Airway Complications in Children Following Lung Transplantation

C.B. HUDDLESTON

INTRODUCTION

Historically, disruption of the airway suture line was the major source of morbidity and mortality in the early days of lung transplantation in adults, particularly in the setting of an en-bloc double lung transplant. Modifications of the technique by wrapping the anastomosis with either omentum or other viable tissues and performing bi-bronchial anastomoses provided reasonable solutions to this problem. Airway anastomotic complications are now a less serious but persistently vexing problem, with an incidence in adult transplants ranging from 10% to 30% of bronchial anastomoses at risk. Most of these bronchial complications are due to stenosis. The incidence of airway complications in the pediatric age group, and those factors leading to this set of problems following lung transplantation, are not well defined due to less experience in children. The experience in adults may not be easily translated to children, for a variety of reasons, including the smaller size of the airways being anastomosed and the expected somatic growth that will occur. This is a review of the literature and of our own experience in children, to evaluate the incidence, risk factors and appropriate treatment associated with these complications in the pediatric population subjected to transplantation.

AIRWAY CHARACTERISTICS UNIQUE TO CHILDREN

In general, the bronchus is mature in virtually all aspects shortly after birth. The blood supply is the same as that seen in adults. The bronchial cartilage is somewhat more compliant and soft in infants than in older children, and particularly adults. This may predispose to malacia of the airway when the donor is young. The major issues that could impact on airway complications relate to the smaller size per se and the need for growth when transplanting very small children rather than to the biology of the bronchus.

UNIQUENESS OF THE BRONCHIAL ANASTOMOSIS

Bronchial blood supply

Normally there are two or three bronchial arteries arising from the aorta. They enter the lung through the hilar region and divide upon reaching the mainstem bronchus. A plexus is formed in the peribronchial space and small arterioles penetrate the muscular layer of the airway to reach the bronchial mucosa, where they form the submucosal plexus from the mainstem bronchus to the terminal bronchioles. At this level the capillary bed from the pulmonary arterial blood supply communicates with the bronchial capillary system. In general, direct bronchial revascularization is not performed in lung transplantation. Thus, blood supply to the bronchus reaches that point by retrograde flow from the pulmonary capillary system into the bronchial capillary system through the submucosal plexus back to the mainstem bronchus to reach the anastomosis. It is this tenuous system of vessels that the proximal donor bronchus depends upon for its nutrient source in the early stages after lung transplantation (Figure 1).

Revascularization of the anastomotic region may be accomplished by either direct bronchial arterial revascularization or 'indirect' revascularization - wrapping the anastomosis with viable tissue which can provide a source for ingrowth of new vessels. Some centers utilize direct bronchial revascularization with a low reported incidence of airway complications. These are all adult patients and relatively small series, however. The disadvantages of direct revascularization are that it is cumbersome, adds to an already lengthy procedure, adds ischemic time to the transplanted organs and increases the risks of bleeding.

Indirect revascularization using omentopexy or other viable tissue flaps was at one time the standard. There is experimental evidence of ingrowth of new vessels to the area of the bronchial anastomosis as early as 4 days post-transplant and extensive neovascularization of the bronchial circulation via collaterals within 3–4 weeks. However, most have now abandoned this adjunct to lung transplantation, and cover the bronchial anastomosis with viable donor peribronchial tissue; this has provided clinical results similar to that achieved with omentopexy, pericardial flaps and intercostal muscle flaps, and avoids the need for laparotomy or mobilization of other tissues. The donor peribronchial tissue is viable and probably provides for the rapid ingrowth of new vessels to the area of the anastomosis in a fashion similar to omentum, although there is no experimental evidence for this. There is, however, experimental evidence that the bronchus will heal normally with no wrap at all, thus taking us...
THE TRANSPLANTATION AND REPLACEMENT OF THORACIC ORGANS

Figure 1 Antegrade flow to the proximal mainstem bronchus stops at the suture line. Nutrient supply to the area of the anastomosis must come retrograde via collaterals between the pulmonary and bronchial circulations.

It is prudent to provide some coverage of the suture line with the peribronchial tissue if for no other reason than to protect the pulmonary artery anastomosis should there be any breakdown at all of the bronchial anastomosis.

It is likely that most airway complications are related to ischemia at the anastomosis. Although omentum and other vascular pedicles may provide indirect revascularization this requires days in which the anastomosis must live off the retrograde perfusion from the pulmonary arterial system. It is relatively common to see bronchoscopic evidence of some ischemia in the proximal donor bronchus - usually a bluish discoloration or, if more severe, a gray appearance that may extend to the level of the orifice of the upper lobe bronchus. This usually resolves over the first week following transplantation. Given that the early blood supply to the anastomatic region is crucial in avoiding airway complications, efforts should be extended to maintain this tenuous collateral microvascular blood flow. Maintenance of excellent pulmonary blood flow, pulmonary preservation, and handling of the proximal donor bronchus are factors which impact upon this.

Pulmonary blood flow

Obviously maintenance of good cardiac output is crucial in the care of any patient postoperatively. In children the luxury of measuring cardiac output by the thermodilution technique is seldom available, except in the teenage group. In general, reliance on clinical assessment of the cardiac output is more frequently necessary - pedal pulses, capillary refill, warmth of extremities, urinary output, etc. In addition, pulmonary vasodilators may have a very positive impact on bronchial healing, as demonstrated by the group from Hannover. They used prostacyclin as a pulmonary vasodilator for 48 hours post-transplant. Heparin was also administered to prevent thrombosis of any small vessels in areas of low flow. They had no significant bronchial complications in 41 anastomoses at risk. We currently use prostaglandin E₁ (PGE₁) in all patients for 48 hours post-transplant in a dose of 25 ng/kg per minute.

Pulmonary preservation

This topic is covered elsewhere in this publication, and has been reviewed in depth by a number of investigators. We use modified Euro-Collins solution (50 ml/kg) after bolus injection of 500 µg of PGE₁. Poor pulmonary preservation and prolonged ischemic times place the microvasculature of the lung at risk; thus the flow via collateral vessels to the bronchial anastomotic area may be diminished. It has been shown experimentally that lungs with better preservation have better healing of the bronchus. In a similar fashion, prolonged ischemic injury to the lung will injure the pulmonary microvasculature and thus diminish the collateral flow to the bronchus. In our series of 79 transplants in 71 patients (153 anastomoses at risk) the ischemic time tended to be longer in those developing complications, but did not reach statistical significance. Interestingly, most bronchial complications were seen on the right (nine versus four). The left lung transplant is always performed first at our center; thus the right lung has on average an additional 40 minutes of ischemic time compared to the left. To truly analyze whether the ischemic time is the causative factor would require randomization of the sequence of the transplants to be certain that other factors are not involved.

Handling of the bronchus

The donor bronchus should be trimmed to within one or two cartilaginous rings of the bifurcation of the mainstem bronchus. This shortens the distance that the collateral blood flow must travel to reach the anastomosis, but still allows sufficient length to perform the anastomosis. When performing a lobar transplant we divide the bronchus just beyond the take-off of the upper lobe. We avoid skeletonizing the donor bronchus and also limit the amount of trauma from forceps grasping. To allow for the potential for growth, monofilament absorbable suture (polyglyconate) is used for the anastomosis. A study in lambs by Friedman et al. has demonstrated that this allows for satisfactory growth of the airway anastomosis. When performing a lobar transplant we divide the bronchus just beyond the take-off of the upper lobe. We avoid skeletonizing the donor bronchus and also limit the amount of trauma from forceps grasping. To allow for the potential for growth, monofilament absorbable suture (polyglyconate) is used for the anastomosis. A study in lambs by Friedman et al. has demonstrated that this allows for satisfactory growth of the airway anastomosis. Finally, there is the issue of whether the anastomosis should be telescoped. The San Antonio group has provided quite convincing data in adults that telescoping of the anastomosis provides the best results in airway healing. In most cases the donor bronchus is of smaller diameter than the recipient and some telescoping is inevitable. However, in our experience and that of others, telescoping with a mattress suture has had a very high incidence of airway stenosis, and we no longer utilize this technique, instead using a simple suture technique.