

Carinal transplantation

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Abstract

Background Current techniques of management of carinal lesions are not always satisfactory. Carinal transplantation, if feasible, would be valuable in certain circumstances.

Methods and results Carinal transplantation experiments were performed in dogs. In early cross transplant experiments there were problems in controlling ventilation and in obtaining satisfactory anastomoses, and the animals failed to live for even a few days. In seven subsequent experiments the carinal graft was removed from one dog and transplanted into a second dog. Two dogs lived for over four months with immunosuppression.

Conclusion The results suggest that carinal transplantation can succeed if (1) the calibre of the graft is matched with that of the recipient; (2) there is an abundant blood supply to the graft; (3) appropriate immunosuppression is provided; (4) ventilation is adequate during surgery.

(Thorax 1992;47:968-970)

Various lesions may affect the carina. Cancer and benign tumours present major problems,¹ and tuberculosis may sometimes affect the carina.² Such carinal lesions may be treated by tracheoplasty or bronchoplasty³ and an artificial carina.^{4,5} Tracheoplasty or bronchoplasty, however, are not always possible and they carry the hazard of dehiscence as a result of the considerable tension on the suture line. A satisfactory carinal prosthesis is not yet available because of chronic problems such as infection, obstruction, and erosion of major vessels.¹ We have obtained good results with canine cervical tracheal transplantation⁶ and

have now investigated the feasibility of carinal transplantation.

Methods

We performed seven carinal transplantations in 14 dogs weighing almost 10 kg. After induction of anaesthesia with pentobarbital (5 mg/kg) two dogs underwent right thoracotomy under general endotracheal anaesthesia. First the carinal graft, including three rings of the trachea and two rings of each main bronchus (fig 1), were removed from the donor dog. The trachea of the recipient dog was then cut and sutured to the graft. The right main bronchus of the recipient was cut and sutured to the graft while the left main bronchus was intubated. Finally, the left main bronchus of the recipient was cut and sutured to the graft. For the anastomosis we used continuous suture with 3-0 Dexon Plus.

After transplantation an omental flap was wrapped round the graft and suture.^{7,8} The omentum was freed from the stomach, transverse colon, and spleen, with preservation of the right gastroepiploic vessels, pulled up through the right diaphragm, and wrapped round the carina.

Mizolibin (Bredinin), a new imidazole nucleotide (4-carbamoyl-1- β -D-ribofuranosyl-imidazolium-5-olate) provided by Asahikasei Company Ltd, Tokyo, was given at a dose of

Results of carinal transplantation

Dog No	Outcome	Cause of death
1	Died (6 days)	Mediastinitis
2	Died (1 month)	Carinal stenosis
3	Died (2 months)	Carinal stenosis
4	Alive (4 months)	
5	Died (8 days)	Mediastinitis
6	Died (2 months)	Carinal stenosis
7	Alive (5 months)	

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Accepted 12 June 1992

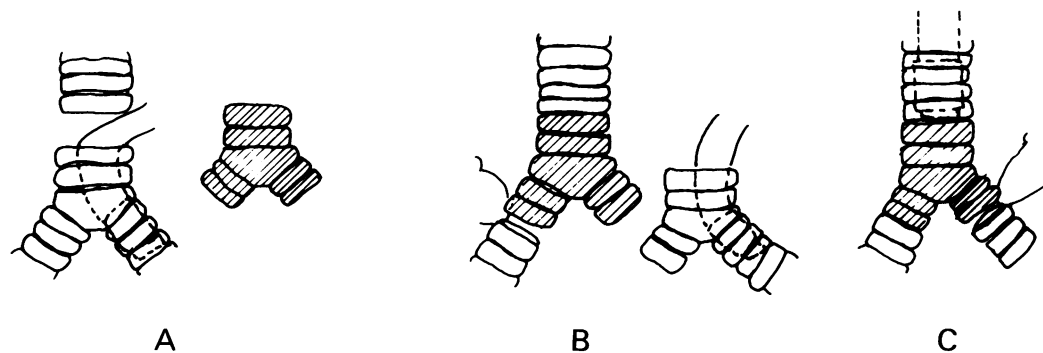
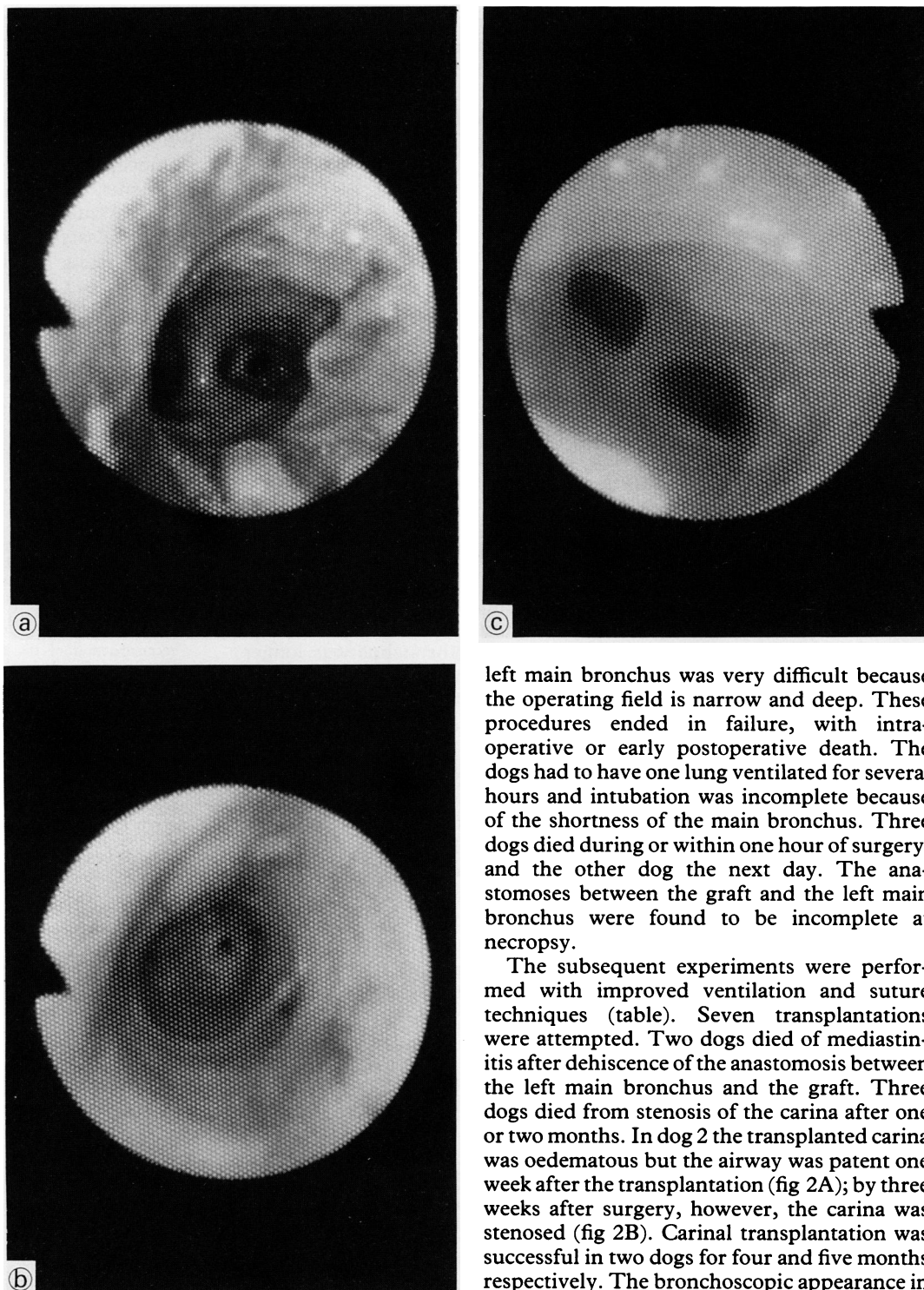


Figure 1 Diagrams illustrating the technique of carinal transplantation. The carinal graft was removed from the donor just before the experiment (A). The trachea of the donor was cut and sutured to the graft (B). Finally the right and left main bronchi were sutured and then wrapped with an omental flap (C).

Figure 2 Bronchoscopic views of the carina: (A) one week after operation (dog 2); (B) three weeks after operation (dog 2); (C) two months after operation (dog 4).



10 mg/kg/day⁹ for immunosuppression. Cefaclor (50 mg/kg) was given for one week to prevent infection.

In preliminary experiments carinal exchange was performed between two dogs in two experiments. The carinas of the two dogs were removed simultaneously, while ventilation was performed through the left main bronchus as there were problems with this approach. The seven subsequent procedures were carried out in the same way.

Results

In the preliminary experiments suture of the

left main bronchus was very difficult because the operating field is narrow and deep. These procedures ended in failure, with intraoperative or early postoperative death. The dogs had to have one lung ventilated for several hours and intubation was incomplete because of the shortness of the main bronchus. Three dogs died during or within one hour of surgery, and the other dog the next day. The anastomoses between the graft and the left main bronchus were found to be incomplete at necropsy.

The subsequent experiments were performed with improved ventilation and suture techniques (table). Seven transplantations were attempted. Two dogs died of mediastinitis after dehiscence of the anastomosis between the left main bronchus and the graft. Three dogs died from stenosis of the carina after one or two months. In dog 2 the transplanted carina was oedematous but the airway was patent one week after the transplantation (fig 2A); by three weeks after surgery, however, the carina was stenosed (fig 2B). Carinal transplantation was successful in two dogs for four and five months respectively. The bronchoscopic appearance in dog 4 two months after transplantation is shown in figure 2C. The graft was viable and acting as the carina. These two dogs are still alive and will be followed up.

Discussion

We believe that carinal transplantation has potential as two dogs have survived for over four months. We applied the knowledge and skill obtained in cervical tracheal transplantation⁶ to carinal transplantation. Cervical tracheal transplantation has been successful when the trachea has been the same size in the donor and the recipient, immunosuppression has been adequate, and the blood supply to the graft has been abundant.⁶ Of these three conditions, a good blood supply is the most impor-

tant. Carinal grafts are poorly supplied with blood because the carina has a poor blood supply from the bronchial and oesophageal arteries. Moreover, there are no organs adjacent to the carina that can supply a good blood flow to the graft. Omentopexy is a useful procedure for augmenting the blood supply. Morrison¹⁰ observed in 1906 that the omentum was capable of revascularising and maintaining viable tissues without any apparent arterial blood supply. Since then it has been used for several procedures, including the repair of bronchopleural fistulas.¹¹ Revascularisation of bronchial autografts and allografts⁸ and tracheal grafts⁶ supplies blood to the carinal grafts.

The preliminary experiment confirmed that carinal transplantation is more difficult than cervical tracheal transplantation. Three anastomoses are required for carinal transplantation. The left main bronchus is particularly difficult to suture because the operative field is narrow and deep. The left main bronchus is short and the intubated tube is apt to come out. In the preliminary carinal exchange experiments the duration of the intubation to the separated left main bronchus was longer than in the later experiments, in which ventilation was better controlled and a better anastomotic technique allowed survival in the early postoperative period.

Why three dogs developed carinal stenosis is uncertain, but it may have been due to ischaemia of the graft caused by rejection or lack of sufficient omental wrapping. Balderman *et al*¹² pointed out that long tracheal grafts (for example, 10 rings) tend to become stenosed and suggested that the omental pedicle graft could not fully sustain the viability of the chondrocytes. In our cervical transplantation experiment 10 ring tracheal grafts have tended to stenose around the centre of the graft as a result of ischaemia at this point. A similar phenomenon may occur with carinal transplan-

tation, and this requires further investigation. The carinal transplant includes three rings of the trachea and two rings from each main bronchus, so our success may be due to the relative shortness of the graft.

We used mizolibin (10 mg/kg/day) as an immunosuppressant, as in our cervical experiments.⁶ This appears to provide adequate immunosuppression.⁹

Tracheoplasty and bronchoplasty are currently being applied to carinal lesions worldwide,¹ but it is impossible to treat very extensive disease with these techniques. Carinal transplantation has the potential to be a useful technique for the management of critical carinal lesions. Further investigation and long term follow up studies of carinal transplantation are now in progress.

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