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Radiologic Assessment in Pulmonary Lobar Transplantation

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Pulmonary lobar transplantation provides a clue to the acute donor shortage. To examine the experimental and clinical applicability of lobar transplantation, the authors observed the extent of lung expansion and infiltrate in the allografted lobe through the sequential analysis of the early chest roentgenograms. Materials and Methods : Twenty two mongrel dogs weighing 17 kg on average were used. Donor lung bloc was taken and flushed with Euro-Collins solution. The left lower lobar bloc was procured and implanted in the pneumonectomized recipient dog. The anastomosis was performed in the order of the pulmonary vein, artery, and bronchus. To assess the radiological pattern in the lobar allograft, a grading system was designed according to the extent of lung expansion and infiltrate. Results : A) Expansion pattern : Good to excellent lung expansion was seen on postoperative day 0 in 6 out of 10 dogs ; on day 1, 4/7 ; day 2, 3/12 ; day 3, 1/1 ; and day 4, 1/3, respectively. Radiographs on day 6, 7, and 12 also showed good expansion in one dog. B) Lung opacity pattern : Clear to minimal infiltrates were seen on day 0 in 8 out of 10 dogs ; day 1, 7/17 ; day 2, 2/12 ; and day 4, 1/3. The same appearances were detected in a single dog on day 6, 7, and 12. C) Expansion-opacity correlation pattern : Radiographs on postoperative day 0 showed good expansion with mild infiltrates, and excellent expansion with minimal infiltrates were observed on day 1 in 3 out of 17 dogs, day 2, 1/12 ; and day 4, 1/3, respectively. In one dog clear to minimal infiltrate with excellent to good lung expansion was seen at day 6, 7, and 12, respectively. Through the sequential analysis of chest roentgenograms, the authors observed lung infiltrates of varying extent during the early postoperative period, though these infiltrates did not match precisely with histopathological evidence of reimplantation response, acute rejection, infection, or secretion. The expansion pattern of the allografted lobe was observed, raising the possibility of lobar expansion in the mature recipient hemithorax.

Key Words : *Pulmonary lobar transplantation, Radiological assessment, Canine.*

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INTRODUCTION

The 3rd International Lung Transplant Symposium (June 23-26, 1993, Zurich) reported 1,992 lung transplant procedures listed in the International Lung Transplant Registry(Cooper, 1993). This report shows that lung transplant has now become an established therapeutic modality for end-stage lung disease. Despite these encouraging results, serious problems such as allograft dysfunction, infection, rejection, as well as shortage of appropriate donors, remain to limit the success of lung transplantation.

The scarcity of donor lungs is especially noticeable in pediatric groups where only 96 pediatric transplant procedures had been performed worldwide as of Jan. 1993. This condition, therefore, necessitates the successful implementation of reduced size lung or lobar transplantation. The method of pulmonary lobar transplantation, in which a pulmonary lobe procured from living related (Goldsmith, 1990) or cadaveric sources is used instead of the entire lung for neonatal transplantation, appears to be feasible(Cromblehome, 1990).

In previous studies, the authors observed a progressive radiological deterioration pattern while assessing the early allograft function of the canine single lung transplantation. The postoperative imaging of the radiological deterioration was primarily thought to be the manifestation of the reimplantation response, infection, acute rejection, and bronchial dehiscenece.

The early postoperative imaging in lobar transplant may prove useful in examining the applicability of a reduced sized lung in a more mature recipient, while focusing on lung expansion and lung size disparity.

To examine the radiological pattern in the transplanted lobe, the authors used 22 mongrel dogs for lober transplantation to monitor allograft function and to assess serial chest roentgenographic findings.

MATERIALS AND METHODS

Twenty two mongrel dogs weighing 15 kg to 20 kg (average 17 kg) were used in this study. Under general endotracheal anesthesia, the chest was entered through a left thoracotomy and then the left lung was mobilized as donor lung bloc with a generous atrial cuff, the pulmonary artery and left bronchus. The donor lung was flushed immediately after removal for about 15 minutes with approximately 1000cc of 4℃ Euro-Collins solution at a pressure of 60 cm H_2O via a cannula placed in the left main pulmonary artery. Then the left lower lobar bloc was prepared with division of the left lower lobe bronchus, the pulmonary artery and the pulmonary vein. The left pneumonectomy was conducted in the same manner on the recipient dog, this time with the pulmonary artery and the pulmonary vein clamped and the left main bronchus divided with the insertion of a bronchial blocker. Then, the end-to-end anastomosis was performed on the prepared donor lobar bloc, first on its pulmonary vein, artery, and bronchus respectively. The vascular anastomosis was performed with 5-0 prolene running suture and the bronchial anastomosis with 4-0 vicryl running suture. After bronchial anastomosis, the lung was reexpanded and reperfused. The chest was then closed with sutures in layers after insertion of a chest tube. During the procedures and early postoperative period, electrocardiograms with hemodynamics and arterial blood gas were monitored continuously. Perioperative immunosuppression using cyclosporine (Sandimun) 15 mg/kg/day was administered intravenously on day 0 and 1 and orally thereafter. The longest survival was 14 days postoperatively.

To assess the radiological pattern in the pulmonary lobar allograft, pre-operative control and postoperative chest roentgenograms with posteroanterior and lateral views were taken in each dog. A grading system for chest radiographs was designed according to the extent of lung expansion and its opacity pattern, as is seen in Table 1. Arterial blood gas analysis, hemodynamic monitoring, perfusion scan and bronchofiberscopy were also performed in a limited number of dogs.

RESULTS

Chest radiographs with postero-anterior and lateral views were taken in pulmonary lobar transplant recipients. On each postoperative day, the postoperative radiographic pattern was graded according to the grading system (Table 1).

A) Radiographic pattern by the extent of expansion

The extent of lung expansion is graded by the number of dogs and each postoperative period(See Table 2). Good to excellent lung expansion is detected on postoperative day 0 in 6 out of 10 dogs, on day 1, 4/17 ; day 2, 3/12 ; day 3, 1/1 ; and

Table 1. Grading System for Radiologic Assessment

Grade	Ⅰ	Ⅱ	Ⅲ	Ⅳ
Extent of expansion (percent of expansion)	Excellent (>75%)	Good (70–50%)	Fair (50–70%)	Poor (<25%)
Opacity pattern (extent of infiltrate)	Normal (Clear)	Minimal infiltrate	Moderate infiltrate	Extensive infiltrate

Table 2. Extent of Expansion

CXR/POD#	0	1	2	3	4	6	7	12
Excellent	2	2	2	1	1	1	·	1
Good	4	2	1	·	·	·	1	·
Fair	2	10	8	·	1	·	·	·
Poor	2	3	1	·	1	·	·	·
Total(n=)	10	17	12	1	3	1	1	1

CXR=Chest radiograph, POD=Postoperative day number, n=number of dogs

Table 3. Opacity Pattern

Opacity/POD#	0	1	2	3	4	6	7	12
Clear	4	4	·	·	·	1	·	1
Min. infiltrate	4	3	2	1	1	·	1	·
Mod. infiltrate	2	6	2	·	1	·	·	·
Ext. infiltrate	·	4	8	·	1	·	·	·
Total(n=)	10	17	12	1	3	1	1	1

Min.=minimal, Mod.=moderate, Ext.=extensive, n=number of dogs

day 4, 1/3 respectively. Radiographs on day 6, 7, and 12 show good expansion in one dog. Fair to poor expansion is presented in Table 2 and Fig. 1. Low survival rate up to postoperative 2 weeks limited sequential observations of the specific progressive pattern in the allografted lobe, but there was a possibility of the implanted lobe expanding during the immediate postoperative period.

B) Radiographic pattern by the opacity pattern

The opacity pattern or the extent of infiltrates is graded according to the number of dogs and post transplant period(See Table 3). Chest radiographs showed clear to minimal infiltrates in lung fields on day 0 in 8 out of 10 dogs ; day 1, 7/17 ; day 2, 2/12 ; and day 4, 1/13 respectively. Clear to minimal infiltrate was detected in one dog on day 6, 7, and 12. Moderate to extensive infiltrate was seen in the rest of the dogs.

C) Radiologic expansion-opacity correlation pattern

Postoperative Day 0

The expansion-opacity pattern was examined in ten dogs. Chest radiographs performed on day 0 showed good to excellent lung expansion with clear to minimal infiltrates in 5 out of 10 dogs. Of the other 5 dogs, 1 dog showed good lung expansion, 2 dogs fair expansion, and 2 dogs poor expansion, respectively. Two dogs out of the 5 dogs had clear lungs and infiltrates were identified in the other 3 dogs (1 minimal, 2 moderate). (Fig. 1 and 2)

Postoperative Day 1

A chest radiograph was taken in 17 dogs. Good to excellent lung expansion with clear to minimal infiltrate was detected in 3 out of 17 dogs on the chest radiograph. In the other 14 dogs, one dog exhibited good lung expansion, 10 dogs fair expansion, and 3 dogs poor expansion, respectively. Three out of the 14 dogs had clear lungs. Infiltrates

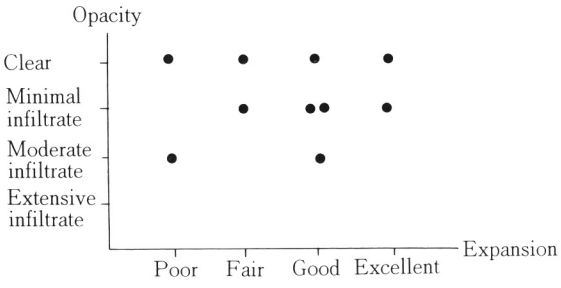

Fig. 1. Radiologic Grade at Postoperative Day 0(n=10)

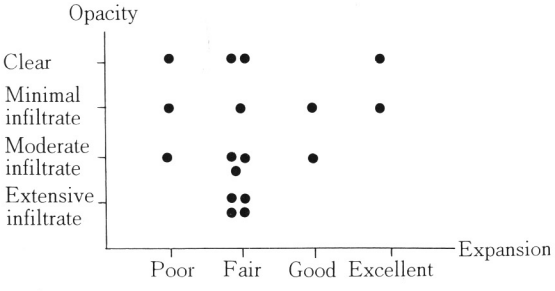

Fig. 3. Radiologic Grade at Postoperative Day 1(n=17)

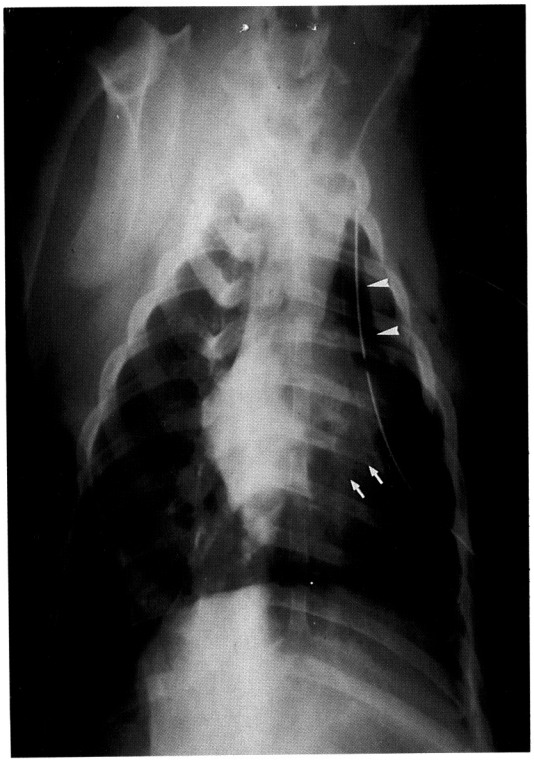

Fig. 2. Chest radiograph of a dog obtained at postoperative day 0 shows good expansion of the allografted left lower lobe with minimal pulmonary infiltration(arrows). Note also small pneumothorax in left side(arrowheads).

Fig. 4. Chest radiograph of a dog obtained at postoperative day 1 shows good expansion of the allografted left lower lobe with moderate pulmonary infiltration (arrows). Note also small pneumothorax in left side(arrowheads).

were detected in the other 11 dogs (2 minimal, 4 moderate, 4 extensive). (Fig. 3 and 4)

Postoperateve Day 2

On the chest radiographs performed in 12 dogs, only 1 dog showed good lung expansion with mild infiltrates. Fair lung expansion with moderate to extensive infiltrate was noticed in 8 out of the other 11 dogs. (Fig. 5 and 6).

Fig. 5. Radiologic Grade at Postoperative Day 2(n=12)

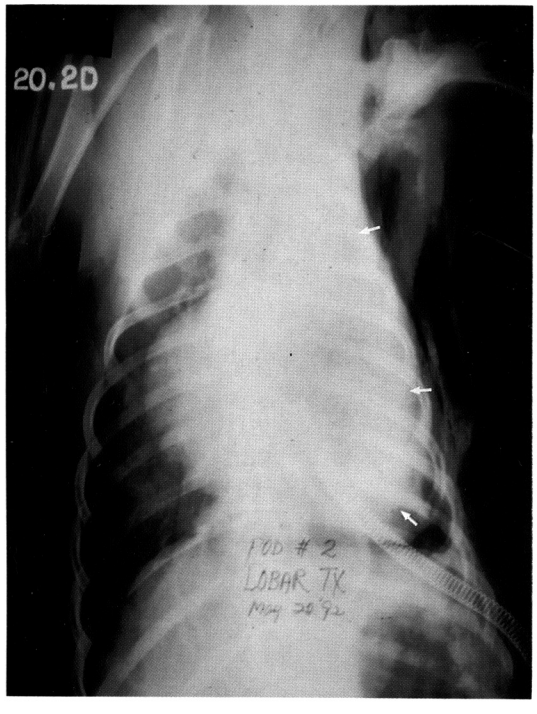

Fig. 6. Chest radiograph of a dog obtained at postoperative day 2 shows fair expansion of the allografted left lower lobe with extensive pulmonary consolidation(arrows).

Postoperative Day 4

Chest radiography was taken in 3 dogs at day 4. Excellent lung expansion with minimal infiltrate was seen in 1 out of 3 dogs. (Fig. 7)

Fig. 7. Chest radiograph of a dog obtained at postoperative day 4 shows good expansion of the allografted left lower lobe with moderate pulmonary infiltration(arrows).

Fig. 8. Chest radiograph of a dog obtained at postoperative day 7 shows good expansion of the allografted left lower lobe with minimal pulmonary infiltration(arrows). Increaed opacity of left middle lung field is due to chest wall swelling and topically applied gauze(arrowheads).

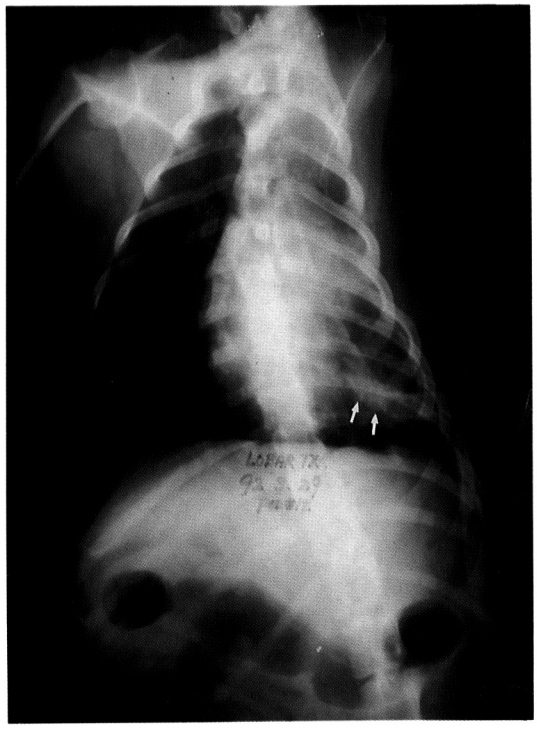

Fig. 9. Chest radiograph of a dog obtained at postoperative day 12 shows excellent expansion of the allografted left lower lobe with minimal pulmonary infiltration(arrows).

Postoperative Day 6-12

Only one dog survived 14 days. Chest P-A was taken in the dog from day 6 through day 12. At day 6, the dog showed clear lung field with excellent lung expansion. At day 7, the dog exhibited good lung expansion with minimal infiltrates. And at day 12, the minimal infiltrates cleared completely and lung expansion was found to be excellent. (Fig. 8 and 9)

Histopathological observations were done in the accessible 10 dogs, which will be dealt with later in the discussion.

DISCUSSION

Pulmonary lobar transplantation, in which mature lobes are implanted to an immature recipient chest, provides a solution to the lack of size-matched immature donor organs, critical in pediatric and neonatal lung transplantation. In Korea where living related renal transplantation has been performed successfully, the living related pulmonary lobar organs are also likely to be available (Backer, 1991).

To assess the early graft function in the canine single lung allografted model, the authors previously resorted to multiple modes of assessment, early postoperative radiographic progression, lung perfusion scan, bronchial patency, and histopathology of the bronchial anastomotic site and allografted lung (Sohn et al, 1993). In this study, the authors attempted to examine the clinical applicability of lobar transplantation by assessing the allograft function in the canine model, focusing on radiologic assessment.

Postoperative radiographic imaging in lung transplantation was primarily expected to produce manifestations of reimplantation response, infection, acute rejection, and bronchial dehiscence (Keshavjee, 1990). The reimplantation response appears in the form of a perihilar infiltrate in the immediate postoperative period or within the first 2 days. It can be misunderstood as an infectious process or early rejection episode. Primary graft failure, mainly caused by hyperacute rejection, is manifested radiographically by pulmonary edema progressing to extensive lung opacification (Anderson et al, 1993).

The authors observed good to excellent lung expansion on postoperative day 0 (6/10 dogs), day 1 (4/7), day 2 (3/12), day 3 (1/1), and day 4 (1/3). Radiographs on day 6, 7, and 12 also showed good expansion in the same single dog.

A study by Hislop et al(1990) reports that a transplanted immature lung continues to grow in the young rat after unilateral left lung transplantation. However, Kern et al(1992), examining the growth potential of reduced-size mature pulmonary transplants, reported that transplanted mature lobes exhibited compensatory growth along with an increase in connective tissues, not through the increase in the alveolar number and size. He suggested that reduced-size lung transplantation, in which a lobe of a more mature donor organ is sized down to fit the immature recipient chest could potentially augment the pediatric donor lung pool.

We also observed nonspecific infiltrates as shown by focal or diffuse, consolidation or atelectasis, perihilar or basilar infiltrates during the immediate postoperative period. Millet et al (1989) reported that radiographic abnormalities were found in both

And ill-defined perihilar opacification and consolidation were seen in CMV pneumonitis, herpes simplex pneumonia, and pneumocystis carinii pneumonia (Millet et al, 1989).

To find the correlation between radiologic and histopathological findings, the authors compared histopathological findings (minimal interstitial edema, cellular infiltration, alveolar damage, and infarction) with radiological findings (minimal, moderate, and extensive infiltrates) in the accessible 10 dogs. These comparisons did produce some correlations as shown by infarction with extensive infiltration and consolidation, but these findings did not match specifically with the evidence of infection, reimplantation response, rejection, or secretion.

In conclusion, the authors observed infiltrates of varying extent in the implanted lobe during the early postoperative period, though these infiltrates hardly seem to match the histopathologic pattern in reimplantation reaction, acute rejection, infection, or secretion. The expansion of the allografted lobe leads us to have reasonable expectations for expansion in the mature recipient hemithorax of the allografted lobe.

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