Operative Techniques in Thoracic and Cardiovascular Surgery

Congenital Tracheal Stenosis: Tracheal Autograft Technique

Carl Lewis Backer, MD,* Lauren D. Holinger, MD,† and Constantine Mavroudis, MD*

At Children's Memorial Hospital we developed and used the tracheal autograft technique for children with tracheal stenosis in a number of patients from 1996 to 2004.[1] Since 2004 we have converted to using the slide tracheoplasty as our operation of choice for long segment tracheal stenosis. However, the technique of tracheal autograft does have some unique capabilities which in certain cases might prove useful to the practicing surgeon. Other surgeons have applied this technique successfully in a number of patients (James E. O'Brien, MD, Kansas City, MO; Jeffrey P. Jacobs, St. Petersburg, FL; and Francois Lacour-Gayet, Denver, CO, personal communications). In many respects, our experience with the tracheal autograft operation enabled us to improve our technique of slide tracheoplasty with which we initially had difficulty in 1996.

The initial inspiration for the tracheal autograft technique developed from a combination of factors. At our institution from 1982 to 1996, we had preferentially used the pericardial patch tracheoplasty originally described by Dr. Farouk Idriss for patients with long segment tracheal stenosis.[2] Our chief of otolaryngology, Dr. Lauren Holinger, who performed the bronchoscopies on all of these patients, commented that because the tracheas in these patients were often excessively long, the pericardial patch tended to suffer from patch tracheomalacia and, the longer the patch, the worse the tracheomalacia following the procedure. This resulted in prolonged hospital stays for many of our patients and a portion of them required tracheostomies. He suggested that we shorten the trachea at the time of the pericardial tracheoplasty by resecting six to eight complete tracheal rings (Fig. 1). This was done and the patient had a good result. Shortly after that operation I reviewed the paper eventually published by Dr. Jeffrey Jacobs in the *Annals of Thoracic Surgery* on the use of tracheal homograft for a child that had had an extensive tracheal resection.[3] I noted a striking similarity between the homograft material that Dr. Jacobs recommended using and the piece of trachea that I had sent to the pathology department during that pericardial tracheoplasty (Fig. 2).

The next patient operated in our series for congenital tracheal stenosis also had a ventricular septal defect and a pulmonary artery sling. The child was 2 months old and weighed 4.5 kg. When we opened the trachea, it was excessively long and, particularly near the carina, it was quite small. The idea came to us during the surgery to use pericardium for the upper portion of the tracheal reconstruction and the piece of resected midportion of the trachea for the area near the carina (Fig. 3). This was the tracheal *autograft*. This child was extubated on postoperative day 13 and discharged from the hospital 20 days later.

This successful result in what we believed was going to be a very difficult patient led us to adopt the tracheal autograft technique as our procedure of choice until early 2004. In 1996 we performed two slide tracheoplasties: one patient had significant problems with granulation tissue and a figure 8 configuration of the trachea which ultimately led to the patient's death.[4] In contrast, the first six patients that we operated on with the tracheal autograft technique survived and had a mean time to extubation of 13 days and a mean time to discharge of 23 days.[5] The tracheal autograft technique can also be performed without the use of autologous pericardium if the tracheal stenosis segment is short enough (Fig. 4).

All cases were performed with cardiopulmonary bypass. If the patient had associated cardiac lesions or pulmonary artery sling, these were corrected first (before opening the trachea). If there were no cardiac lesions, the patients were operated on with mild systemic hypothermia (32°C). Initial mobilization of the trachea, innominate artery, and vein, aorta, and right and left pulmonary arteries was performed as much as possible before the initiation of cardiopulmonary bypass with heparinization. However, the completion of the dissection was performed with the patients heparinized and with the extensive use of electrocautery. Care must be taken in the region of the recurrent laryngeal nerves on either side. Care must also be taken during the dissection near the thyroid cartilage to avoid the recurrent laryngeal nerve in that region. After fully mobilizing the trachea, it is incised anteriorly through the complete extent of the complete tracheal rings. An assessment is then made of the length of the tracheal stenosis which must be relieved. The typical tracheal autograft length was 1.5 to 2.0 cm (six to eight tracheal rings).

*Division of Cardiovascular-Thoracic Surgery, Children's Memorial Hospital, Department of Surgery, Northwestern University Feinberg School of Medicine, Chicago, Illinois.

†Division of Pediatric Otolaryngology, Children's Memorial Hospital, Department of Otolaryngology, Head and Neck Surgery, Northwestern University Feinberg School of Medicine, Chicago, Illinois.

Address reprint requests to Carl Lewis Backer, MD, Division of Cardiovascular-Thoracic Surgery, Children's Memorial Hospital, 2300 Children's Plaza, mc 22, Chicago, IL 60614. E-mail: cbacker@childrensmemorial.org

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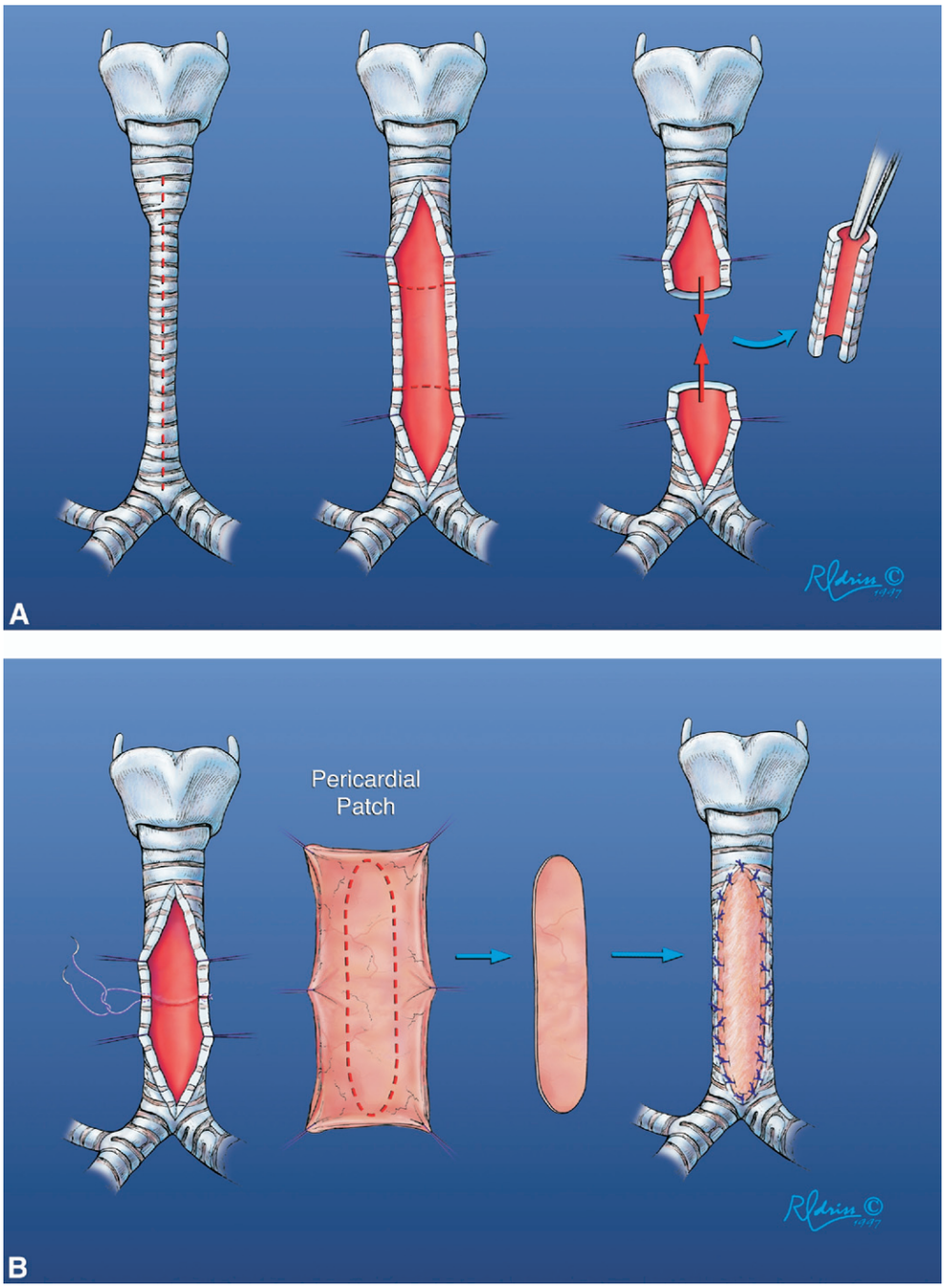

Figure 1 (A) This illustration is the index case which led to our interest in using the tracheal autograft. The child has complete tracheal rings from the third tracheal ring to the carina. With the child on cardiopulmonary bypass, the trachea was incised anteriorly from just below the cricoid cartilage to the carina. In an effort to improve the outcome of the pericardial tracheoplasty, the midportion of the tracheal stenosis was resected to shorten the trachea. (B) A posterior end-to-end anastomosis was performed with interrupted PDS sutures. The pericardial patch was then trimmed appropriately and sutured in place with interrupted PDS sutures.

The tracheal autograft was harvested from the midportion of the trachea and then a posterior tracheal anastomosis was performed with interrupted 6.0 polydioxanone (PDSII) monofilament suture (Ethicon, Somerville, NJ). The tracheal autograft was then trimmed as illustrated in the figures and the anastomosis near the critical area near the carina was performed first, again with interrupted suture technique. Finally, the autologous pericardial patch (harvested at the beginning of the operation) was sutured in place to cover the upper portion of the tracheal opening and anastomosed directly to the tracheal autograft. The endotracheal tube was positioned in the midportion of the tracheal autograft so that the pericardium was stented. The tracheal suture lines were covered with a thin coating of Tissel glue (Baxter Health Care Corp., Glenlake, CA) to seal the suture holes and help prevent air leaks. The anastomosis was tested by insufflating the lungs serially to a tracheal pressure of 35 to 40 cm of water to identify any air leaks at the anastomosis. We reported our

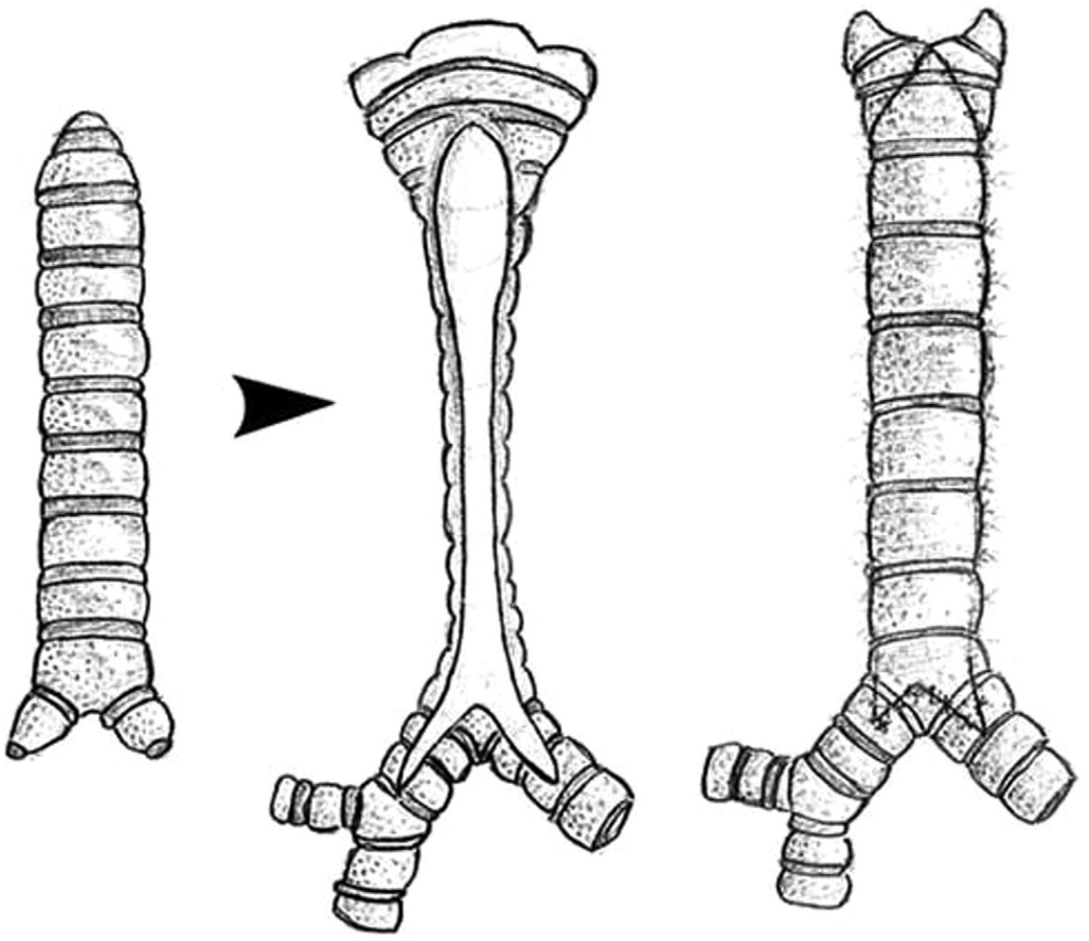

Figure 2 This illustration shows how a tracheal homograft can be used to repair a residual tracheal stenosis after tracheal resection with resultant residual stenosis. The homograft has been harvested from a cadaver, fixed in formalin, washed in methiolate and alcohol, and stored in acetone. The similarity of the tracheal homograft to the piece of trachea that was resected and shown in Figure 1A and that was originally discarded at that time is striking. (From Jacobs JP, Elliott MJ, Haw MP, et al: Pediatric tracheal homograft reconstruction: a novel approach to complex tracheal stenoses in children. J Thorac Cardiovasc Surg 112:1549-1558, 1996.)

intermediate results in 2000 in the *Journal of Pediatric Surgery*.[6] At that time we had 10 patients with only one death. The one death was in a child who had simultaneous repair of tetralogy of Fallot and required extracorporeal membrane oxygenation postoperatively.

The postoperative management of infants after congenital tracheal stenosis repair requires a dedicated team to provide postoperative bronchoscopic support. At our institution, the Division of Otolaryngology has had a long tradition of providing this support. Many patients after tracheal autograft or other congenital tracheal stenosis procedures develop inspissated secretions or granulation tissue or have problems from residual tracheobronchomalacia. These patients may require emergent bronchoscopy because of difficulty with ventilation in the postoperative period. Our routine for the patient who does not have postoperative difficulties with ventilation has been to leave the child intubated and paralyzed for the first 48 to 72 hours following the procedure. Then, the paralytic support is withdrawn and they are allowed to breathe on their own. Before extubation, either a flexible or a rigid bronchoscopy is performed to assess the repair. In most cases this is a rigid bronchoscopic evaluation performed in the operating room at about 5 to 7 days postoperatively. The endotracheal tube is removed and bronchoscopy is performed. This allows visualization of the anatomy of the repair and removal of granulation tissue and/or secretions that have not been suctioned. In the immediate postoperative period as part of our protocol, we are careful not to exceed airway pressures of 30 to 35 cm of water during suctioning and bagging. The nurses are cautioned to pass the suction catheters gently and then stop when they meet gentle resistance. In a series of tracheal autograft repairs, we have had only one dehiscence and this was related to a clear postoperative mediastinitis with pseudomonas in a patient that had preoperative pneumonia but an unstable airway requiring emergency operation. The importance of sophisticated bronchoscopic expertise cannot be underestimated in the care of these patients. This has been true in our series of tracheal stenosis patients no matter what procedure we have used.

We studied the tracheal autograft technique in the laboratory in a rabbit model of tracheal reconstruction.[7] Thirty-two rabbits underwent resection of an elliptical-shaped portion of trachea which was then soaked in a Petri dish with either saline or vascular endothelial growth factor (VEGF) solution

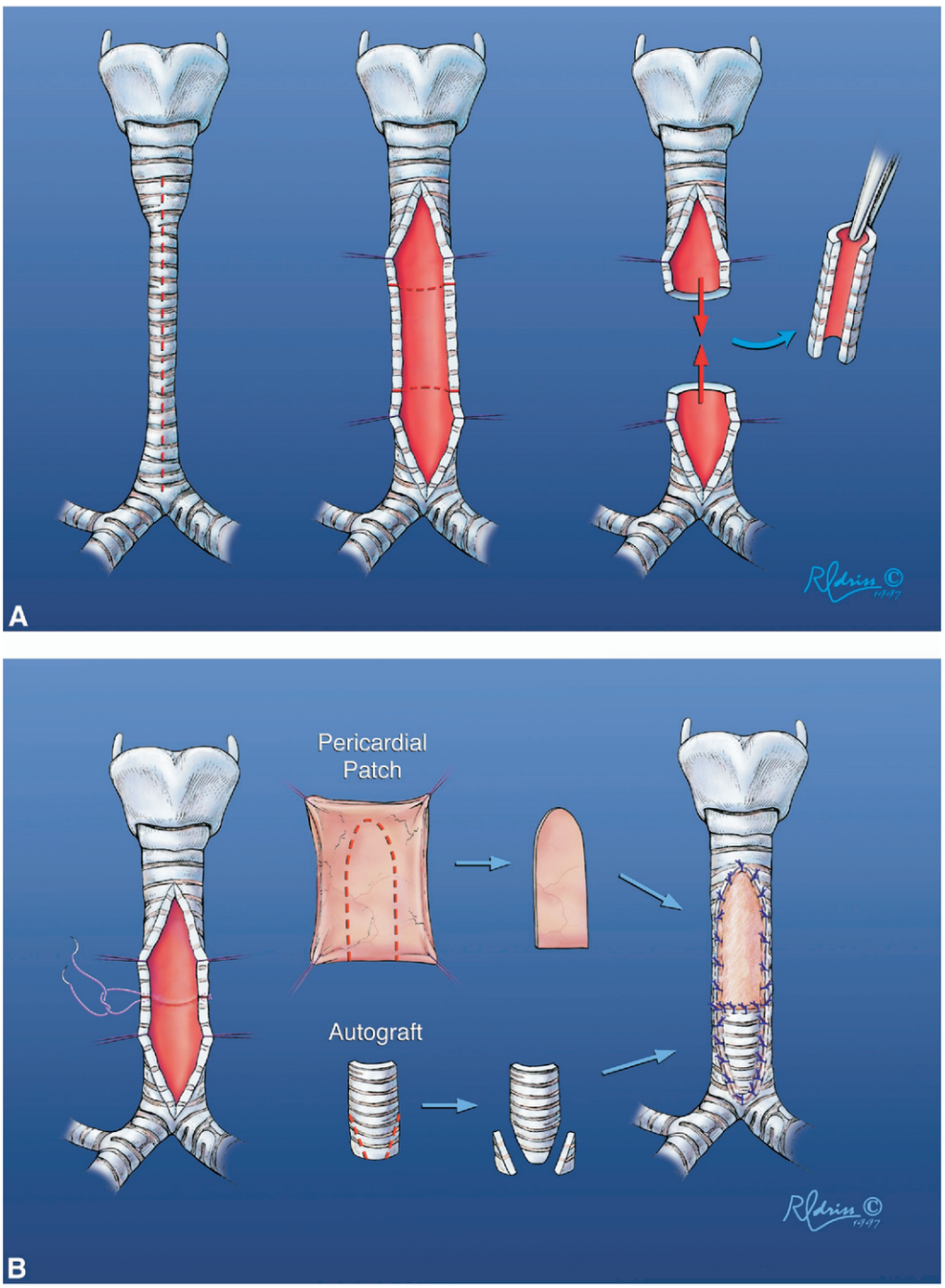

Figure 3 The first tracheal autograft we performed as mentioned in the text was on a 2-month-old, 4.5 kg child that also had a pulmonary artery sling repair and ventricular septal defect closure immediately before the tracheal procedure. (A) On cardiopulmonary bypass the anterior trachea was incised as indicated by the dotted line. The midportion of complete tracheal rings was resected. This entailed seven complete tracheal rings. (B) A posterior end-to-end anastomosis was then created as shown in the far left panel. The portion of the trachea that was used as an autograft was then trimmed as shown in the lower middle panel. This tracheal autograft was inserted into the distal trachea and sutured in place with interrupted PDS sutures. An autologous pericardial patch was then trimmed as shown and used to augment the upper portion of the trachea. This was sutured in place with interrupted PDS sutures.

for 15 minutes. These autografts were then placed back into the tracheal opening and secured with interrupted PDS suture, very similar to our clinical tracheal autograft technique. The autograft survived in all rabbits. Of great interest, the healing of the autograft was enhanced with the use of vascular endothelial growth factor as evidenced by accelerated autograft revascularization, reduced submucosal fibrosis and inflammation, and enhanced preservation of the normal tracheal architecture. We postulated that topical vascular endothelial growth factor may improve future results of tracheal reconstruction. We have not studied VEGF since then and have not used it clinically.

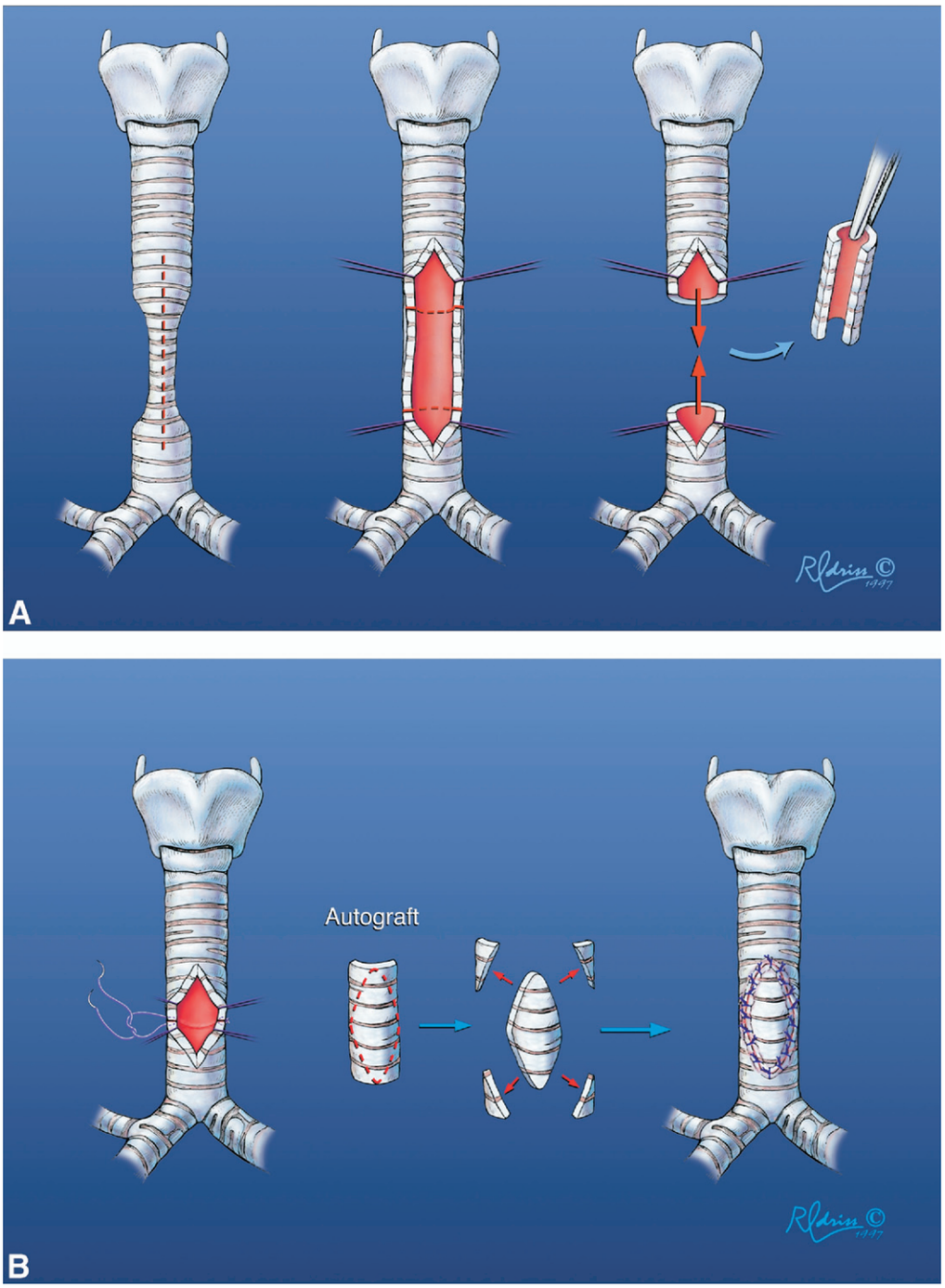

Figure 4 We had several cases with a long segment congenital tracheal stenosis that we felt was too long to have a successful resection, but short enough that the autograft could be used to complete the repair without pericardial augmentation. (A) On cardiopulmonary bypass the trachea is incised through the length of the tracheal stenosis. The autograft is resected as shown in the middle panel. One of the benefits of the autograft technique is that precise definition of the midportion of the stenosis is not required as the incision can be carried inferiorly and superiorly until normal membranous trachea is encountered. Usually this incision must be taken into at least one or two normal tracheal rings for correct augmentation of the tracheal lumen. (B) A posterior end-to-end anastomosis is created with interrupted PDS sutures. The autograft is trimmed at all four corners as shown in the middle panel and then inserted in the resultant anterior orifice remaining in the trachea. The autograft is sutured in place with interrupted PDS suture. The tracheal repair has been completed without pericardial augmentation.

Evidence that the slide tracheoplasty was a significant advance in the treatment of patients with tracheal stenosis was provided by Martin Elliott in 2004 when he reported 15 patients with a 13% mortality.[8] Further evidence of this was provided by the group from Cincinnati and Peter Manning, who reported 40 patients in 2006 with only four deaths.[9] These studies followed the pioneering work of Goldstraw and colleagues[10] and Grillo.[11] Our own analysis of the literature of patients having slide tracheoplasty found 76 cases with only eight deaths for an 11% mortality. This is better than our

experience with 20 tracheal autografts and four deaths for a 20% mortality. Although we concluded in our overview of tracheal surgery published in 2001 and presented at the European Association for Cardiothoracic Surgery that the tracheal autograft was our operation of choice for long segment stenosis,[12] we have changed our strategy to preferentially use the slide tracheoplasty.

However, there are certain principles from the tracheal autograft technique that are important and may apply in certain patients undergoing tracheal surgery. The first principle is that the tracheal autograft can be safely used and develops a blood supply. We demonstrated this in the laboratory and had only one dehiscence in our clinical series. That patient had a significant mediastinal infection. In some respects the tracheal autograft technique is geometrically easier than the slide tracheoplasty, which requires a precise transaction of the trachea at the midportion of the stenosis. Our recent results with the slide tracheoplasty have been successful in the past six patients and, as I mentioned, this is now our procedure of choice. Our success has been facilitated by utilization of a running everting suture technique which tends to avoid the figure 8 configuration of the trachea at the conclusion of the operation. The use of the running PDS suture has helped to decrease the incidence of postoperative granulation tissue formation as compared with our original use of the interrupted suture technique. The use of the running suture technique has also made the cardiopulmonary bypass times considerably shorter and this may have contributed to better healing of the marginally perfused trachea in the immediate postoperative period. In conclusion, the tracheal autograft technique did provide us with better results than we had achieved with the pericardial tracheoplasty with improved times to extubation and improved times to discharge. The overall hospital mortality of 10% was quite acceptable. However, several of our patients developed recurrent problems with tracheomalacia and tracheal stenosis, often secondary to the residual pericardial patch. Our strategy is now focused on using the slide tracheoplasty as our primary technique of choice for patients with long segment congenital tracheal stenosis.

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