Surgical treatment of tracheal collapse using pliable total ring prostheses: Results in one experimental and 4 clinical cases

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Abstract — Pliable total ring prostheses were created from the polyvinyl chloride drip chambers of intravenous administration sets. The total ring prostheses were placed in one clinically normal research dog and in 4 client-owned dogs diagnosed with tracheal collapse. The research dog was euthanized one month after placement of the prostheses. Histopathological analysis of the trachea adjacent to the prostheses revealed a mild inflammatory response. The follow-up period for the clinical cases was from 4 months to 11 years. Radiographs taken and fluoroscopy performed 1 day to 5 months after surgery revealed improvement or resolution of the tracheal collapse. One dog was asymptomatic 28 weeks following surgery. Two dogs died 7 and 9 years after surgery, with one requiring intermittent medical management for coughing. They were euthanized for nonrespiratory illness. One dog had a persistent nonproductive cough, due to collapse of the mainstem bronchi, when last evaluated 4 months postoperatively. Pliable total ring prostheses provided adequate stability to the trachea and had the advantage of conforming to the trachea and being easy to create, place, and suture.

Résumé — Traitement chirurgical du collapsus trachéal par utilisation de prothèses totales composées d'anneaux flexibles. Des prothèses totales composées d'anneaux flexibles ont été fabriquées à partir de chambres de débit en chlorure de polyvinyl de dispositifs d'administration intraveineuse. Les prothèses totales d'anneaux ont été mises en place chez un chien de recherche normal et chez 4 chiens de clients chez lesquels on avait diagnostiqué un collapsus trachéal. Le chien de recherche a été euthanasié un mois après l'implantation de la prothèse. Des analyses histopathologiques de la trachée adjacente à la prothèse ont révélées une réponse inflammatoire peu importante. La période de suivi pour les cas cliniques s'est échelonnée de 4 mois à 11 ans. À la radiographie et à la fluoroscopie réalisées du jour 1 jusqu'au 5e mois après la chirurgie on a constaté une amélioration ou une résolution du collapsus trachéal. Un chien était asymptomatique 28 semaines après la chirurgie. Des deux chiens morts 7 et 9 ans après la chirurgie, l'un d'eux nécessitait un traitement médical intermittent contre la toux. Ils ont été euthanasiés pour des maladies non-respiratoires. Un chien présentait une toux non-productive persistante suite à un affaissement des bronches principales lors de son dernier examen 4 mois après l'opération. Les prothèses totales d'anneaux flexibles ont fourni une stabilité adéquate à la trachée et ont eu l'avantage de prendre la forme de la trachée et d'être facile à fabriquer, placer et suturer.

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Introduction

Multiple surgical techniques have been described in the veterinary literature for the treatment of tracheal collapse. These include tracheal ring chondrotomy, plication of the dorsal tracheal membrane, tracheal resection and anastomosis, and intra- and extraluminal tracheal prostheses (1–5). The majority of these techniques have not been successful, due to inadequate support of the tracheal cartilages or dorsal tracheal membrane and interference with normal mucociliary flow (3). At present, extraluminal prostheses, that is, total ring (TRP) and spiral ring (SRP) prostheses, have had the most repeatable long-term success (3). These prostheses, made from polypropylene syringe cases, are stiff, which can make placement awkward, and require predrilled holes (1).

The purpose of this study was to investigate the utility of polyvinyl chloride (PVC) TRPs made from the drip chambers of IV administration sets. It was proposed that the more pliable plastic of the PVC prosthesis would be easier to apply than the rigid plastic of the polypropylene prosthesis, would not require predrilled holes, and would conform better to the trachea while providing adequate stability. It was also proposed that the PVC material would be essentially inert and tolerated as an implant.

Materials and methods

Preparation of the total ring prosthesis

The TRPs were made from the drip chambers of IV administration sets (Baxter, Toronto, Ontario; Figure 1). The drip chambers were packed with rolled gauze squares to prevent their collapse and then steam sterilized. At the time of implantation, the cylinders were cut with scissors into 4–7 mm widths and then split to

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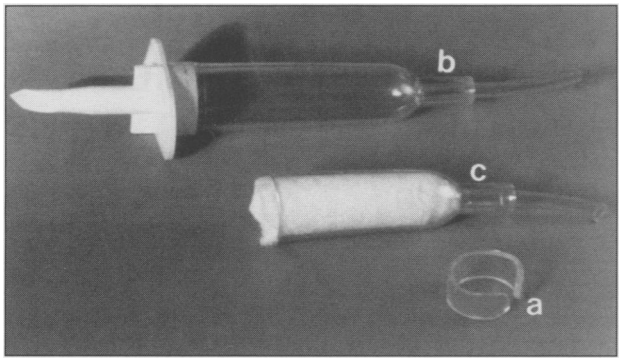

Figure 1. The total ring prosthesis (a) was manufactured from the drip chamber (b) of an IV administration set. A rolled gauze square was placed inside the drip chamber (c) to prevent collapse during steam sterilization.

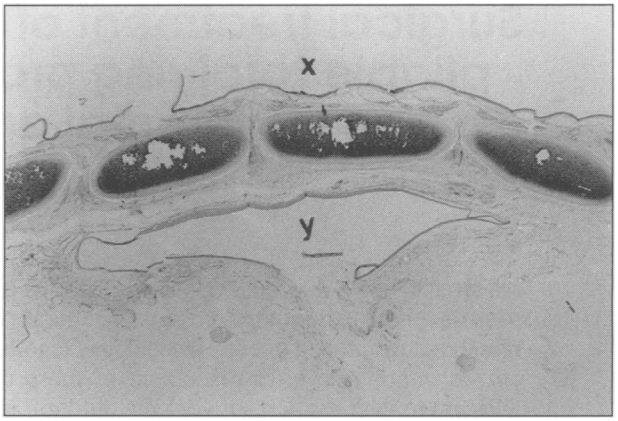

Figure 2. Histological appearance of the trachea in a clinically normal dog 1 mo following placement of the prosthesis. The tracheal lumen is denoted by x and the site of the prosthesis has been denoted by y. The prosthesis has been removed. There is minimal inflammatory reaction in the periprosthetic tissue.

make C-shaped rings. The edges of the prostheses were rounded. One drip chamber yielded 5 to 6 TRPs.

Surgical procedure utilized in all dogs

The surgical procedure was as described by Hobson (5). The dog was maintained with general anesthesia and placed in dorsal recumbency. A routine ventral midline cervical approach to the trachea was performed. For stent placement, minimal dissection was performed around the trachea at each site. Caution was exercised to ensure that the recurrent laryngeal nerves and tracheal vessels were minimally disturbed and that they were not trapped between the trachea and the prosthesis. Four to seven stents were applied with the open portion of the "C" on the ventral surface of the trachea. Gentle cranial traction was applied to the cervical trachea for placement of the more caudal TRPs. The distance between the stents was approximately equal to the diameter of the trachea. Each stent was affixed with 4 to 6 simple interrupted sutures of polypropylene (Prolene, Ethicon, Peterborough, Ontario) or polydioxanone (PDS II, Ethicon), with swaged reverse cutting and taperpoint needles, respectively. The sutures were placed through the dorsal tracheal membrane and the ventrolateral aspect of the trachea, bilaterally. The suture encircled the adjacent tracheal rings, penetrating the tracheal lumen. The needle passed easily through the wall of the prosthesis; therefore, predrilled holes were not necessary. The fascial and skin incisions were closed routinely and the dog was allowed to recover from anesthesia. Animals were monitored following surgery for evidence of dyspnea and pain. Oxygen and analgesics were administered as needed.

Pilot study

One 15 kg, mature male, mixed breed dog, scheduled for euthanasia from a project not associated with this study, was selected for the plot study. The dog had no history of respiratory problems. The dog was premedicated with butorphanol tartrate (0.2 mg/kg body weight (BW); Ayerst Laboratories, Montreal, Quebec) and acepromazine maleate (0.05 mg/kg BW) (Ayerst Laboratories) by IM injection. Anesthesia was induced with an IV injection of thiopental sodium (10 mg/kg BW) (Abbott Laboratories, Montreal, Quebec); the dog was then intubated and 100% oxygen was administered through a Bain circuit. Anesthesia was maintained with halothane (MTC Pharmaceuticals, Cambridge, Ontario). Four stents were placed on the cervical trachea with 4–0 polypropylene suture.

The surgical site was inspected daily and the respiratory pattern and frequency of coughing were recorded. One month following surgery, the dog was euthanized and a histopathological assessment of the trachea was made. The trachea and prostheses were harvested en bloc and placed in 10% neutral buffered formalin for 48 h. After removal of the TRP, 6-mm sections of the trachea were prepared and stained with hematoxylin and eosin.

Clinical cases

Ninety-eight dogs were referred to the Veterinary Teaching Hospital (VTH), University of Guelph, between January 1983 and December 1998 for evaluation of tracheal collapse. Surgical treatment was recommended for 7 dogs. Four had placement of the PVC, C-shaped TRPs and the records of these 4 dogs were evaluated for this study. The signalment, including breed, sex, and age, was recorded. Presenting complaint, previous medical management, clinical signs at presentation, diagnostic tests, surgical treatment and postoperative recovery, and time until discharge were noted. The response to surgery was assessed with medical record documentation of follow-up visits at the VTH and phone contact with the owner. The need for further medical management, the owner's assessment of the dog's quality of life, and the time until death or last owner contact were evaluated.

Results

Pilot study

The dog recovered from surgery without complication. There was minimal (2 to 3 times per day) coughing for 2 wk following surgery and the dog had a normal breathing pattern. The surgical site healed without incident. Histopathological analysis of the periprosthetic tissues revealed a 20- to 100-mm layer of collagen with a monolayer of inflammatory cells, primarily macrophages,

Table 1. Case histories of 4 dogs with tracheal collapse treated with surgical implantation of polyvinyl chloride total ring prostheses

Case	Breed	Age (y)	Sex	Weight (kg)	Surgical treatment
1	Yorkshire terrier	4	FS	3	5 stents placed with 4–0 polypropylene
2	Yorkshire terrier	7	M	5	4 stents placed with 4–0 polypropylene
3	Poodle mix	12	M	6.7	6 stents placed with 4–0 polypropylene
4	Yorkshire terrier	9	MC	5.5	7 stents placed with 4–0 polydioxanone

FS — neutered female, M — male, MC — neutered male

Table 2. Long term outcome for 4 dogs following surgical placement of polyvinyl chloride total ring prostheses

Case	Follow-up with owners
1	Pleased with outcome; cough recurred 2 y following surgery (less severe than prior to surgery); responsive to medical management; had normal exercise tolerance; euthanized 9 y following surgery for nonrespiratory illness.
2	Very pleased with outcome; had a normal quality of life and was very active; no recurrence of the cough and no medical management was required; euthanized 7.5 y following surgery for nonrespiratory illness.
3	Lost to follow-up — collapse of the mainstem bronchi documented 4 mo after surgery.
4	28 wk following surgery: Active, no coughing or collapsing episodes; no medical management required; permanent tracheostomy site healed open without complications.

adjacent to the implant (Figure 2). There was no evidence of sepsis.

Clinical cases

The case histories are summarized in Table 1. Dogs 1–3 presented with a history of a nonproductive 'honking' cough that was exacerbated by exercise and excitement. Dog 4 had a history of multiple episodes of severe upper airway obstruction, cyanosis, and vomiting. He was sedated with diazepam and referred to the VTH with an endotracheal tube in place. A diagnosis of laryngeal paralysis was made, and a castellated laryngofissure and temporary tracheostomy were performed. All dogs had had progression of their clinical signs despite medical management. Medical management included various combinations of corticosteroids, bronchodilators, antibiotics, diuretics, opiates, and oxygen supplementation.

Upon physical examination, a nonproductive cough could be elicited from dogs 1–3 following palpation of the cervical trachea. Cervical and thoracic radiographs and fluoroscopy were performed for all dogs and revealed collapse of the cervical (all dogs) and thoracic trachea (dogs 1 and 3). Four to 7 (mean 5) TRPs were placed (Table 1). Dogs 1, 3, and 4 had their thoracic trachea mobilized via a ventral cervical midline approach. In each of these dogs, 2 stents were placed on the thoracic trachea between the thoracic inlet and the 2nd intercostal space. Recovery from general anesthesia was uneventful for all 4 dogs. Dog 2 developed acute respiratory distress 24 h following surgery. A diagnosis of laryngeal hemiplegia with secondary upper airway obstruction was made. A castellated laryngofissure was performed and the dog recovered from general anesthesia without incident. Dog 4 required a permanent tracheostomy, 48 h following placement of the TRPs.

Following surgery, none of the dogs was dyspneic or cyanotic and dogs 1 and 2 were coughing less frequently. The dogs were discharged from hospital 2 to 8 d (mean 5.5 d) following placement of the TRPs. They were discharged with various combinations of corticosteroids, antibiotics, and antitussives. Treatment was continued for several weeks, until the coughing resolved. Clinically, all dogs were significantly improved following surgery. Fluoroscopic evaluation of the cervical and thoracic trachea was performed 1 d to 5 mo after surgery. The diameter of the tracheae of dogs 1, 3, and 4 was normal. Dog 2 had mild narrowing of the cervical trachea, but it was improved from prior to surgery. Dog 3 was evaluated a 2nd time 4 mo after surgery, due to the recurrence of a nonproductive cough. Fluoroscopy confirmed that the diameter of the cervical and thoracic trachea was normal; however, he had developed collapse of the mainstem bronchi. He was lost to further follow-up. The owners of dogs 1, 2, and 4 were contacted 28 wk to 11 y after surgery and the results are summarized in Table 2.

Discussion

Medical and surgical treatment of tracheal collapse has been described in the veterinary literature (1–9). In 22% to 35% of dogs, tracheal collapse is not responsive to medical management and surgical intervention is necessary (2,4,9). Of the dogs referred to the VTH for treatment of tracheal collapse during our 15-year study period, 7% (7/98) required surgical intervention. Historically, polypropylene TRPs and SRPs have been used.

Hobson (5) described the TRP made from polypropylene syringe cases. The prostheses were 5 mm wide and were placed 6–12 mm apart (5,9). Holes were predrilled in the prosthesis for suture placement. Polypropylene TRPs have been shown to support the cervical trachea and, via the cervical approach, they can be applied to the cranial thoracic trachea as far caudal as the 2nd or 3rd intercostal space (3,5,7). Alternatively, they can be applied to the thoracic trachea via a thoracotomy. Tracheoscopy, performed in 14 clinical dogs 6 mo following placement of TRPs, revealed maintenance of a normal tracheal diameter (7). Critics of the polypropylene TRP have cited that suturing through the predrilled holes can be difficult, particularly once the prosthesis has been placed (1). It has also been proposed that the rigid

conformation of the C-shaped ring prevents the prosthesis from conforming to the trachea. Due to the lack of uniform contact, there could be areas of focal pressure with secondary tracheal necrosis (1,10,11). As well, in larger patients, stretching or flattening of the prosthesis during placement could cause the ring to break (3). In smaller patients, the collapsed tracheal rings may not conform to the over-sized C-shaped prosthesis, causing tension to be applied to the suture (1). This could cause the suture to tear through the dorsal tracheal membrane with recurrence of the tracheal collapse. It has been hypothesized that tracheal flexibility would be reduced as the prosthesis spanned multiple annular ligaments (1). The clinical significance of this purported reduction in tracheal flexibility has not been objectively assessed and may be an academic issue.

An alternative to the TRP is the SRP. Its proponents describe it as being easier to place, leaving no segment of the trachea unsupported. It is also thought to have less impact on tracheal flexibility, as it does not span annular ligaments over their entire circumference and its spring-like properties provide inherent flexibility (1). One disadvantage is that a thoracotomy is required in order to place it caudal to the 1st intercostal space (6). Whereas, in our study, 2 dogs had collapse of the thoracic trachea and placement of the TRP as far caudal as the 2nd intercostal space via a ventral cervical midline approach provided adequate support of the thoracic trachea, thereby avoiding a thoracotomy. In another study, it was observed that support of the cranial thoracic trachea via a cervical approach prevented collapse of the caudal thoracic trachea, which continued to be patent when the dogs were reevaluated 6 mo following surgery (7). A second disadvantage with the SRP is that it requires more dissection of the tracheal vessels than does the TRP. When the technique for application of the SRP was initially described, the left and right lateral vascular pedicles were dissected completely from the trachea to allow placement. This was documented to potentially cause tracheal necrosis (12). The technique has subsequently been modified, with complete dissection of the left lateral pedicle and focal fenestration of the right (10).

Polyvinyl chloride is a more pliable plastic than polypropylene. The PVC TRP can be cut with scissors without the development of rough edges. Predrilled holes are not required with the PVC TRP. This reduces preoperative preparation time and allows placement of the suture where it best suits the trachea, not where the holes have been predrilled. It is easy to place the flexible prosthesis around the trachea and it can conform to tracheae of different sizes without risk of breaking, kinking or placing excessive tension on the sutures. Based on the results of this study, the pliable PVC TRP appears to provide adequate support to the trachea long term.

The pilot project, although only investigating the placement in 1 dog for a 1-month period, provided evidence that minimal tissue reaction can be anticipated with this PVC prosthesis. The reaction was similar to the response seen with nonabsorbable suture material, such as polypropylene, indicative of an essentially biologically inert implant. Polyvinyl chloride is typically used for long-term indwelling intravascular catheters (13–15). Other uses include indwelling urethral catheters, abomasal shunts, and T tubes for drainage of the common bile duct (16–18). In one study, T tubes made of PVC were compared with silicone, latex, and red rubber tubes (18). The tubes were placed in the common bile duct of 38 dogs for 15 to 98 d. At necropsy, the dogs with the PVC T tubes had the fewest peritoneal adhesions and the common bile duct had minimal histopathological changes. Polyvinyl chloride was the most inert material tested. In another study, a T-shaped PVC cannula was placed into the abomasum of 3 male buffalo calves for 6 mo (16). The cannula exited the ventral abdominal wall. A histological examination was not made; however, the authors indicated that the cannula was nonirritating and did not interfere with normal wound healing and fibrosis.

The outcome in our small number of clinical cases was similar to that documented in the literature following placement of the polypropylene TRP or SRP. With a follow-up period in the literature of up to 4 y following placement of TRP, 40% to 50% of the dogs were asymptomatic, with no medical management required. Twenty to 25% were improved requiring intermittent medical management, 2% were unchanged, and 1% was worse (2,4,5,7,9,11). Approximately 30% had died, with more than one-half of these due to nonrespiratory illness. Of the dogs with SRP, at 2 to 17 mo following surgery, 60% had excellent results, 20% had died, and 20% were improved and being managed intermittently with antitussives (6,19,20). In our study, dogs 1 and 2 had a normal quality of life and dog 4 was asymptomatic 28 wk following surgery. The poor outcome for dog 3 was due to collapse of the mainstem bronchi, not failure of the PVC TRP. The collapse of the mainstem bronchi was not documented preoperatively or 5 wk following surgery with either tracheoscopy or fluoroscopy. It is uncertain why involvement of the mainstem bronchi was not apparent earlier. It may have been due to progressive cartilage degeneration or extraluminal support of the cervical and thoracic trachea may have unmasked incompetent mainstem bronchi. CVJ

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