesthesia or volatile agent anesthesia, with the commencement of muscle relaxation only when there is appropriate surgical and anesthesia confidence (eg, able to pass the rigid bronchoscope beyond the obstruction).
4. Intravenous anesthesia with muscle relaxation.[6,9]

While numerous guidelines for the management of the difficult airway have been published by numerous anesthesia societies and groups,[22-24] there are few guidelines that provide a structured approach to the management of patients with tracheal stents in situ. Accordingly, the authors outline a suggested airway management algorithm for patients who present with tracheal stents (Fig 3). In summary, the authors here described the effective management of a rare case of tracheal stent obstruction from a displaced tracheal stent strut. They presented an overview of the preoperative planning strategies considered for patients with tracheal stents in situ. Moreover, they recommended using bronchoscopy or advanced radiologic imaging techniques (CT or magnetic resonance imaging) to assess airway and stent patency for all patients with tracheobronchial stents in situ, especially when controlled advancement of an ETT through the stent is indicated.

Conflict of Interest

The authors declare they have no competing interests.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1053/j.jvca.2022.01.028.

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