Experiences with Prosthetic Airway Replacement

Jean Deslauriers, MD, FRCSC, CM[a,*],
Nicolas Aubrée, MD, FRCSC[b], Farid M. Shamji, MBBS, FRCSC[c,1]

KEYWORDS

• Airway surgery • Prosthetic tracheal replacement • Airway engineering

KEY POINTS

- The use of a prosthesis to reconstruct tracheal defects is seldom necessary because more than one-half the trachea can now be safely resected and the airway primarily reconstructed.
- The use of a tracheal prosthesis is associated with major and significant morbidities, as well as poor long-term outcomes.
- Two types of airway prostheses are currently available: a solid-type prosthesis with a smooth inner surface, and a porous type that are incorporated by adjacent mediastinal tissues.
- Tracheal transplantation and tissue engineering strategies using the recipient's own stem cells and biologic scaffolds derived from decellularized donor trachea remain experimental but show great promise.

INTRODUCTION

After tracheal resection, the airway can usually be reconstructed primarily with an end-to-end anastomosis. Available techniques such as lateral mobilization of the trachea, elevation of the carina through intrapericardial mobilization of both hilum, neck flexion, and laryngeal release are now allowing surgeons to resect more than one-half of the tracheal length and reconstruct the airway without having to resort to the use of an interposed prosthesis. On occasion, however, longer segments of trachea need to be removed and an end-to-end anastomosis cannot be performed. Under such circumstances, surgeons may be tempted to use an interposed graft or a prosthesis.

Over the past 50 years, a great variety of tracheal prosthetic tubes have been designed and tried in both experimental and clinical settings, but the results have generally been unsatisfactory. Much research has also been done to design the ideal prosthesis, but the issue is very complex and, to date, this research has not provided satisfactory answers. On the surface, the problem seems to be easy to solve because the trachea is often considered as a simple tube without much physiologic function. The reality is, however, much different; this tube is in permanent contact with contaminated secretions from both the oropharyngeal region and ambient air, so that it is constantly exposed to infection. This is the main reason why the use of tracheal prostheses over the past one-half century has generally been associated with significant morbidities and poor long-term results.

Disclosure: The authors have nothing to disclose.
[a] Laval University, Quebec City, Quebec, Canada; [b] Centre Hospitalier Régional de Lanaudière, 1,000 Boulevard Ste-Anne, St-Charles Boromée, Quebec J6E-6J2, Canada; [c] University of Ottawa, Ottawa, Ontario, Canada
[1] 1, Burdock Grove, Nepean, Ontario K2R1A1, Canada.
* Corresponding author. 6364 Chemin Royal, Saint-Laurent-de-L'île-d'Orléans, Quebec G0A3Z0, Canada.
E-mail address: jean.deslauriers@chg.ulaval.ca

Thorac Surg Clin 28 (2018) 377–384
https://doi.org/10.1016/j.thorsurg.2018.05.003

HISTORICAL HIGHLIGHTS IN THE EXPERIMENTAL DEVELOPMENT AND CLINICAL USE OF A TRACHEAL PROSTHESIS

The first tracheal resection with primary anastomosis was done in dogs by Gluck and Zeller in 1881 and then in humans in 1884 by Kuster.[1] From those early days until the mid-1960s, it was generally accepted that surgeons could remove no more than 2 or 3 tracheal rings and predictably be able to reconstruct the airway with primary anastomosis. In the late 1960s, however, this concept was being challenged and surgeons began to resect longer and longer segments of trachea. It is at around that time that surgeons began to look at the possibility of prosthetic replacement of the trachea.

In 1940, Taffel described an experimental technique by which he repaired tangential tracheal defects in dogs with autogenous fascia lata grafts.[2] According to the author, "these grafts did not appear to be viable but acted temporarily as an airtight scaffold quickly to be replaced by proliferating fibroblasts. These fibroblasts would, in turn, become differentiated into collagen-bearing adult connective tissue which remained as a permanent supportive structure spanning the defect."[2] Taffel also observed that regeneration of the respiratory mucosa was complete at the end of the second postoperative week.

In 1945, Ronald Belsey was the first to report on a case where he had done a circumferential tracheal resection with reconstruction using a tracheal prosthesis made of metallic rings covered by a strip of fascia lata for an adenoid cystic carcinoma.[3] His patient survived the operation but died 1 year later of recurrent disease.

Early Work

Realizing that tracheal tumors would require more extensive, potentially curative tracheal resection, different types of airway surgery in animal models were undertaken with circumferential resection, partial tailoring tracheal resection and reconstruction with an autologous pedicle patch supported by wire mesh, and various kinds of prostheses. Problems were frequently encountered with the replacement of a long length of trachea with a prosthesis.

In 1948, Daniel[4] used rigid tubes made of glass, stainless steel, or vitallium in an experimental animal model to bridge defects in the trachea and recorded incomplete epithelial regeneration, pneumonia, and prosthetic dehiscence.

Clagett and associates[5] from the Mayo Clinic (1948) used polyethylene tubes to perform quick anastomosis of the cervical and thoracic trachea in dogs. Failures were owing to anastomotic dehiscence with the prosthesis becoming loose and to tracheal collapse. When the technique was applied to humans for tumor resection of the mediastinal trachea, it failed.

Detailed experimental resection of the trachea was reported in 1950 by Ferguson and associates[6] from the University of Minnesota in a dog model. Measurements of the elasticity of the trachea, resectable length of the trachea, amount of tension at the anastomosis that did not affect healing, technique of anastomosis, and use of tracheal homografts, tracheal autografts, costal cartilage transplant, and aortic homotransplants were all studied. The conclusion of the authors was that the surgical problems involved in short length tracheal resections and anastomosis were relatively simple. However, the problems associated with tracheal reconstruction after extensive resections were much more significant and could not be solved. One of the problems associated with the use of prosthetic rigid tubes is that they would unexpectedly become loose and obstruct the airway. Attempts at reconstruction by means of tracheal homografts, tracheal autografts, free transplants of costal cartilages, aortic grafts, and tantalum gauze all proved unsuccessful.

In 1960, Michelson and colleagues[7] from The John Hopkins University School of Medicine performed experiments in tracheal reconstruction and concluded that there were essential differences in the reconstruction of partial and circumferential defects. Small window defects could be successfully repaired using semirigid prosthetic and autologous material such as fascia lata reinforced with wire. In circumferential segmental resection, however, the use of an externally applied rigid prosthesis was invariably unsuccessful, with the occurrence of stenosis at the anastomotic level with subsequent migration of the prosthesis. More success was recorded when the prosthesis was placed within the lumen, a technique that required proper length measurement to avoid kinking, angulation, compression, or erosion into major contiguous blood vessels and organs. The absence of reepithelialization by ciliated respiratory epithelium also prevented adequate clearance of tracheobronchial secretions.

Over subsequent years, 2 types of tracheal prostheses have been researched, the porous variety, which becomes incorporated by surrounding fibroblastic tissues, and the solid nonporous type, which becomes encapsulated and is thus not incorporated.