Unilateral radiographic abnormalities after bilateral lung transplantation: Exclusion from the definition of primary graft dysfunction?

Takahiro Oto, MD, Anne P. Griffiths, FRCNA, Bronwyn J. Levvey, RN, Trevor J. Williams, MD, and Gregory I. Snell, MD

Objectives: Unilateral infiltrates on chest x-ray films are occasionally seen after bilateral lung transplantation. In the primary graft dysfunction grading system, the presence or absence of a radiographic abnormality is crucial in determining the incidence and severity of primary graft dysfunction. However, no consideration is given as to whether unilateral infiltrates have the same impact and relevance as bilateral infiltrates. This study aims to describe the incidence, features, and outcomes of posttransplant unilateral infiltrates and their effect on the novel primary graft dysfunction grading system.

Methods: Depending on posttransplant radiographic appearance, 144 patients who underwent bilateral lung transplantation were divided into 3 groups: no infiltrates (clear), unilateral infiltrates (unilateral), or bilateral infiltrates (bilateral).

Results: Radiographic abnormalities were seen in 43% of donors and 61% of posttransplant recipients (sensitivity = 76%, specificity = 50%). The percentage of recipients in the unilateral, clear, and bilateral groups was 26%, 39%, and 35%, respectively. Lower posttransplant oxygenation ($P < .05$), longer intubation hours, and more intensive care unit days ($P < .0001$) were seen in the bilateral compared with the unilateral and the clear groups. A significant difference in the prevalence of primary graft dysfunction ($P < .0001$) was seen, depending on whether unilateral infiltrates were included or excluded from the primary graft dysfunction grading.

Conclusions: The incidence of unilateral infiltrates is relatively high after bilateral lung transplantation. The early posttransplant outcome of the unilateral infiltrates is similar to that in the group having a clear chest x-ray film and significantly better than that in those with bilateral infiltrates. In bilateral lung transplantation, only bilateral infiltrates should be used as part of the definition of primary graft dysfunction.

From the Department of Allergy, Immunology, and Respiratory Medicine, Lung Transplant Unit, The Alfred Hospital, Melbourne, Australia.

Received for publication May 24, 2006; revisions received June 26, 2006; accepted for publication Aug 8, 2006.

Address for reprints: Gregory I. Snell, Department of Allergy, Immunology, and Respiratory Medicine, The Alfred Hospital, Commercial Road, Melbourne, Victoria 3004, Australia (E-mail: g.snell@alfred.org.au).

J Thorac Cardiovasc Surg 2006;132:1441-6
0022-5223/\$32.00

Copyright © 2006 by The American Association for Thoracic Surgery

doi:10.1016/j.jtcvs.2006.08.003

Although surgical techniques and medical management have been improved, primary graft dysfunction (PGD) remains a major cause of early morbidity and mortality after lung transplantation.¹⁻⁹ To assist with diagnosis and research into this problem, the International Society for Heart and Lung Transplantation (ISHLT) Working Group on Primary Graft Dysfunction has recently reported a standardized consensus defining criteria of PGD, which is based on the recipient oxygenation ratio and presence of radiographic abnormality.¹⁰

Abbreviations and Acronyms

ECMO	= extracorporeal membrane oxygenation
Fio ₂	= inspired oxygen consumption
ICU	= intensive care unit
ISHLT	= International Society for Heart and Lung Transplantation
PaO ₂	= arterial oxygen tension
PGD	= primary graft dysfunction
T	= time

Unilateral infiltrates on chest x-ray films are occasionally seen after bilateral lung transplantation. In the absence of unilateral pulmonary venous anastomotic obstruction, pulmonary contusion, hemorrhage, atelectasis, or pneumonia, this phenomenon may be due to unilateral ischemia-reperfusion injury.

Theoretically, in the absence of cardiopulmonary bypass, during the second lung implantation the newly implanted first lung is exposed to the entire cardiac output with resultant doubling of normal pulmonary arterial blood flow, pulmonary hypertension, and increased microvascular hydrostatic pressure.¹¹ In the first lung, this might amplify ischemia-reperfusion injury, resulting in a unilateral radiographic infiltrate; however, the actual incidence and etiology of these unilateral infiltrates remain unknown.

In the official ISHLT PGD grading system, the presence or absence of a radiographic abnormality has a critical role in determining the incidence and severity of PGD, as the absence of radiographic infiltrates is considered as grade 0 even if the ratio of arterial oxygen tension and inspired oxygen consumption (PaO₂/Fio₂) is less than 300.¹⁰ It is noted that this definition of PGD mimics that of the acute respiratory distress syndrome, which is based on bilateral disease. In this grading system, no consideration is given as to whether a unilateral infiltrate has the same impact and relevance as a bilateral infiltrate.

We therefore hypothesized that consideration of unilateral radiographic infiltrates as either “present” or “absent” in bilateral lung transplantation might influence the apparent severity of the PGD grading when compared with a clear chest x-ray film or one with bilateral infiltrates. Therefore, this study aims to describe the incidence, features, and outcomes of unilateral infiltrates on chest x-ray films and their effect on the novel PGD grading system.

Patients and Methods

From January 2000 to March 2006, 159 bilateral lung transplants were performed at The Alfred Hospital; 144 patients were included in this study because complete donor and recipient radiographic information on 15 patients was not available and these patients were therefore excluded.

Study Group

All patients were divided into 3 groups depending on radiographic appearance: no infiltrates (clear group), unilateral infiltrates (unilateral group), or bilateral infiltrates (bilateral group). The presence or absence of radiographic infiltrates consistent with reperfusion edema was assessed by blinded reviewers at the time of arrival in the intensive care unit (ICU) (T 0), at 24 hours (T 24), and at 48 hours (T 48) after transplant. On the basis of the radiographic features (clear, unilateral, or bilateral), 3 patient groups were analyzed at each time point (T 0 to T 48).

Primary Graft Dysfunction Grading

Details of the grading of PGD severity have been described elsewhere.¹⁰ In brief, the classification scheme is based on the chest x-ray film and PaO₂/Fio₂: grade 0, PaO₂/Fio₂ greater than 300 without radiographic infiltrates; grade 1, PaO₂/Fio₂ greater than 300 with radiographic infiltrates; grade 2, PaO₂/Fio₂ between 200 and 300 with radiographic infiltrates; and grade 3, PaO₂/Fio₂ less than 200 with radiographic infiltrates. There are other specific inclusion/exclusion criteria: a requirement for supplemental oxygen via nasal cannula or with an Fio₂ less than 0.3 is graded as 0 or 1 depending on radiographic features; the absence of radiographic infiltrates is graded as grade 0 (even if PaO₂/Fio₂ ratio < 300); the requirement of extracorporeal membrane oxygenation (ECMO) or mechanical ventilation with Fio₂ greater than 0.5 on nitric oxide beyond 48 hours after transplant is graded as grade 3. Furthermore, when grading beyond 48 hours, venous anastomotic obstruction, pneumonia, hyperacute rejection, and cardiogenic pulmonary edema should be excluded or assessed separately.

Donor Assessment and Management

The lung donor assessment and management have been described elsewhere.¹²⁻¹⁵ Preoperative immunologic evaluation including donor-recipient T-cell and B-cell cross-matching was routinely performed and found to be negative in all cases. Active donor management, including an initial bronchoscopic examination and repeated suctioning, physiotherapy, revision of antibiotic therapy, and fluid management, are usually undertaken to optimize the donor for transplantation. A repeat assessment, including chest x-ray films and serial arterial blood gases, may need to be undertaken after donor management changes before a final decision is made to accept or decline donor organs.

Donor Lung Procurement and Preservation

Lung procurement and preservation followed previously described procedures.^{16,17} Perfadex (Kabi Pharmacia, Uppsala, Sweden) replaced Euro-Collins preservation solution in September 2004. An intravenous infusion of prostacyclin (Flolan; Wellcome, Sydney, Australia) at 40 to 80 ng · kg⁻¹ · min⁻¹ for approximately 10 minutes before crossclamp was performed when Euro-Collins solution was used for lung preservation. A single antegrade flush with cold preservation solution followed by heart-lung en bloc procurement was routinely performed.

Lung Transplant Surgical Technique and Perioperative Management

Lung transplant procedures have been described elsewhere.^{18,19} Cardiopulmonary bypass was only routinely performed in our

TABLE 1. Demographics of the donor factor in 144 bilateral lung transplant recipients

Variables	Radiographic infiltrates (T 0)			P
	Unilateral (n = 38)	Clear (n = 56)	Bilateral (n = 50)	
Donor factor				
Age (y)	36 ± 2	35 ± 2	39 ± 2	>.2
Sex (M/F)	27/11	30/26	28/22	>.2
Smoking history > 20 pack-years	6	5	8	>.2
Cause of death				>.2
CVA	19	30	22	
Trauma	14	14	16	
Anoxia	3	11	8	
Others	2	1	4	
Radiographic abnormality	20	15	27	.005
Pao ₂ /Fio ₂ ratio	470 ± 17	471 ± 13	450 ± 12	>.2
Unexpected pulmonary emboli (yes/no)	6/13	4/27	17/14	.003

Continuous data are expressed as mean ± SEM. T 0, at the time of arrival at ICU; CVA, cerebrovascular accident; Pao₂/Fio₂, ratio of arterial oxygen tension and inspired oxygen consumption. P values for donor cause of death were given by overall comparison.

institution for heart-lung transplantation and only otherwise considered when intolerance of single lung ventilation due to hemodynamic instability was seen. As a part of lung graft preparation, a retrograde exploratory flush was performed to detect any unexpected donor pulmonary artery embolism before implantation.⁴ Before completion of implantation, retrograde followed by antegrade reperfusion and deairing was performed via untied pulmonary vascular anastomotic suture lines. An evaluation of the venous anastomosis by transesophageal echocardiogram was routinely performed at the end of the operation. An additional reconstruction/repair of the pulmonary venous anastomosis was performed when the donor left atrial cuff was inadequate for single end-to-end anastomosis.¹⁶ Postoperative management in the ICU was performed to ensure satisfactory end-organ perfusion while maintaining a relatively low filling pressure (cardiac index > 2.4, pulmonary capillary wedge pressure < 10 mm Hg, and central venous pressure < 7 mm Hg). Patients with PGD received a standardized evaluation (including transesophageal echocardiogram) and therapy with increasing complexity depending on the degree of ventilatory and hemodynamic compromise (including ECMO and inhaled nitric oxide).²⁰ Details of immunosuppression and transbronchial lung biopsy protocols are described elsewhere.^{3,4,12-14}

Data Collection

Data were retrieved from the transplant database and a review of ICU and donor records. Data of arterial blood gas analysis and the existence of infiltrates on chest x-ray film at each time point of T 0, T 24, and T 48 after transplant were used to define PGD grade.

Statistical Analysis

Continuous data were reported as mean ± standard error of the mean, whereas categorical data were reported as count and proportions. Comparison among groups was performed with 1-way analysis of variance followed by post hoc analysis with the Fisher test for parametric continuous variables and the χ^2 test for categorical variables. Duration of intubation and length of ICU stay were estimated by the Kaplan-Meier method and the curves were analyzed by use of log-

rank test. For analysis of pulmonary arterial pressure during the second lung implantation, data from patients without cardiopulmonary bypass were used. Intubation hours and ICU days were both found to be well approximated by a log-normal distribution. Univariate correlation analysis between PGD grades and log-transformed intubation hours and log-transformed ICU days was performed with Pearson correlation coefficients. Logistic regression analysis was used to estimate the relationship of individual factors with the occurrence of unilateral radiographic infiltrates. Analysis was performed with Statview 5.0 software package (SAS Institute, Inc, Cary, NC).

Results

Incidence of Radiographic Infiltrates

Overall, chest x-ray abnormalities were seen in 62 of 144 donors (43%) before procurement and 88 of 144 recipients (61%) after transplant at T 0 (sensitivity = 76%, specificity = 50%). The percentage of recipients in the various unilateral, clear, and bilateral infiltrate groups was 26%, 39%, and 35% (at T 0), 30%, 32%, and 38% (at T 24), and 23%, 29%, and 48% (at T 48), respectively. Approximately 23% of the recipients with a clear donor chest x-ray film and 32% of the recipients with an abnormal donor chest x-ray film had unilateral radiographic infiltrates after transplant at T 0. The percentage of recipients with bilateral infiltrates increased with time after transplant.

Donor and Recipient Demographics

Detailed demographics including donor, recipient, and operative factors in the 3 groups at T 0 are shown in Tables 1 and 2. Significant differences among the 3 groups are seen in the presence of an abnormal donor chest x-ray film ($P = .005$), donor unexpected pulmonary emboli ($P = .003$), recipient underlying disease ($P = .02$), and cardiopulmonary bypass use ($P < .001$). There were no significant differences in donor Pao₂/Fio₂ before procurement and pulmonary arterial pressure during the second lung implantation ($P > 0.2$).

TABLE 2. Demographics of the recipient and operative factors in 144 bilateral lung transplant recipients

Variables	Radiographic infiltrates (T 0)			P
	Unilateral (n = 38)	Clear (n = 56)	Bilateral (n = 50)	
Recipient factor				
Age (y)	40 ± 2	41 ± 2	42 ± 2	>.2
Sex (M/F)	21/17	32/24	31/19	>.2
Diagnosis				.02
COPD	11	20	12	
CF	23	27	18	
ILD	3	7	12	
PH	1	2	8	
Operative factor				
First implanted lung (left/right)	25/13	38/18	28/21	>.2
PAP during second lung implantation (mm Hg)	32 ± 2	33 ± 2	36 ± 3	>.2
CPB use	5	6	19	<.001
Ischemic time				
First implanted lung (min)	281 ± 19	280 ± 15	278 ± 18	>.2
Second implanted lung (min)	391 ± 21	378 ± 15	386 ± 19	>.2

COPD, Chronic obstructive pulmonary disease; CF, cystic fibrosis; ILD, interstitial lung disease; PH, pulmonary hypertension; PAP, pulmonary arterial pressure; CPB, cardiopulmonary bypass. P values for underlying disease were given by overall comparison.

Posttransplant Oxygenation

Recipient $\text{PaO}_2/\text{FiO}_2$ after transplant is shown in Figure 1. The $\text{PaO}_2/\text{FiO}_2$ in the unilateral and clear groups was significantly greater than that in the bilateral group at T 0 and T 48. $\text{PaO}_2/\text{FiO}_2$ in the unilateral group tended to be greater ($P = .07$) than that in the bilateral group at T 24, and the $\text{PaO}_2/\text{FiO}_2$ in the clear group was significantly greater ($P < .0001$).

Duration of Intubation and Length of ICU Stay

The percentage of recipients remaining intubated and the percentage of recipients remaining in the ICU were significantly different among the 3 groups ($P < .0001$, Figure 2). The percentages of the recipients remaining intubated 24 hours after transplantation in the unilateral, clear, and bilateral groups were 22%, 24%, and 62%, respectively. The percentages of the recipients remaining in the ICU 7 days after transplant in the unilateral, clear, and bilateral groups were 5%, 7%, and 44%, respectively. The curves in the unilateral and clear groups were

similar, with a lower percentage of recipients remaining intubated and a lower percentage staying in the ICU when compared with those in the bilateral group.

PGD Grading

When a unilateral radiographic infiltrate was considered as “present,” the incidence of PGD grades 0, 1, 2, and 3 in the unilateral group was 0%, 38%, 16%, and 46% (at T 0), 0%, 62%, 23%, and 15% (at T 24), and 0%, 70%, 20%, and 10% (at T 48), respectively. When a unilateral radiographic infiltrate

Figure 1. Oxygenation ratio ($\text{PaO}_2/\text{FiO}_2$) within the first 48 hours after transplant.

Figure 2. A, Percentage of patients remaining intubated versus time (hours) after transplant. B, Percentage of patients remaining in ICU versus time (days) after transplant.

Figure 3. Comparing the incidence of various PGD grades (0 to 3) using a definition in which unilateral radiographic infiltrates were either characterized as “present” or “absent” (ie, the current grading system versus a proposed modification). *Comparing the incidence of PGD grade 3 between “present” and “absent” ($P = .02$).

was considered as “absent,” the incidence of PGD grade in the unilateral group was 100% (grade 0) at T 0, 98% (grade 0) and 2% (grade 3) at T 24, and 90% (grade 0) and 10% (grade 3) at T 48, respectively. In the unilateral group, a small number of patients were classified as PGD grade 3 owing to the requirement for ECMO ($n = 1$) at T 24 or the requirement for ECMO ($n = 2$) or nitric oxide ($n = 1$) at T 48. The effect of incorporating the unilateral radiographic infiltrate into the apparent overall PGD grading is shown in Figure 3. A significant difference in the incidence of severe PGD grade 3 is seen at T 0 ($P = .02$), depending on whether or not a unilateral infiltrate is included or excluded from the PGD grading.

Correlation Between PGD Grade (T 0) and Early Outcomes

Univariate correlation analysis between the early outcomes and PGD grades (0 to 3) at T 0 defined with unilateral infiltrates as either “present” or “absent” was also performed. The correlation coefficients (r) between the intubation hours and PGD grades (defined with the unilateral infiltrate included/excluded in the definition) were as follows: unilateral infiltrate “present” ($r = 0.34$, $P < .0001$); unilateral infiltrate “absent” ($r = 0.47$, $P < .0001$). The correlation coefficients between the ICU days and PGD grades were as follows: unilateral infiltrate “present” ($r = 0.33$, $P < .0001$); unilateral infiltrate “absent” ($r = 0.51$, $P < .0001$).

Risk Factor Analysis for Unilateral Infiltrates

In the unilateral group, 1 patient required pulmonary venous anastomotic repair/reconstruction because of an inadequate

donor left atrial cuff, with a widely patent anastomosis and adequate blood flow through the anastomosis confirmed by postoperative transesophageal echocardiography. The incidence of unilateral infiltrates seen in the individual paired right versus left lungs was 56% versus 44%, and in the first versus second implanted lungs was 41% versus 59%. Overall, no donor, recipient, or operative factors were significantly associated with the development of unilateral infiltrates.

Discussion

The results of this study demonstrate that the incidence of unilateral radiographic infiltrates is relatively high during the first 48 hours after bilateral lung transplant. Importantly, however, the early posttransplant outcomes of the patients with unilateral infiltrates are significantly better than those of the patients with bilateral infiltrates and indeed similar to those of patients with clear chest x-ray films. For PGD grading purposes, the different considerations of a unilateral infiltrate as being either “present” or “absent” significantly affect the subsequent PGD grade and the relation of that grade with intubation time and ICU stay.

This study demonstrates that a high proportion of donor chest x-ray films are abnormal and that this contributes to an abnormal posttransplant chest x-ray film (sensitivity = 76%, specificity = 50%). Although the present study is limited in not having sufficient detail available to determine whether donor radiographic infiltrates were unilateral or bilateral, interestingly, an abnormal donor chest x-ray film appears to be a more potent predictor of subsequent recipient $\text{PaO}_2/\text{FiO}_2$ than the traditional measure of preoperative donor $\text{PaO}_2/\text{FiO}_2$.^{12,21}

An abnormal donor x-ray film cannot be the only explanation for the development of posttransplant unilateral infiltrates, because 23% of the patients with a clear donor chest x-ray film still had unilateral infiltrates after transplant. Indeed, many factors, including the use of cardiopulmonary bypass, pulmonary venous anastomotic obstruction, hyperacute rejection, ischemia-reperfusion injury, cardiac failure, atelectasis, and pneumonia, potentially contribute to the development of radiographic infiltrates within the first 48 hours after transplant.^{1-9,22,23}

Theoretically, without cardiopulmonary bypass, the newly implanted first lung is exposed to an entire cardiac output, which may result in double the normal pulmonary arterial blood flow, pulmonary hypertension, and increased microvascular hydrostatic pressure during the second lung implantation. In contrast, the second implanted lung is susceptible to a longer ischemic time with resultant greater ischemic damage. These might contribute to amplify ischemia-reperfusion injury and result in unilateral radiographic infiltrates. Sheridan and colleagues¹¹ investigated the effect of bilateral lung transplantation on the first transplanted lung in 19 patients without cardiopulmonary bypass. The authors found no difference in radiographically apparent

lung injury at 1 and 24 hours after transplant and in quantitative lung perfusion scan at 3 to 12 months after transplant when comparing the first and second implanted lungs. In the current study, no donor, recipient, or operative factors (including the first or second implanted lungs and the side of implanted lungs) could be associated with the development of unilateral infiltrates after transplant. Further study is needed to clarify the cause of posttransplant unilateral infiltrates on chest x-ray films.

Whether radiographic changes are included or excluded from the PGD diagnostic criteria has a critical role in determining the apparent incidence and severity of PGD, particularly for grade 0. In the current study, the consideration of radiographic changes has an impact on the apparent incidence of PGD grade 0 across the whole first 48 hours after transplant, although there was also a significant effect on the apparent incidence of PGD grade 3 at T 0 (Figure 3). In fact, the incidence of PGD grade 3 in bilateral lung transplantation generally decreases over time postoperatively.²³ Moreover, in this study, beyond 24 hours, and especially beyond 48 hours, a number of patients in PGD grade 3 fell into this category primarily because of the requirement for ECMO or nitric oxide. Therefore, the impact of the radiographic appearance on PGD grade 3 may be the strongest at T 0 and decrease beyond 24 hours after transplant.

In conclusion, the incidence of unilateral radiographic infiltrates is relatively high throughout the first 48 hours after bilateral lung transplantation. The donor radiographic abnormality plays a role in the recipient radiographic infiltrates, but the mechanism of the unilateral infiltrates remains unknown. The early posttransplant outcomes of those patients with unilateral infiltrates are similar to those with a clear chest x-ray film and significantly better than those with bilateral infiltrates. Therefore, in bilateral lung transplantation only bilateral infiltrates should be used as part of the PGD definition.²⁴

We gratefully acknowledge Sharon Daly for assembling and verifying the clinical data, and we also extend our appreciation to members of the Heart and Lung Transplant Service, The Alfred Hospital, for their assistance.

References

- Christie JD, Kotloff RM, Pochettino A, Arcasoy SM, Rosengard BR, Landis JR, et al. Clinical risk factors for primary graft failure following lung transplantation. *Chest*. 2003;124:1232-41.
- Thabut G, Vinatier I, Stern JB, Lesèche G, Loirat P, Fournier M, et al. Primary graft failure following lung transplantation: predictive factors of mortality. *Chest*. 2002;121:1876-82.
- Oto T, Levvey B, Pilcher DV, Bailey MJ, Snell GI. Evaluation of the oxygenation ratio in the definition of early graft dysfunction after lung transplantation. *J Thorac Cardiovasc Surg*. 2005;130:180-6.
- Oto T, Rabinov M, Griffiths AP, Whitford H, Levvey BJ, Esmore DS, et al. Unexpected donor pulmonary embolism affects early outcomes after lung transplantation: a major mechanism of primary graft failure? *J Thorac Cardiovasc Surg*. 2005;130:1446-52.
- Lee KH, Martich GD, Boujoukos AJ, Keenan RJ, Griffith BP. Predicting ICU length of stay following single lung transplantation. *Chest*. 1996;110:1014-7.
- Khan SU, Salloum J, O'Donovan PB, Mascha EJ, Mehta AC, Matthay MA, et al. Acute pulmonary edema after lung transplantation: the pulmonary reimplantation response. *Chest*. 1999;116:187-94.
- Meyers BF, de la Morena M, Sweet SC, Trulock EP, Guthrie TJ, Mendeloff EN, et al. Primary graft dysfunction and other selected complications of lung transplantation: a single-center experience of 983 patients. *J Thorac Cardiovasc Surg*. 2005;129:1421-9.
- Chatila WM, Furukawa S, Gaughan JP, Criner GJ. Respiratory failure after lung transplantation. *Chest*. 2003;123:165-73.
- King RC, Binns OA, Rodriguez F, Kanithanon RC, Daniel TM, Spotnitz WD, et al. Reperfusion injury significantly impacts clinical outcome after pulmonary transplantation. *Ann Thorac Surg*. 2000;69:1681-5.
- Christie JD, Carby M, Bag R, Corris P, Hertz M, Well D. Report of the ISHLT Working Group on Primary Graft Dysfunction part II: definition. A consensus statement of the International Society for Heart and Lung Transplantation. *J Heart Lung Transplant*. 2005;24:1454-9.
- Sheridan BC, Hodges TN, Zamora MR, Lynch DL, Brown JM, Campbell DN, et al. Acute and chronic effects of bilateral lung transplantation without cardiopulmonary bypass on the first transplanted lung. *Ann Thorac Surg*. 1998;66:1755-8.
- Gabbay E, Williams TJ, Griffiths AP, Macfarlane LM, Kotsimbos TC, Esmore DS, et al. Maximizing the utilization of donor organs offered for lung transplantation. *Am J Respir Crit Care Med*. 1999;160:265-71.
- Williams TJ, Snell GI. Organ procurement—strategies to optimize donor availability. *Semin Respir Crit Care Med*. 2001;22:541-50.
- Snell GI, Griffiths A, Macfarlane L, Gabbay E, Shiraishi T, Esmore DS, et al. Maximizing thoracic organ transplant opportunities: the importance of efficient coordination. *J Heart Lung Transplant*. 2000;19:401-7.
- de Perrot M, Snell GI, Babcock WD, Meyers BF, Patterson GA, Hodges TN, et al. Strategies to optimize the use of currently available lung donors. *J Heart Lung Transplant*. 2004;23:1127-34.
- Oto T, Rabinov M, Negri J, Marasco S, Rowland M, Pick A, et al. Techniques of reconstruction for inadequate donor left atrial cuff in lung transplantation. *Ann Thorac Surg*. 2006;81:1199-204.
- de Perrot, Keshavjee S. Lung preservation. *Semin Thorac Cardiovasc Surg*. 2005;16:300-8.
- Esmore DS, Brown R, Buckland M, Briganti EM, Fetherston GJ, Rabinov M, et al. Techniques and results in bilateral sequential single lung transplantation. *J Card Surg*. 1994;9:1-14.
- Oto T, Rabinov M, Rosenfeldt F, Esmore DS. Extended pericardiectomy avoids cardiopulmonary bypass during bilateral sequential lung transplantation. *J Thorac Cardiovasc Surg*. 2005;129:466-7.
- Oto T, Rosenfeldt F, Rowland M, Pick A, Rabinov M, Prevolos A, et al. Extracorporeal membrane oxygenation after lung transplantation: evolving technique improves outcomes. *Ann Thorac Surg*. 2004;78:1230-5.
- McGiffin DC, Zorn GL Jr, Young R Jr, Kirklin JK, Leon KJ, Wille KM, et al. The intensive care unit oxygen challenge should not be used for donor lung function decision-making. *J Heart Lung Transplant*. 2005;24:1902-5.
- Barr MI, Kawut SM, Whelan TP, Girgis R, Böttcher H, Sonett J, et al. Report of the ISHLT working group on primary lung graft dysfunction part IV: recipient-related risk factors and markers. *J Heart Lung Transplant*. 2005;24:1468-82.
- de Perrot M, Bonser RS, Dark J, Kelly RF, McGiffin D, Menza R, et al. Report of the ISHLT working group on primary lung graft dysfunction part III: donor-related risk factors and markers. *J Heart Lung Transplant*. 2005;24:1460-7.
- Oto T, Griffiths AP, Levvey BJ, Pilcher DV, Williams TJ, Snell GI. Definitions of primary graft dysfunction after lung transplantation: differences between bilateral and single lung transplantation. *J Thorac Cardiovasc Surg*. 2006;132:140-7.