Tracheal Reconstruction With Polytetrafluoroethylene Graft in Dogs

David L. Cull, MD, Kevin P. Lally, MD, Eric A. Mair, MD, Mara Daidone, MD, and David S. Parsons, MD

Departments of General Surgery and Otolaryngology, Wilford Hall United States Air Force Medical Center, Lackland Air Force Base, Texas

Use of prosthetic materials for long-segment tracheal reconstruction has been limited owing to infection, graft migration, ingrowth of fibrous tissue, and stenosis. Polytetrafluoroethylene (PTFE) is flexible and porous, and it may resist infection more than previously used materials. We evaluated PTFE for use in long-segment tracheal reconstruction. A 5-cm segment of trachea was resected in 9 dogs and replaced with a 20-mm reinforced PTFE graft using 4-0 Vicryl sutures. In 2 control dogs, one tracheal arch was resected and a primary anastomosis was performed. The animals were followed up with weekly bronchoscopy and endoscopic photography. Euthanasia was performed at 16 weeks or when signs of respiratory distress developed. At postmortem examination, the anastomoses were examined grossly and with light and scanning electron microscopy. In all 9 dogs that underwent tracheal replacement with PTFE, granulation tissue developed at the anastomoses resulting in airway obstruction after 3 to 8 weeks. No epithelial growth occurred over the graft between the anastomoses. The control animals did well. We conclude that granulation tissue formation at the anastomosis and the lack of respiratory epithelial ingrowth across the graft makes PTFE unsuitable for long-segment tracheal reconstruction.

Material and Methods

Eleven mongrel dogs weighing 16 to 31 kg were used. All animals received humane care in compliance with the “Principles of Laboratory Animal Care” formulated by the National Society of Medical Research and the “Guide for the Care and Use of Laboratory Animals” prepared by the National Institutes of Health (NIH publication No. 85-23, revised 1985). The dogs were anesthetized with nitrous oxide, oxygen, and halothane. Electrocardiogram, blood pressure, and serial arterial blood gases were monitored throughout the procedure.

The intrathoracic trachea was exposed through a right thoracotomy and the trachea was mobilized. In 9 dogs, the trachea was transected 2 to 3 cm proximal to the carina, and the left main bronchus was intubated through the surgical field. A 5-cm segment of trachea (7 to 8 tracheal arches) was resected.

The trachea was reconstructed using a 20-mm reinforced PTFE graft. A proximal end-to-end anastomosis was performed using 4-0 Vicryl (Ethicon, Somerville, NJ) sutures, which were tied on the outside of the anastomosis. The anastomosis was created such that the tracheal edge was invaginated within the graft approximately 5 mm and was tension-free. The distal anastomosis was performed using the same technique. The graft was then covered with pleura. In the 2 control dogs, one tracheal arch was resected and a primary anastomosis was performed using the same technique as in the experimental group.

A thoracostomy tube was placed, connected to a Heimlich valve, and removed 48 hours postoperatively. The
animals were given cefoxitin, 15 mg/kg, intravenously at induction of anesthesia and every 8 hours for 3 weeks postoperatively and analgesics as needed.

The animals underwent weekly bronchoscopy with photographic documentation of the trachea. The animals were killed at 16 weeks postoperatively, or earlier if they showed signs of respiratory distress. At postmortem examination, the grafts were resected and examined grossly and with light and scanning electron microscopy.

**Results**

Bronchoscopic examination in the immediate postoperative period showed the anastomoses to be widely patent. In the experimental animals a smooth glistening layer developed that covered most of the graft after 1 week. In all dogs that underwent tracheal replacement with PTFE granulation tissue developed at both the proximal and distal anastomosis. This granulation tissue resulted in substantial airway obstruction between the third and eighth week, which required euthanization of the dogs (Fig 1). Most of the dogs had copious mucopurulent secretions and pneumonia developed in 5 dogs. None of the dogs had subcutaneous emphysema, air leak, or erosion of the graft into surrounding structures.

Gross examination of the prostheses at postmortem examination showed a dense fibrous reaction surrounding the graft. The grafts were lined with a smooth, glistening, gray amorphous layer. Light and electron microscopy showed this layer to be comprised of fibrin, inflammatory cells, and bacteria (Fig 2). There was no evidence of respiratory epithelial growth beyond the anastomosis.

No granulation or stenosis developed at the anastomosis in the control animals, and the anastomosis remained widely patent at 16 weeks. Electron microscopy near the anastomosis in the control animals showed normal respiratory epithelium (Fig 3).

**Comment**

Primary tracheal anastomosis may not be feasible in cases of extensive tracheal resection for tumors, trauma, tracheomalacia, or stenosis, or if extensive scarring from mediastinitis or irradiation prevents mobilization of the trachea. Numerous prosthetic materials have been used experimentally [9-11] and clinically [4, 12, 13] in an attempt to bridge long tracheal defects. Prosthetic tracheal substitution has been generally unsuccessful because the foreign material becomes infected and granulation tissue forms and obstructs the airway. Additionally, several prosthetic materials are quite rigid and can erode into blood vessels resulting in exsanguinating hemorrhage [2-4].

The ideal tracheal prosthesis should be flexible to prevent erosion into major blood vessels, allow for respiratory epithelial ingrowth, be resistant to bacterial invasion, and have minimal tissue reaction. Polytetrafluoroethylene is flexible, and surrounding rings of fluorinated ethylene propylene make the graft noncollapsible. As a vascular
prosthesis, the graft is resistant to infection and is associated with minimal tissue reaction.

The use of PTFE for tracheal replacement has been examined in three previous studies. Bottema and Wildenvuur [8] replaced 1-cm segments of trachea in rabbits with nonreinforced PTFE. Although graft infection was common and granulation tissue formed at the center of the graft, epithelial growth across the graft was observed after 2 to 4 weeks. This epithelial ingrowth was attributed to the anastomotic technique, which invaginated the tracheal mucosa within the graft.

Recently, Shaha and associates [6] replaced cervical tracheal segments of 7 to 8 arches with reinforced PTFE graft. They noted no mucosal lining of the graft and concluded incorporation of PTFE graft does not occur. However, unlike in the study of Bottema and Wildenvuur, the trachea was anastomosed outside the graft. Because no epithelial growth occurred with the trachea outside the graft, we believed that tracheal invagination would be important for epithelialization.

Trojan and co-workers [7] replaced 5-cm segments of trachea with reinforced PTFE graft using an anastomotic technique similar to ours. They reported long-term survival in several animals and epithelialization of the graft. As in our study, the graft was lined with bacteria and fibrin for the first 2 weeks; however, this was replaced with a continuous layer of flat epithelium between 2 and 4 weeks, and pseudorespiratory epithelium between the fifth and sixth week. An endoscopic photograph of the distal anastomosis at 4 weeks in the report by Trojan and co-workers shows a stenosis identical to that seen in our experimental animals. Because the anastomotic technique and early results between Trojan's study and our study are identical, it is unclear why they observed a cessation of the stenosis and epithelialization of the graft whereas we observed progression of the stenosis and no epithelialization.

Although steroids and cautery of granulation tissue at tracheal anastomoses have been used clinically to treat stenoses, we were interested in the normal healing response at the graft-tracheal interface and did not want to introduce additional variables that would alter this response. We therefore made no attempt to remove or treat the stenoses in our study.

In conclusion, a suture technique that invaginated the trachea within the graft resulted in the development of granulation tissue at the anastomosis and eventual airway obstruction. No epithelial lining developed within the graft. This study indicates PTFE is probably an unsuitable material for long-segment tracheal reconstruction.

References