Treatment of tracheal collapse with an intraluminal stent in a Miniature Horse

Laurent L. Couëtil, DVM, DACVIM; Laurie L. Gallatin, DVM; William Blevins, DVM, DACVR; Imad Khadra, MD

A 7-month-old Miniature Horse weighing 50 kg (110 lb) was referred because of respiratory distress that had become progressively worse during the previous 4 days. The owner had purchased the horse 1 month earlier, and the horse had been flown from Oregon to Indiana. The horse’s vaccination status was adequate, and an anthelmintic (ivermectin, PO) had been administered 3 weeks before the horse was purchased. The horse was fed a commercial concentrate and alfalfa hay cubes twice daily and was housed in a stall with access to a paddock during the day. One week before referral, clinical signs of increased respiratory difficulty were detected, particularly when the horse was in situations determined to be stressful. Treatment with trimethoprim and sulfamethoxazole (20 mg/kg [9.1 mg/lb], PO, q 12 h) was administered for 5 days.

On physical examination, the horse was in good body condition (body condition score 6/9) and had a quiet demeanor. The owner reported some coughing, which had been noticed for the first time that morning. Rectal temperature was within reference range; however, pulse rate (64 beats/min; reference range, 26 to 50 beats/min), obtained via the facial artery, and respiratory rate (28 breaths/min; reference range, 8 to 15 breaths/min) were mildly increased. Mild bilateral mucoid nasal discharge was observed. Intermittent nostril flaring was observed during inspiration, as were moderately increased abdominal expiratory efforts. Results of auscultation of the respiratory tract indicated increased intensity of breath sounds and wheezing, which were louder over the distal portion of the cervical trachea and dorsal third of the thorax. Excitement of the horse resulted in inspiratory stridor followed by abrupt interruption of all breath sounds during inspiration. This was most noticeable during auscultation of the trachea. Breath sounds and wheezes were heard after each episode; however, the horse never collapsed to the ground. The abnormal respiratory pattern suggested a dynamic extrathoracic airway obstruction with possible pulmonary disease; therefore, cervical and thoracic radiographs were obtained. Radiography revealed narrowing of the trachea at the level of the thoracic inlet. In addition, an area of increased opacity and a lobar sign were superimposed over the cardiac silhouette, which were consistent with pneumatic changes. No evidence of a peritracheal mass was observed. The trachea was collapsed over a 7-cm-long segment with a minimal lumen diameter of approximately 1 to 2 mm centered at the thoracic inlet (Figure 1). Results of CBC and serum biochemical analyses indicated mild neutrophilia and mild hyperglycemia and hyperglobulinemia, respectively.

Intraluminal implantation of a self-expanding metallic (nitinol) stent was chosen as a treatment because the location of tracheal collapse made implantation of an extraluminal prosthesis difficult, and the lack of evidence of an external structure compressing the trachea negated the need for surgical exploration. Tracheal diameter was estimated by use of a magnification factor calculated from a radiographic skin marker as follows: ratio (absolute skin marker length/skin marker length as measured on radiograph) = (absolute tracheal diameter/tracheal diameter as measured on radiograph). The diameter of the tracheal lumen was estimated to measure 12 mm proximally to the collapsed area and 17 mm distally. The diameter of the stent (18 mm) was chosen to be approximately 4 mm greater than the collapsed area when fully dilated. Ideally, stent length should extend at least 10 mm beyond the proximal and distal limits of the collapsed area. An 80-mm-long stent was chosen because it was the longest available. Before the stent was placed, the

Figure 1—Lateral radiographic view of the cervical portion of the vertebral column and cranial portion of the thorax of a 7-month-old Miniature Horse with respiratory distress. Notice tracheal collapse at the thoracic inlet. A 5-cm-long radiographic skin marker is visible ventral to the cervical portion of the trachea.
horse was treated with potassium penicillin (22,000 U/kg [10,000 U/lb], IV, q 6 h), gentamicin (6.6 mg/kg [3.0 mg/lb], IV, q 24 h), and flunixin meglumine (1.1 mg/kg [0.5 mg/lb], IV, q 12 h) for 5 days beginning on the day of admission and then switched to trimethoprim-sulfamethoxazole (30 mg/kg [13.6 mg/lb], PO, q 12 h) for 2 weeks.

Implantation of the stent was performed during general anesthesia 11 days after the horse was admitted to the referral hospital. The horse was premedicated with xylazine (25 mg, IV) and butorphanol (1 mg, IV), and anesthesia was induced with ketamine (125 mg, IV) and diazepam (5 mg, IV). Subsequently, anesthesia was maintained by constant rate infusion (2 mL/min) of a solution containing 10% guaifenesin (150 mL), ketamine (150 mg), and xylazine (25 mg). The horse was intubated orally with an 11-mm tracheal tube and ventilated manually with 100% oxygen. Endoscopy and fluoroscopy confirmed the location and extent of tracheal collapse. Positive pressure ventilation, with peak airway opening pressure of 40 cm H2O, was required to oppose the added resistance caused by tracheal narrowing. Fluoroscopy of the trachea during manual ventilation did not detect tracheal expansion even at the highest airway pressure used (60 cm H2O). A guide wire was first introduced through the endotracheal tube beyond the collapsed area. Then, a noncovered nitinol stent prefolded over an introducing catheter by a crochet-knotting technique was advanced over the guide wire. Proper placement in the trachea was verified by fluoroscopy. The folded stent was released by pulling on the thread while maintaining the insertion catheter steady. The catheter was pulled slowly during fluoroscopy to insure that the device would not be dislodged. Stent placement resulted in immediate dilation of the trachea to approximately 50% of normal diameter. Concomitantly, peak airway opening pressure during manual ventilation decreased to < 5 cm H2O. Endoscopy was performed to inspect stent placement.

The horse recovered from anesthesia without complications and coughed out a large amount of mucopurulent material after standing. Breath sounds were normal on auscultation of the thorax. The horse whinnied repeatedly for the first time according to the owner. Radiography performed 3 days after stent implantation revealed that the stent had migrated distally (Figure 2). The horse was sedated with xylazine (25 mg, IV), and the stent was repositioned by pulling it proximally with biopsy forceps during endoscopy while the horse was standing (Figure 3). A week later, the horse was clinically normal and radiography confirmed that the stent had not moved and was dilated to approximately 90% of its normal diameter. Endoscopy revealed no evidence of tracheal inflammation; however, there was a moderate amount of mucus in the ventral aspect of the trachea at the level of the stent, suggesting decreased mucus clearance. Recommendations made to the owner included housing the horse in a low-dust environment, feeding pelleted diet on the ground to facilitate clearance of mucus, and slowly resuming normal physical activity.

The horse was reevaluated 6 months after stent implantation. The owner had not noticed coughing or exercise intolerance. Results of physical examination were unremarkable except for a mild mucoid nasal discharge from the left nostril. The horse weighed 69 kg (151.8 lb). Radiography revealed that the stent was in the correct position, and the tracheal diameter was maintained throughout the length of the trachea. Endoscopy revealed small nodules protruding through the stent mesh (Figure 4). No further treatment was recommended.

Ten months after placement of the stent, the horse was admitted because of lethargy and increased respiratory efforts that had been noticed since the horse had returned from training 1 week earlier. Rectal temperature was within reference range; however, pulse (60 beats/min) and respiratory (30 breaths/min) rates were
mildly increased. Results of auscultation indicated increased intensity of tracheal sounds and breath sounds bilaterally over the dorsal lung fields. Endoscopy of the respiratory tract revealed increased proliferation of nodular tissue through the stent with a moderate amount of mucopurulent material, resulting in substantial narrowing of the trachea, compared with physical examination findings obtained 6 months after stent placement. Results of CBC indicated a mild neutropenia; the fibrinogen concentration was within reference limits. Cytologic examination of fluid from a tracheal wash performed during endoscopy indicated septic neutrophilic inflammation; fluid was also submitted for bacteriologic culture of tracheal wash fluid, all of which were susceptible to trimethoprim-sulfamethoxazole (30 mg/kg, PO, q 12 h for 2 weeks), and the horse was discharged on the third day of hospitalization because of respiratory improvement. Streptococcus zooepidemicus, Actinobacillus suis, and an alpha-hemolytic Streptococcus spp were identified on bacteriologic culture of tracheal wash fluid, all of which were susceptible to trimethoprim-sulfamethoxazole. Four weeks after discharge, the owner reported that the horse appeared healthy and had no signs of exercise intolerance.

Eleven months after placement of the stent, the horse was clinically healthy and no coughing was detected during exercise. Radiography of the cervical region and thorax revealed that the stent was in place and fully dilated. The horse was sedated with xylazine (40 mg, IV). Endoscopy, performed with the horse standing, revealed continued proliferation of granulation tissue, particularly through the ventral aspect of the stent. Electrocautery was applied to the granulation tissue by use of an electrocautery loop snare after 20 mL of dilute lidocaine solution (2.5 mL of 2% lidocaine in 17.5 mL of saline [0.9% NaCl] solution) was applied topically. The electrosurgery unit was used on blend mode with the power set at 30 W. Energy application for each particular lesion was maintained for 1 to 3 seconds maximum. Best results were seen when the probe gently touched the lesion and not when pressure was applied to the tissue. Several of the polypoid lesions attached to the wall of the trachea by a stalk were removed by slowly closing the snare around the stalk as the electrocautery unit was activated to permit simultaneous cutting and coagulation. Minimal bleeding was observed, and the horse tolerated the procedure well. The horse was reevaluated 2 weeks later, and electrocautery was repeated with the same settings. After electrocautery, a minimal amount of granulation tissue remained (Figure 5). Results of endoscopic examination 6 weeks later indicated mild proliferation of the granulation tissue, which was again treated with electrocautery.

Decreased size of the tracheal lumen may be secondary to tracheal stenosis or collapse. Tracheal stenosis may result from a primary defect of the tracheal wall or be secondary to compression by external structures. Traumatic injury to the cervical region and thickening of the tracheal wall by infection can result in primary tracheal stenosis. Narrowing of the lumen may be secondary to compression by peritracheal abcesses, tumors, and hematoma. Tracheal collapse is not frequently reported in horses and can result from congenital or degenerative abnormalities of the cartilage rings or be secondary to pulmonary infection. Tracheal collapse has been reported in horses, ponies, Miniature Horses, donkeys, and mules. Dorsoventral narrowing of the tracheal lumen is usually observed with protrusion of the dorsal wall ventrally. Chondrodysplasia with fibrous joint formation at the most lateral aspect of the tracheal rings has been described in a 2-month-old Miniature Horse. Histologically, the affected rings were similar to lesions described in small-breed dogs that are commonly affected by this condition. In dogs, weakening of the cartilage is associated with hypopcellularity, decreased chondroitin sulfate and glycosaminoglycan content, and transformation of normal hyaline cartilage into fibrocartilage. The most notable difference between dogs and Miniature Horses with tracheal collapse is that dogs develop clinical signs when they are middle-aged to older, whereas the Miniature Horses in the previous report and of this report were young animals. However, anecdotally, tracheal collapse also develops in middle-aged Miniature Horses. Congenital tracheal collapse attributable to primary collagen disorder such as chondrodysplasia is also described in human infants. Tracheal cartilage of affected segments appears thinner and smaller with an increased width of the membranous trachea leading to the typical anteroposterior compression. In the Miniature Horse of this report, chondrodysplasia was suspected on the basis of history and clinical findings; however, samples of cartilage were not obtained for histologic examination.

Clinical manifestation of tracheal collapse depends on the location and severity of airway narrowing. Because...
A diagnosis of tracheal collapse can often be made on the basis of clinical signs. However, endoscopy and radiography are useful for confirmation of the diagnosis and evaluation of the extent and severity of the collapse. Radiography of the thorax should also be performed to rule out pulmonary disease. Fluoroscopy may be useful for assessing whether the tracheal collapse results in a significant increase in airway pressure. In the horse of this report, a large increase in airway pressure did not increase airway diameter; however, the flexible endoscope could be easily passed through the narrowed tracheal lumen. Therefore, a tracheal obstruction that can be dilated by the gentle passage of an endoscope may be a good indication for the appropriateness of intraluminal stenting.

The goals of treatment for tracheal collapse are to increase airway size sufficiently to restore normal respiration and treat underlying problems. Medical treatment consisting of appropriate antimicrobial and anti-inflammatory drugs is indicated in animals with lower respiratory tract infection and extratracheal abscess formation. Administration of a cough suppressant (eg, butorphanol) may help control clinical signs in horses with mild airway obstruction. Several surgical treatment options have been described, including tracheal resection and anastomosis, implantation of external tracheal prostheses, and tracheostomy. These techniques are limited to the cervical portion of the trachea or the most proximal portion of the thoracic trachea. In humans, various types of intratracheal stents are being used increasingly because the procedure is noninvasive, is better tolerated by patients, and has a low rate of complications. In addition, intraluminal stents may be placed anywhere along the tracheobronchial tree. Principal indications in humans include tumors obstructing major airways, postsurgical strictures, tracheobronchial stenosis, and tracheobronchomalacia in pediatric patients. Airway stents are metallic (stainless steel) or composed of silicone, with the newest types being self-expandable metallic stents (stainless steel or nitinol) that are inserted with bronchoscopic guidance. Nitinol stents are made of a nickel-titanium alloy with flexibility comparable to tracheal cartilage and thermal shape-memory properties (Marmen effect). The stent continues to self-expand as it heats up after placement in the airway, permitting precise placement with bronchoscopic forceps. Conversely, cooling of the device results in the collapse of the stent, which facilitates its extraction. The major advantage of this type of device, compared with surgical techniques, is the immediate improvement in quality of life for most human patients.

Intraluminal stents have been used in dogs; however, early attempts using stainless steel stents were not successful. Experimental implantation of stents in healthy dogs led to an unacceptable rate of complications, such as stent migration and collapse, acute pulmonary edema, and isolation of bacteria from tracheal washes. Successful treatment of tracheal collapse in dogs by use of nitinol and stainless steel stents has been reported.

In the horse of this report, the largest diameter commercially available nitinol stent was used. Therefore, the diameter of the collapsed airway is a major limitation to the application of this technique in large animals. Placement of the stent was easy and rapid (30 minutes from induction of anesthesia to the end of the procedure) and provided immediate relief of respiratory obstruction. Complications encountered with stent placement were migration of the device, proliferation of tracheal mucosa through the mesh, decreased mucus clearance, and pneumonia. Stent migration is a common complication in humans and dogs and was observed within 3 days of implantation in this miniature horse. The stent was repositioned properly during endoscopy while the horse was monitored properly during endoscopy while the horse was monitored.
standing and subsequently did not migrate during a 1-year follow-up period. Proper sizing of the device appears to be essential; positioning of a radiopaque skin marker adjacent to the trachea helps correct for radiographic magnification. It is recommended that a device approximately 10% larger than the normal airway size in humans and 25% to 50% larger in dogs be used. This large difference may be due to the redundant dorsal membrane of dogs with tracheal collapse, which permits excessive dis- tension of the trachea as the stent expands. In the horse of this report, a nitinol stent 20% larger than the estimated tracheal diameter was used. This middle-range choice was a compromise between concerns of oversizing or undersizing the device. Undersizing would increase the chances of device migration. Oversizing may cause pressure necrosis but would permit further stent expansion as the horse grows to adult size. Also, the length of the stent should be 2 to 3 cm longer than the length of the collapsed trachea. Further work is needed to determine appropriate guidelines for stent sizing in horses.

In the horse of this report, proliferation of granulation tissue into the stent was first observed 6 months after implantation. Ten months after implantation, the horse had increased respiratory efforts probably resulting from a combination of lower respiratory tract infection and tracheal obstruction from exuberant granulation tissue. Medical treatment with antimicrobials resulted in rapid improvement of breathing. The decision to resect the granulation tissue was made 1 month later because of concerns that continued proliferation may result in tracheal obstruction and recurrence of respiratory difficulty. This problem is commonly reported in humans, particularly with metallic stents. In humans, metallic stents become incorporated and epithelialized in approximately 6 weeks and then are believed to provide a more physiologic mucus clearance than silicone stents. The degree of local inflammation varies depending on the type of stent used and the nature of the coating material. In humans implanted for months to years with various types of airway stents, chronic inflammation leads to formation of granulation tissue in 7.5% of cases. Use of coated (polytetrafluoroethylene) or covered stents (silicone, polypropylene, or expanded polytetrafluoroethylene) appears to reduce the rate of growth and increase ease of removal. However, these types of stents also tend to reduce mucus clearance rate. In general, coated and covered stents are recommended in humans treated for airway neoplasia or granulation tissue obstructing the airway lumen and uncovered stents are advocated for airway collapse secondary to tracheobronchomalacia. In humans, several techniques have been used to resect tissue obstructing airways including electrocautery, neodymium:yttrium-aluminum-garnet laser treatment, cryotherapy, brachytherapy, and photodynamic therapy. In this horse, endotracheal electrocautery was chosen for several reasons. The shape and size of the granulation tissue were amenable to electrocautery with a loop snare instrument. The technique appears to be effective and safe in humans and is considered a less expensive and successful alternative to laser photoresection. Settings on the electrocautery unit and time of application were based on reports in humans and trials performed in fresh bovine trachea obtained postmortem.

The degree of tissue necrosis obtained by electrocautery depends on the voltage used, the contact surface area, the duration of energy application, and the presence of blood or secretions. For example, application of a monopolar electrocautery probe to normal human airway mucosa for a duration of 1 to 5 seconds and a power setting of 30 W results in a depth of necrosis ranging between 0.2 ± 0.1 mm and 1.9 ± 0.8 mm, respectively. The extent of mucosal damage visible during electrocautery compares well with results of histologic examination. However, care must be taken not to push too hard on the probe when it is directed perpendicularly to the airway wall and between cartilage rings. More profound tissue damage can be obtained with laser (eg, neodymium:yttrium-aluminum-garnet or diode) treatment; hence, there is a perceived higher risk of airway perforation, compared with electrocautery or argon-plasma laser. In the horse of this report, 3 sessions of electrocautery during a 2-month period controlled proliferation of granulation tissue. Future treatment sessions may be required, and endoscopic examination was recommended to the owner every 6 months or when abnormal respiratory noise or efforts were observed. Results of a study in humans involving 38 patients with 68 different lesions treated with electrocautery indicated that 3 patients required 2 sessions, 1 patient required 3 sessions, and another patient required 4 sessions to prevent tissue regrowth. Other potential complications with endotracheal electrocautery are pneumothorax and endotracheal fire. Also, circumferential treatment of lesions should be avoided to decrease the risk of tracheal stenosis.

Pneumonia may develop secondary to stent placement, presumably because of decreased mucociliary clearance and local inflammation. Pneumonia was detected 10 months after stent placement in the horse of this report. To enhance mucociliary clearance, it was suggested to the owner to feed the horse on the ground as a way to encourage lowering of the horse's head. Presumably, mucociliary clearance will improve as the stent becomes more epithelialized.

Treatment of tracheal collapse with placement of an intraluminal stent appears to be a practical alternative to surgical techniques in miniature and young equids and ponies. The procedure was minimally invasive and provided immediate relief of respiratory obstruction. Implantation of the device and follow-up examinations were performed with a flexible endoscope permitting monitoring, diagnosis, and treatment of potential complications. Future use of intraluminal stents in large animals should help refine indications for the procedure and provide guidelines for choosing appropriate devices.
References

Observer variation in visual assessment of forelimb horseshoe characteristics on Thoroughbred racehorses
Diane K. Gross et al

Objective—To assess the accuracy and reliability of a visual method of evaluating horseshoe characteristics.

Animals—1,199 Thoroughbred racehorses.

Procedure—Characteristics of 1 forelimb horseshoe were visually assessed on horses immediately prior to racing by 5 field observers at 5 major racetracks in California. Characteristics evaluated included horseshoe type; toe grab height; and the presence of a rim, pad, and heel traction devices. Sensitivity and specificity for observer assessment of horseshoe characteristics were calculated by comparing observer assessments to a postmortem laboratory standard for horses that died within 48 hours of a race. Intraobserver agreement was assessed in a subset of horses by comparing horseshoe observations made before and after the horse’s race. Interobserver agreement was evaluated by comparing horseshoe assessment among observers who examined the same subset of horses prior to racing on select days.

Results—The sensitivity and specificity of this visual method of evaluating horseshoe characteristics were good and ranged from 0.75 to 1 and 0.67 to 1, respectively. Agreement beyond chance (weighted kappa values) between observers and the laboratory standard for toe grab height was fair (0.60 to 0.62). Intraobserver and interobserver agreements (kappa values) were high (0.86 to 0.99 and 0.71 to 1, respectively).