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Management of Refractory Tracheal Collapse in a Dog using Self-Expanding Intraluminal Prosthesis

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Abstract: Tracheal collapse is commonly seen in small breed dogs and is caused by a progressive weakening of the tracheal rings. A 5 year-old male Yorkshire terrier (weighing 1.97 kg) was presented Veterinary Teaching Hospital at Kangwon National University (S. Korea) with goose honking cough and cyanosis. On the radiographical and endoscopical examination, trachea was collapsed from the mid of cervical trachea to the mid of thoracic trachea. A self-expanding intraluminal stent (Zilver® 635 biliary stents, COOK, USA) was implanted to restore collapsed trachea. After implantation, the dog was medicated with cough suppressant (methylephedrine, 2 mg kg^{-1} BID), prednisolone (0.5 mg kg^{-1} BID) and cefazoline (5 mg kg^{-1} BID) for 2 weeks, to reduce side effects from metallic stenting. Clinical improvement was noticed right after implantation. Although mild transient dry cough lasted for a month, the dog was clinically recovered from tracheal collapse.

Key words: Dog, tracheal collapse, biliary stent, intraluminal stenting, honking

INTRODUCTION

Trachea is often collapsed if the C shaped cartilage flattens due to weak cartilage. The collapsed trachea causes increased secretion and inflammation, promoting more coughing and worsening collapse (Johnson and McKiernan, 1995; Johnson, 2000). The trachea may be collapsed along its entire length, only in the intrathoracic section, or only in the extrathoracic section. However, the junction of extra thoracic and intrathoracic trachea covering thoracic inlet is the most commonly affected. Tracheal collapse is most commonly found in toy breed dogs including Poodles, Yorkshire terriers and Pomeranians but is rarely found in large breed dogs (Johnson, 2000). Although it can occur at any age, it usually becomes problematic in middle age. Despite suspect of genetic aetiology, no study has found inheritance pattern and gene defect, to date. Obesity, upper respiratory infection (i.e., kennel cough), respiratory irritants in the air (i.e., cigarette smoke, dust) and cardiomegaly are predisposing factors for tracheal collapse (Johnson and McKiernan, 1995).

Narro wed trachea on thoracic radiography and goose honking cough on physical examination are characteristic in tracheal collapse. Differential diagnosis should be made from upper respiratory stridors and other causes of coughing (Johnson and McKiernan, 1995; Johnson, 2000).

Medical management with weight loss program is often successful for mild to moderate case of tracheal collapse. Cough suppressants (e.g., hydrocodone, torbutrol), corticosteroids (e.g., prednisone) and antibiotics are mostly used to alleviate clinical signs. Bronchodilators such as theophylline or terbutaline are controversial as they may dilate lower airways but not the actual trachea. One retrospective study found that 71% (71/100) responded to medical management with weight loss (Buback *et al*., 1996).

Several surgical corrections including plication of the dorsal tracheal membrane, tracheal ring chondrotomy and intra-and extra-luminal stabilization using polypropylene were applied to restore the collapsed trachea (Ayres and Holmberg, 1999; Rubin *et al*., 1973; Fingland *et al*., 1987, 1989). However, only extraluminal prophylene stabilization gave a favourable outcome. Despite favourable outcome of extraluminal stabilization, this method needs open surgery and can induce several complications including persistent coughing, iatrogenic laryngeal paralysis, dyspnoea. Success rate of this method is varied from 75 to 85% (Johnson, 2000).

Various types of self-expanding intraluminal prosthesis are recently introduced to stabilize collapsed trachea (Rauber *et al*., 1992, 1997; Rousseau *et al*., 1993; Mittleman *et al*., 2004). Those prostheses are originally designed either to maintain tracheal lumen from tumors suppressing trachea or to expand collapsed arteries in human. Advantages over surgical stabilization are non-invasiveness, no necessity of intensive care after implantation and short application time (5 to 10 min

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depending on practitioner's skill). However, the expensive cost of stent (more than $1,000 per each stent) will be problematic for populating these devices in veterinary practice.

MATERIALS AND METHODS

Case history and clinical signs: A 5-year-old, intact male Yorkshire terrier, weighing 1.97 kg, was referred from local practitioner, because of persistent coughing and dyspnoea. At presentation, the dog was cyanotic, especially after excitement. Goose honking sound was heard when the dog coughs. The dog was fed a homemade diet which consisted of chicken, mince and rice, as well as, commercial dry food (Science diet®).

Diagnostic workup: A blood sample (2 mL) was collected from the jugular vein and immediately placed into EDTA blood bottles for haematology (1 mL) and lithium heparin for biochemistry (1 mL). Haematology was measured using an automated cell count (Hemavet 8000, USA). Blood biochemistry was done on a Spotchem (EZ sp-4430, Arkray, Inc. Japan). Blood gas was analysed by I-Stat (Heska, USA). Thoracic radiographs were taken at left lateral and dorsoventral projection at the inspiration and expiration using a standard radiographic equipment (Toshiba, Japan). Echocardiography was performed using a ultrasound machine (SONOACE 8800, Medison, Korea). Electrocardiography was performed using digital 3-lead digital cardiography (PH1, CU medical systems, Korea) and 12-lead electroncardiography (Schiller, Switzerland). Tracheoscopy was performed using electronic scope (EB-1570K video bronchoscope, Pentax, Japan).

RESULTS

Haematology and blood chemistry: The dog was polycythemic (9.2×10^{12} μL^{-1}; reference range $5.5\text{-}8.2\times10^{12}$ μL^{-1}) and hypoxic (SpO^2: 88%) in heamatology and blood gas analysis. No other abnormalities were observed in haematology and chemistry.

Thoracic radiography and endoscopy: On the thoracic radiographs, the trachea was collapsed especially in the thoracic inlet. The collapsed was graded into 4 and 5 depending on the region of trachea (Fig. 1). On endoscopic exam, no elongation of soft palate and no abnormalities in larynx were observed (Fig. 2).

Implantation of intraluminal stent: The dog was heavily sedated with propofol (5 mg kg^{-1}), atropine (0.02 mg kg^{-1}) and diazepam (0.2 mg kg^{-1}, IV). The dog was intubated with 4.5 Fr intratracheal tube. Using lateral and dorsoventral view of thoracic radiographs with radiographic ruler, the length and diameter of trachea

Fig. 1: Lateral projection of thoracic radiography. The trachea was collapsed especially in the thoracic inlet

Fig. 2: Endoscopic examination of pharynx and larynx. Pharynx and larynx were perfectly normal. No elongation of soft plate was observed

Fig. 3: The self-expanding intraluminal stent (Zilver (R) 635 biliary stents, COOK USA) implanted in this case

was measured. A 10 mm (diameter)×80 mm (length) self-expanding intraluminal stent (Zilver® 635 biliary stents, COOK, USA) was selected based on the method described in elsewhere (Moritz *et al*., 2004) (Fig. 3). The following calculation was used to determine the size of stent: ([Mean tracheal diameter in lateral view + mean tracheal diameter in dorsoventral view]×2)/3.14. The stent was inserted into the intratracheal tube and then released at the 1 cm away from the end of larynx and carina on the fluoroscopy (Fig 4). The trachea was successfully restored and maintained its lumen contour (Fig. 5 and 6).

Follow-up: After implantation, the dog showed mild dry coughing, but not goose honking coughing. The cyanosis was no longer existed even in excitement. However the dry coughing persisted for a month, although the intensity and frequency of coughing

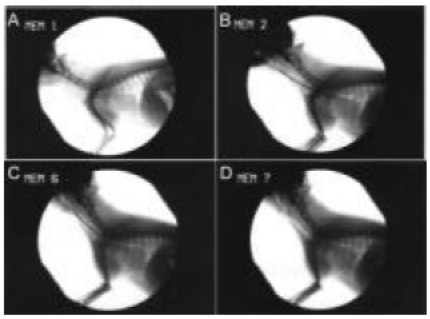

Fig. 4: Deployment of stent with a fluoroscopic guide. A: Insertion of endotracheal tube, B: Insertion of stenting device inside of endotracheal tube, C: Deployment of stent, D: After deployment of stent

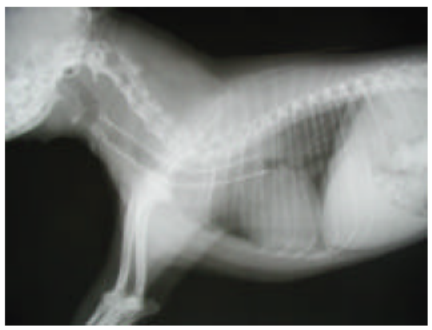

Fig. 5: Lateral projection of thoracic radiography taken after self-expanding intraluminal stent implantation. The stent was placed in about 1 cm away from the larynx and carina

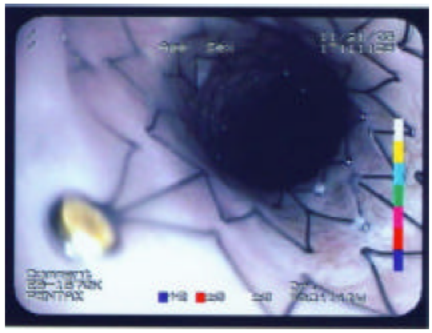

Fig. 6: Tracheoscopy taken right after self-expanding intraluminal stent implantation. The stent restored lumen patency of trachea

were greatly reduced with time. Cough suppressant (methylephedrine, 2 mg kg^{-1} BID), prednisolone (0.5 mg kg^{-1} BID) and cefazoline (5 mg kg^{-1} BID) were administered for 2 weeks, to minimize side effect from metallic stent implantation. The polycythemia and hypoxia was no longer existed after 1 week of implantation (RBC: 7.2×10^{12} μL^{-1}, SpO^2: 98%). On the clinical examination at the 4 weeks after implantation, the dog was clinically normal and did not show any clinical signs related to tracheal collapse. However the proximal end of stent was shortened and narrowed while the distal end was not deformed. Tracheoscopy was performed at the 3 month after implantation, the stent except the proximal end appeared to be buried in tracheal stroma. Mild tissue proliferation was observed at the end of stent, although no collapse of fracture of the stent was observed. The dog is still clinically normal and respiratory signs were not observed.

DISCUSSION

Tracheal collapse is a structural, obstructive airway disease with a dynamic component that can affect the intra-and extrathoracic trachea and mainstem bronchi (Gellasch *et al*., 2002). Using the criteria of Tangner and Hobson (Tangner and Hobson, 1982) a configuration of the tracheal rings and dorsal membrane inducing a reduction of the tracheal lumen by 25% was regarded as grade 1 tracheal collapse (Moritz *et al*., 2004). A 50% reduction was regarded as grade 2, a 75% reduction as grade 3 and a complete reduction (100%) as grade 4 tracheal collapse, respectively (Moritz *et al*., 2004). In this case, the tracheal collapse was graded into grade 3 to grade 4 depending on the region of collapse. The collapse was severer in the thoracic inlet.

Many surgical techniques have been described for tracheal collapse, including tracheal ring chondrotomy, plication of the dorsal tracheal membrane, tracheal resection and anastomosis and placement of extraluminal devices (Ayres and Holmberg, 1999; Rubin *et al*., 1973; Fingland *et al*., 1987, 1989). However, the procedure of extraluminal stabilization is difficult and invasive (Moritz *et al*., 2004). This method was more time-consuming than intraluminal stenting (median surgical time was reported to be 105 min; range, 60-220 min) (Tangner and Hobson, 1982). Furthermore, surgical placement of extraluminal stents is considered to be unrewarding in patients with a collapse of the thoracic portion of the trachea (Tangner and Hobson, 1982; White and Williams, 1994). Therefore surgical reconstruction of the thoracic tracheal segments is not usually recommended owing to risk of high mortality (Herrtage and White, 2000). Iatrogenic laryngeal paralysis is a common complication associated with surgical extraluminal stabilization of the trachea. In addition, extraluminal prosthetic devices comprising rings or spirals has been associated with complications such as infection, disruption of the innervation or blood supply to the trachea causing necrosis of the trachea, loosening or failure of the implant and chronic coughing (Ayres and Holmberg, 1999; Rubin *et al*., 1973; Fingland *et al*., 1987, 1989). Furthermore, application of extraluminal devices is restricted to the extrathoracic trachea and limited portions of the intrathoracic trachea (Ayres and Holmberg, 1999; Rubin *et al*., 1973; Fingland *et al*., 1987, 1989).

Unlike extraluminal prosthesis, intraluminal stents can feasibly be used to treat regions of collapse throughout the length of the trachea and mainstem bronchi (Gellash *et al*., 2002). The implantation of stents is atraumatic, comparatively quick and technically easy to perform (Moritz *et al*., 2004). With experience, the implantation of the stent could be performed within 5-15 min (Buback *et al*., 1996). Intraluminal stabilization of the trachea could be performed along the entire length of the trachea (Buback *et al*., 1996; Fingland *et al*., 1987). Stabilization of the trachea with intraluminal endoprostheses (stents) is also of increasing importance in management of human patients with obstructive tracheal disorders due to neoplasia (Rauber *et al*., 1997). In contrast with surgical procedures, intensive care is not required after stent implantation (Moritz *et al*., 2004).

However, implantation of certain intraluminal tracheal stents can be associated with complications and therefore may best be regarded as a salvage procedure for dogs with end-stage disease that are refractory to appropriate medical management, have extensive collapse of the intrathoracic portion of the trachea, or are poor candidates for surgery (Mittlman *et al*., 2004). The reported problems associated with intraluminal stenting are the substantial cost of stent, shortening of stent, transient coughing, laryngeal spasm and perforation of tracheal mucosa. Most critical problem associated with intraluminal stenting is a laryngeal spasm (Moritz *et al*., 2004). However, it can be prevented if the stent is placed longer than 1 cm away from the larynx. Transient dry cough can be managed by short-term medication of cough suppressant. In our case, we initially placed the stent 1 cm away from the larynx. At the day of implantation, the dog showed moderate dry coughing and more severely coughed when excited. The dog was depressed and less energetic at the day of implantation. The clinical improvement was obvious after the second day of implantation, although the dry cough lasted almost for a week with medication of cough suppressant. The frequency and severity of cough were dramatically lessened day by day. Cough suppressant (methylephedrine) was administered for 2 weeks. After 2 weeks, cough was managed without medication. However, owner reported the mild transient cough lasted for almost a month.

A shortening of the intraluminal prosthesis with a simultaneous increase in the diameter of the stent is commonly noticed in self-expanding intraluminal prosthesis (Moritz *et al*., 2004). Also the 2nd collapse in the region of the proximal and distal end of stent located is another problem of stenting (Gellasch *et al*., 2002). Therefore when the stent is selected for implantation, the length of stent should be 2 to 3 cm longer or is better to cover the entire trachea. As reported previously (Gellasch *et al*., 2002; Radlinsky *et al*., 1997) the shortening especially proximal end of stent was also observed in our case. However, it was not affect the clinical improvement, because the stent was placed in the almost entire trachea.

Another severe adverse of stents is migration of the implant due to choice of too small stent (Rauber *et al*., 1997; Radlinsky *et al*., 1997). In dogs with tracheal collapse, a redundant dorsal membrane may allow excessive distention of the trachea upon deployment of the stent and prevent the stent from obtaining adequate purchase to the tracheal mucosa (Gellasch *et al*., 2002). Therefore, it may be prudent to select a stent that is 1.25 to 1.5 times the diameter of the trachea as estimated from a lateral thoracic radiograph or via Computed Tomography (CT) (Gellasch *et al*., 2002). However, it is possible that excessive distention of the trachea by placement of an excessively large stent may cause pressure necrosis, leading to erosion of the trachea, pneumomediastinum and pneumothorax (Gellasch *et al*., 2002). In our case, the calculated diameter and length of trachea were 9.5 mm and 100 mm, respectively.

Therefore we selected 10.0 mm (0.5 mm wider) diameter and 80 mm length (2 cm shorter). However, the stent was progressively shortened and widened (but narrowed at the proximal end of stent). When we measured the diameter and length of stent after 2 month implantation, the maximum diameter was 10.5 mm and the length was 70 mm. However it was not affect the clinical condition of the dog.

The adverse effect of stent implantation is the formation of steroid-responsive granulomas (Moritz *et al*., 2004). Granulomas can be occurred especially at the ends of the stent. However, it is not caused by toxic effects of the metal but by the mechanical effects (Moritz *et al*., 2004). In our case, to minimize adverse foreign body reaction in the trachea, we administered prednisolone 3 days prior to implantation. The prednisolone was administered for another 14 days after implantation.

An ideal stent should be easily applicable, be available in different sizes, maintain its position without migration, be firm enough to resist compressive forces and be made of inert material and allow mobilization of respiratory secretions (Gellasch *et al*., 2002).

Several intraluminal stents have been used for tracheal collapse in dogs. Gianturco-Z stents are self-expanding stents that gradually adapt to the tracheal shape by simultaneous shortening and an increase of their diameter during expansion (Moritz *et al*., 2004). However, they tend to develop fatigue fractures in human patients Saito *et al*., 2004) and thus are not recommended for long-term stabilization of the trachea (Rauber *et al*., 1992, 1997).

Self-expanding Wallstents (nickel-titanium alloys) are elastic stents that gradually adapt to the tracheal lumen after deployment (Rauber *et al*., 1992). Although the implantation of Wallstents is limited in humans because only diameters up to 22 mm are available (Rauber *et al*., 1992, 1997) it is not problematic in dogs, since the tracheal collapse is commonly observed in toy to small dog breeds. The drawback of this stent is a progressive shortening with concurrent increase in the diameter and irremovable after placement. Palmaz-Schatz stent is a rigid type stent. Therefore, shortening of the stent will not be problematic in this type of stent (Rauber *et al*., 1992, 1997) However it is not commonly recommended in canine tracheal collapse, because of high rate of complications, including development of pneumothorax, infection, mucous plugs resulting in tracheal obstruction, stent migration and compression of the upper stent ends (Rauber *et al*., 1992, 1997; Radlinsky *et al*., 1997).

Thermal shape memory NiTi alloys have good compatibility, but stent implantation is technically complex (Rauber *et al*., 1992). Recently, bioabsorbable airway stents (Poly-L-lactic acid stents) was developed and used experimentally in dogs. The stent preserves the airway and its function for intended period (depending on the time of degradation of particles) (Saito *et al*., 2004). However, it is not applicable in canine tracheal collapse, since the canine tracheal collapse is a permanent defect.

The stent used in this study is a self-expanding Wallstent. In our case, although the progressive shortening of stent was also observed as reported previously, the implantation was successful since the stent used was 0.5 mm larger in diameter than the estimated size of trachea and the stent was placed in 1 cm away from the larynx and carina.

Determining size of the diameter of the stent is the most important factor for success of implantation. In humans, Computed Topography (CT) and bronchoscopy are used to determine diameter and length of the tracheal lesion (Gellasch *et al*., 2002). However, in the dog, such an approach was problematic since there was grave concern regarding the ability of the dog to recover from anaesthesia required for CT or bronchoscopy (Gellasch *et al*., 2002). In addition, determination of appropriate stent diameter by bronchoscopy requires specialized bronchoscopes and computer programs to calculate relevant tracheal dimension. Therefore, in veterinary practice, stent size is usually estimated by radiographs obtained from inspiration and expiration (Gellasch *et al*., 2002). Measurements obtained from radiographic images may result in underestimation of the normal diameter of the collapsed trachea (Gellasch *et al*., 2002). Thus, an estimate of the diameter of the trachea should be made as accurately as possible; selection of a stent that has a diameter 3 to 5 mm larger than the estimated tracheal diameter to accommodate stretching of the dorsal tracheal membrane may be beneficial. Preoperative fluoroscopy is beneficial in determination of the extent of airway collapse (Gellasch *et al*., 2002).

CONCLUSION

In conclusion, the implantation of biliary stents was minimally invasive and provided stabilization of collapsed trachea. Although transient dry cough lasted for a month after implantation, the case was successfully managed.

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