Assessment of lungs for transplantation: a stepwise analysis of 476 donors

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Abstract

Objective: This study aims to assess the suitability rates and the causes of lung-donor refusal, to determine which factors could be improved to expand the donor pool available for transplantation (LTx). Methods: Lung donors offered to our Lung Transplantation Unit from October 1993 to December 2007 were reviewed to assess the causes of unsuitability. The donor-lung evaluation was divided into three stages: stage 1 (PaO2/FiO2 ratio, chest X-ray, bronchoscopic findings), stage 2 (donor-lung inspection and palpation) and stage 3 (assessment of grafts after harvesting). Variables from donors and recipients were analysed and compared between 1993–2001 (group A) and 2002–2007 (group B). An additional subgroup of extended donors was analysed to assess the recipient outcomes. Results: A total of 476 lung donors were assessed (278 men and 198 women; mean age 29 ± 13 years). Causes of death were trauma in 255, intracranial bleeding in 202 and others in 19. As many as 273 donors were suitable for LTx (57%; 162 double LTx and 111 single LTx). Acceptability rates were 68%, 58% and 57% at stages 1, 2 and 3, respectively, and were significantly higher in group B than in group A (overall: 64% vs 54%; stage 2: 91% vs 79%), with no changes in stages 1 and 3. Abnormal bronchoscopy precluded LTx in 79 cases (16%). Group B donors were older (p = 0.000), ventilated longer (p = 0.07) and with shorter ischaemic times (p = 0.000) than group A. In the recipients, primary graft dysfunction (PGD) (17% vs 15%) and 30-day mortality (11% vs 6%) did not differ between both the groups. No differences were observed between extended and ideal donors in terms of recipient 30-day mortality (extended 6% vs ideal 9%; p = 0.315) and development of PGD (extended 21% vs ideal 15%; p = 0.342). Conclusions: Despite the high rate of organ donation in Spain, the acceptability rate remains low (57%), mainly due to failure to meet the criteria for acceptance at the early stages of donor-lung assessment. Improvements in multi-organ donor care must be made to expand the lung-donor pool. The use of extended donors does not seem to have a negative impact on recipient outcomes.

Keywords: Lung transplantation; Donors; Donor assessment; Lung procurement; Extended donors

1. Introduction

The shortage of donor organs is a major problem for all solid organ transplantation programmes. This shortage, however, is more dramatic in lung transplantation (LTx), reflecting the fact that the lungs are very susceptible of being compromised in brain-dead patients. This has led to an increasing gap between the number of suitable lung donors and the number of patients on waiting lists for LTx.

Based on data from the Organ Procurement and Transplantation Network (OPTN), of 34,081 donors in year 2008, only 2599 lungs were recovered from 1388 donors suitable for LTx (http://www.unos.org/data/about/viewDataReports.asp (accessed, 11 April 2009)). In the Eurotransplant zone, among 2003 cadaveric donors reported in the year 2008, only 508 (25%) served as lung donors (http://www.eurotransplant.org/?id=peryear_public (accessed 11 April 2009)). In Spain, data from the Organización Nacional de Trasplantes (ONT) revealed that, despite the increasing donation rate, reaching 34.2 donors per million population in 2008, the number of lungs suitable for transplantation remained low (from 1577 cadaveric donors, 84% were actual multi-organ donors, from which only 21.3% were offered for LTx) (http://www.ont.es (accessed 11 April 2009)).

On the one hand, a number of approaches have been advocated to improve the number of lung transplants performed, such as transplantation of organs with extended criteria [1], living-related donor lungs [2] and non-heart-beating donors [3]. On the other hand, there has been an effort directed towards an active medical management of potential cadaveric lung donors to ameliorate the deleterious effects of brain death on lung function.

Both the causes (e.g., trauma) and the consequences (e.g., aspiration and oedema) of brain death may result in...
deteriorating pulmonary function, and, interestingly, those factors that are not inherent to lung-donor characteristics (such as age and smoking history), but those acquired as a result of the trauma itself (e.g., contusion, haemodynamic instability and neurogenic oedema) or secondary to their medical management at the intensive care unit (ICU) (e.g., blood transfusions, fluid overload, mechanical ventilation, atelectasis and aspiration pneumonia), are susceptible to be managed and modified to recover donors initially deemed not suitable for transplantation.

The initial experience of our transplant group analysing 280 lung donors demonstrated that only 54.7% were suitable for transplantation, mainly due to the failure to meet the criteria for acceptance at the early stages of donor-lung assessment [4]. In the present series, we re-assess the issue, by examining the current donation rate and the causes of donor unsuitability at three stages of the lung-donor assessment, to determine which factors could be improved to expand the donor pool available for transplantation.

2. Patients and methods

2.1. Study population

From 473 donors offered to our Lung Transplant Program between October 1993 and December 2007, 440 donors completed the three-staged assessment and were included in the study.

A total of 273 recipients were reviewed. There were 156 double LTx, 94 single LTx, three cadaveric lobar LTx, three double LTx, 94 single LTx, three cadaveric lobar LTx, three combined liver–LTx and 17 twinned single LTx with another hospital.

2.2. Study design

For the purposes of this study, the donor-lung assessment was divided into three stages.

- Stage 1: Assessment of PaO2/FiO2 ratio, chest X-ray and bronchoscopic findings.
- Stage 2: Donor-lung inspection and palpation in the operating field.
- Stage 3: Assessment of grafts after harvesting, by inspection and palpation of the posterior aspect of lungs, and evaluation of the vascular cuffs while performing an additional retrograde second flushing of the preservation solution.

Our early experience in donor-lung assessment was analysed by using this study design previously [4]. This group of early donors (group A) was then compared with a prospective cohort of donors assessed between 2002 and 2007 (group B). No significant changes in the donor-procurement technique were done throughout the study period, other than the introduction of Perfadex® (Vitrolife, Göteborg, Sweden) instead of Eurocollins® as the preservation solution, from year 2002 onwards.

A subsequent analysis of a subgroup of cases fulfilling the criteria of extended donors was done to compare recipient outcomes between extended and ideal donors.

2.3. Donor-lung assessment and management

All potential donors offered to our Lung Transplant Unit were initially assessed by the members of our transplant staff, recording and discussing general donor data provided by the National Transplant Coordination (e.g., age, sex, weight, height, thoracic measurements, cause of death, ABO group, chest X-ray findings, PaO2/FiO2 ratio, serological status and co-morbidities). After checking the initial suitability of the donor and the availability of an appropriate recipient, the donor surgical team travelled to the donor hospital for on-site assessment and management and organ retrieval. In eight donors, the assessment and retrieval were done by another transplant group, and the lungs sent to our hospital for implantation.

A fibre-optic bronchoscopy with bronchoalveolar lavage (BAL) was performed on the majority of potential donors by a staff surgeon. In some cases, bronchoscopy was not performed due to technical reasons (paediatric donors with small tracheal lumen and unavailability of an appropriate bronchoscope), donor instability on arrival of the retrieval team (with insufficient time to perform the procedure) or donors assessed and harvested by other transplant teams who do not perform it routinely.

2.4. Donor selection criteria

In general, donors accepted for transplantation met the standard criteria for donor acceptability [5]: age less than 55 years, PaO2/FiO2 ratio above 300 mmHg, clear chest radiographs, a tobacco history of less than 20 pack-years, absence of purulent secretions or aspiration on bronchoscopy and absence of macroscopic lung abnormalities at the time of retrieval.

However, in selected cases, donors older than 55 years, with mild unilateral abnormalities in chest radiographs, with presumed smoking habit above 20 pack-years, with some amount of secretions in the airways or limited signs of pulmonary parenchymal contusion were also deemed suitable for transplantation. Nevertheless, lungs with PaO2/FiO2 less than 300 mmHg at the time of retrieval were not considered acceptable for transplantation.

2.5. Lung procurement and preservation

The donor lung was procured following the standard technique of combined cardiopulmonary extraction [6]. Immediately after lung harvesting, an additional retrograde second flushing of the preservation solution was given to optimise lung preservation by perfusing the bronchial circulation [7]. The preservation solution used was modified Eurocollins® until year 2001, and thereafter Perfadex® solution (Vitrolife, Göteborg, Sweden) was introduced routinely.

2.6. Transplantation procedure and postoperative management

In the recipients, either single- or double-lung transplantation was performed through a posterolateral thoracotomy or a clamshell incision. On completion of the bronchial anastomosis, the pulmonary artery and the left atrium were
anastomosed in a standard fashion. Cardiopulmonary bypass was instituted in case of inability to maintain the recipient on one lung during pneumonectomy or implantation or in case of graft dysfunction after the first lung was implanted. After completion of the transplantation, a fibre-optic bronchoscopy was performed to assess the viability of the bronchial anastomoses and to aspirate secretions in the airways.

Immunosuppression was based on a triple therapy: cyclosporine or tacrolimus, azathioprine or mycophenolate mofetil and steroids. Methylprednisolone administration was begun intravenously in the operating room (10 mg kg\(^{-1}\) before reperfusion). Immediately after completion of the lung transplantation, cyclosporine (Sandimmun\(^\circledR\); Novartis, Basle, Switzerland) was started at sufficient doses to achieve blood levels of 350–400 ng ml\(^{-1}\), and methylprednisolone was maintained at diminishing doses until the fourth postoperative day, to be switched to deflazacort (Dezacor\(^\circledR\); Hoechst Marion Roussel, Barcelona, Spain) (1.5 mg kg\(^{-1}\) per day). Azathioprine (Imurel\(^\circledR\); Medeva Pharma, Madrid, Spain) (2 mg kg\(^{-1}\) per day) was started 48–72 h postoperatively after obtaining donor and recipient cultures. However, mycophenolate mofetil (Cellcept\(^\circledR\); Roche Lab., Inc. Nutley, NJ, USA) (2–3 g per day) instead of azathioprine was given in some patients. Patients with recurrent acute rejection episodes, cyclosporine-related toxicity or those who developed bronchiolitis obliterans syndrome were switched from cyclosporine to tacrolimus (Prograf\(^\circledR\); Fujisawa, Killorglin, Kerry, Ireland) at sufficient doses to achieve blood levels of 10–20 ng ml\(^{-1}\). No cytotoxic therapy was systematically used.

Antimicrobial therapy was administered based on antibiotic sensitivities from preoperative sputum cultures of the recipient and from the donor bronchoaspirate. Postoperative bronchoscopies were performed 24–48 h post-transplant, at the time of extubation and at discharge, and thereafter whenever a clinical suspicion of infection or rejection appeared. Late postoperative routine surveillance bronchoscopies were not performed.

2.7. Definitions

Extended donors were considered when at least two of the following were present: donors older than 55 years, mild abnormalities in chest X-ray, evidence of mucopurulent secretions at bronchoscopy and smoking habit above 20 pack-years. Primary graft dysfunction (PGD) was defined according to the previously published criteria [8].

2.8. Data collection

Donor factors recorded were age, sex, cause of death, smoking habit, chest X-ray and bronchoscopic findings, PaO₂/FiO₂ at offer and retrieval, donor BAS at offer, operative findings and rates of acceptability.

Recipient factors were age, sex, indication and type of LTx, use of extracorporeal circulation, ischaemic times, immediate postoperative graft function and 30-day mortality.

2.9. Statistical analysis

Demographic characteristics of donors from groups A and B and the radiological, bronchoscopic and laboratory findings were analysed and compared. Pearson’s chi-square test and Fisher’s exact test were used to assess differences between categorical variables. Unpaired t test was used to compare means between two quantitative variables from normally distributed data, and Mann–Whitney test for non-normally distributed data. Continuous variables are expressed as means ± standard deviation. Categorical variables are expressed as counts and proportions with 95% confidence intervals (95% CIs). Differences with p values less than 0.05 were considered significant. The statistical analysis was performed using SPSS (SPSS 11.0 for Windows: SPSS Inc, Chicago, IL, USA).

3. Results

3.1. Donor population

A total of 476 donors were recorded. There were 278 males and 198 females, with mean age of 28.8 ± 13.4 years (10–62 years). Causes of death were trauma in 255, intracranial bleeding in 202 and other causes in 19 donors. Donor characteristics and general findings of donor assessment are summarised in Table 1.

3.2. Staged donor analysis (Fig. 1)

From 476 donors offered, 13 were not considered for on-site assessment due to presumed long ischaemic times, no
adequate recipients, simultaneous lung transplants or unavailability of ICU beds. Twenty-three potential donors did not complete the assessment due to donor cardiac arrest or donor instability that precluded the completion of assessment and harvesting. In seven cases, donor assessment and retrieval were not performed because of clinical problems in the recipient, with insufficient time to re-offer the donor to another transplant team.

Validity rate at stage 1 was 68% (95% CI, 64—72%). A total of 115 donors were considered unsuitable for transplantation due to low PaO2/FiO2 ratio (47; 11%), abnormal chest X-ray findings (52; 12%) or abnormal bronchoscopic findings (79; 16%).

From 325 donors assessed at stage 2, 47 were considered unsuitable for transplantation (validity rate at stage 2: 58%; 95% CI, 54–62%) because of abnormal findings on surgical exploration, most frequently, the presence of extensive contusion and/or granulomatous lesions.

A total of 278 lung donors were harvested and assessed at stage 3 on the back table. Three donors were deemed unsuitable for transplantation due to technical errors during the retrieval procedure. Two donors presented extensive contusion of the posterior aspects of lung parenchyma and were also not considered for transplantation (validity rate at stage 3: 57%, 95% CI, 53–61%).

Among 273 final valid donors, 17 lungs were sent to another hospital for twinned single LTx. Eight donors were assessed and retrieved by other teams and grafts sent to another hospital for implantation. A total of 273 lung transplants were performed: 111 single LTx and 162 bilateral LTx, including three lobar LTx and three combined liver—LTx.

3.3. Comparisons between early donors (group A) and late donors (group B)

Donors from group B were older and were ventilated for longer periods than group B donors. Donor PaO2/FiO2 ratio, either at offer or at the time of harvesting, did not improve significantly with time. Conversely, the chest X-ray assessment demonstrated a higher incidence of pulmonary infiltrates or contusion in donors from group B than those from group A. Bronchoscopic examination was found to be normal in 83% of group B donors as opposed to only 54% of donors in group A. However, the incidence of donors with evidence of aspiration did not differ between groups (Table 2).

The overall validity rate was 54% (95% CI: 48–60%) in group A and 64% (95% CI: 57–71%) in group B (p = 0.013), with a significant improvement in validity rate at stage 2.

Table 2
Comparison between the two groups of donors (group A and group B) according to donor characteristics, findings on assessment, and validity rates.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Group A (n = 267)</th>
<th>Group B (n = 196)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>27 ± 13</td>
<td>33 ± 13</td>
<td>0.000</td>
</tr>
<tr>
<td>Intubation time (h)</td>
<td>38 ± 32</td>
<td>45 ± 55</td>
<td>0.074</td>
</tr>
<tr>
<td>Ischaemic time 1st graft (h)</td>
<td>341 ± 52</td>
<td>300 ± 54</td>
<td>0.000</td>
</tr>
<tr>
<td>Ischaemic time 2nd graft (h)</td>
<td>487 ± 67</td>
<td>440 ± 64</td>
<td>0.000</td>
</tr>
<tr>
<td>Twinned donors (%)</td>
<td>4 (1.5)</td>
<td>21 (15.3)</td>
<td>0.000</td>
</tr>
<tr>
<td>Donor assessment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PaO2/FiO2 (offer) (mmHg)</td>
<td>241 (88)</td>
<td>152 (77)</td>
<td>0.003</td>
</tr>
<tr>
<td>PaO2/FiO2 (harvest) (mmHg)</td>
<td>1 (0.3)</td>
<td>5 (2.5)</td>
<td>0.000</td>
</tr>
<tr>
<td>Pleural effusion/pneumothorax</td>
<td>13 (5)</td>
<td>7 (3.5)</td>
<td>0.000</td>
</tr>
<tr>
<td>Extensive atelectasis</td>
<td>5 (2)</td>
<td>7 (3.5)</td>
<td>0.000</td>
</tr>
<tr>
<td>Infiltrates/contusion</td>
<td>15 (5)</td>
<td>25 (13)</td>
<td>0.002</td>
</tr>
<tr>
<td>Chest radiographs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>116 (54)</td>
<td>143 (83)</td>
<td>0.031</td>
</tr>
<tr>
<td>Oedema</td>
<td>39 (18)</td>
<td>20 (6)</td>
<td>0.000</td>
</tr>
<tr>
<td>Pleural effusion/pneumothorax</td>
<td>16 (9)</td>
<td>0</td>
<td>0.000</td>
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<tr>
<td>Extensive atelectasis</td>
<td>1 (0.5)</td>
<td>5 (3.5)</td>
<td>0.000</td>
</tr>
<tr>
<td>Contusion</td>
<td>17 (9)</td>
<td>5 (3.2)</td>
<td>0.000</td>
</tr>
<tr>
<td>Donor characteristics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>143 (77)</td>
<td>128 (91)</td>
<td>0.013</td>
</tr>
<tr>
<td>Abnormal</td>
<td>42 (23)</td>
<td>12 (9)</td>
<td>0.001</td>
</tr>
<tr>
<td>Granulomas</td>
<td>16 (9)</td>
<td>0</td>
<td>0.000</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>6 (3)</td>
<td>0</td>
<td>0.000</td>
</tr>
<tr>
<td>Atelectasis</td>
<td>3 (1.6)</td>
<td>2 (1.4)</td>
<td>0.000</td>
</tr>
<tr>
<td>Nodules/masses</td>
<td>1 (0.5)</td>
<td>5 (3.5)</td>
<td>0.000</td>
</tr>
<tr>
<td>Foreign bodies</td>
<td>2 (1)</td>
<td>0</td>
<td>0.000</td>
</tr>
<tr>
<td>Inspection/palpation</td>
<td></td>
<td></td>
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<tr>
<td>Normal</td>
<td>143 (77)</td>
<td>128 (91)</td>
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<td>Contusion</td>
<td>17 (9)</td>
<td>5 (3.2)</td>
<td>0.000</td>
</tr>
</tbody>
</table>

* Number of cases, group A = 275, group B = 196.
* Number of cases, group A = 213, group B = 173.
* Number of cases, group A = 185, group B = 140.
Interestingly, validity rates at stage 1 did not differ between both the groups (Table 2).

3.4. Time-dependent changes of donor profile

Donor causes of death have evolved with time, cerebrovascular accidents becoming the most frequent over traumatic causes. In 2007, only 28% of donor deaths were traumatic as opposed to 72%, who suffered from cranial bleeding (Fig. 2).

Significant changes have been observed in donor assessment characteristics over time. In the past decade, the proportion of donors with mild-to-moderate pulmonary infiltrates or contusion seen at chest X-ray has increased significantly (Fig. 3A). In addition, before year 2001, the bronchoscopic examination was reported to be abnormal, with mucopurulent secretions or evidence of aspiration in more than 40% of donors (Fig. 3B). Similarly, in the early years, the surgical assessment of the donor lungs was deemed to be pathological in 30% of cases, with extensive contusion, lobar atelectasis or tuberculous granulomas (Fig. 3C).

Both overall and stage 2 validity rates have significantly improved with time. On the contrary, the rate of donor acceptance has remained unchanged at stage 1 throughout the period of study (Fig. 4).

Transplantation of single lungs from the same donor into two recipients (twinning procedure) has become a usual practice since 2001, reaching 30% of all donors in 2007.

3.5. Recipient outcomes

A total of 273 lung transplantations were performed in 176 males (65%) and 97 females (35%), with a mean age of 38 ± 17 years (range: 5—67 years). Indications for transplantation were emphysema in 69, alpha-1 antitrypsin deficiency in five, cystic fibrosis in 81, pulmonary fibrosis in 80, bronchiectasis in 11, bronchitis obliterans syndrome in 11 (re-do transplants), pulmonary hypertension in four and other indications in 12 patients. Twelve percent of cases (33 patients) were under mechanical ventilation at the time of transplantation, and 14% of cases (38 patients) required extracorporeal circulation during the procedure.

In total, the 30-day mortality rate was 8% (95% CI: 5—11%) (23 patients). The main cause of death was cardiac failure in nine, sepsis in six, PGD in five and surgical in three patients. PGD developed in 44 recipients (16%).

The 30-day mortality rate was 11% (95% CI: 6—17%) for recipients from group A donors (16 of 146 patients) and 6% (95% CI: 2—10%) for recipients from group B donors (7 of 127 patients) (p = 0.066). PGD developed in 17% (95% CI: 14—20%) of recipients from group A donors (25 of 146 patients), and in 15% (95% CI: 12—18%) of recipients from group B donors (19 of 127 patients) (p = 0.362).

A subsequent analysis identified 48 donors fulfilling at least two of the criteria to be considered as extended donors. When compared with 225 ideal donors in terms of recipient 30-day mortality and development of PGD, no significant differences were observed. Three recipients (6%; 95% CI: 4—
8%) from extended donors died as opposed to 20 deaths (9%; 95% CI: 6—12%) in the ideal group ($p = 0.315$). Finally, 10 recipients (21%; 95% CI: 17—25%) from the extended group developed PGD as opposed to 34 (15%; 95% CI: 12—18%) who did in the ideal group ($p = 0.342$).

4. Discussion

Although there remains a greater demand than availability of donor organs and patients die awaiting LTx, it is essential to explore ways in which transplantation rates can be increased. On the one hand, the use of extended donors has been recognised as a viable option to increase the number of lung donors without significant adverse consequences in recipient outcomes [1,9—11]. On the other hand, an aggressive early management of potential donors has been considered to be of paramount importance in recovering donors suitable for LTx. Improvements in lung procurement with donor management strategies have been reported recently to increase transplant rates by the application of a proactive, flexible strategy of perioperative lung-donor evaluation, management and intervention [12—14]. In these studies, the increase in organ donation was not associated with a change in survival rates of the recipients.

Our study was designed to assess at which point in time of the evaluation the donor was deemed unsuitable. This approach enabled us to identify weak points of donor management, and donor factors susceptible to be prevented or modified to further recover donors initially considered unsuitable for transplantation. Changes in stage 1 assessment could reflect not only modifications in donor characteristics but also in donor management (modifiable factors). Stage 2 represents the assessment of non-modifiable donor factors such as pathological findings at the time of retrieval. Stage 3 represents both pathological findings and data from surgical technique at the time of harvesting (modifiable and non-modifiable factors).

Validity rates improved in stage 2, but did not change in stage 1. At this early stage, when the causes of unsuitability of donor lungs are more directly related to the preoperative care of potential donors, the validity rates did not differ between early and late donors, suggesting that little has been done in improving donor management at the early stages of brain death. This is further explained by the worsening of oxygenation ratios at the time of harvesting as compared with those at the time of the offer, in spite of recruitment manoeuvres carried out by the donor transplant team upon arrival at the donor hospital.

On the contrary, the validity rates at stage 2 improved significantly. However, it is difficult to assess whether there is a bias in the interpretation of what is considered as pathological. In the early experience, some donor lungs were considered unsuitable due to the presence of granulomatous lesions. At present, we no longer reject lungs with apical granulomas, since they are resected at the time of lung retrieval.

In our experience, the overall lung-donor validity rate was 57%, with a significant improvement between the early-period and late-period donors (67% in the year 2007). Taking into account that in the year 2007, only 21.3% of donors in Spain were offered for LTx (http://www.ont.es (accessed 11 April 2009)), the suitability rate of 67% reflects only 14% of all multi-organ donors. These figures remain less than those of other countries: 17% and 47% of valid lung donors in USA and Australia respectively, in the year 2005 [13], or 26% and 33% in Belgium and Austria, respectively, in the Eurotransplant zone in the year 2008 (www.eurotransplant.nl/files/annual_report/ar_2008.pdf (accessed 26 July 26 2009)). Furthermore, this improvement was at the expense of stage 2, with stage 1 remaining unchanged throughout the period of study. This reveals that medical management of a potential donor could be improved in our ICUs. In fact, 11% of potential donors were deemed unsuitable due to unrecoverable low oxygenation, 12% due to abnormal chest X-ray findings and 16% due to abnormal bronchoscopic findings. Whether any of these donors could have been recoverable for transplantation is difficult to assess in retrospect. In fact, at the time of retrieval, little can be done to improve a low oxygenation index, other than the administration of diuretics and correct

![Fig. 4. Proportion of donors (expressed as percentage of donors assessed at each stage) suitable for transplantation at the three stages of assessment, throughout the period of study (1993—2007). Stage 1 ($p = 0.371$), stage 2 ($p = 0.000$), and stage 3 ($p = 0.013$) (number of donors assessed within each year in parenthesis).](image-url)
ventilator parameters to recruit functional lung parenchyma. Therefore, those interventions aimed at preserving lung function must be started at the time of brain death declaration, rather than at the time of donor offer.

In the group of the later-period donors, the incidence of abnormal bronchoscopic and radiological findings was lower than that of the early donors. This may reflect either the improved care of donor airways or the less strict criteria in defining what is considered an abnormal finding at bronchoscopic examination, coupled with the lower rate of donor traumatic deaths. Furthermore, the subjectivity of the observer in defining what is abundant secretions or aspiration might have changed with increased expertise over time. Finally, results of culture tests are not generally available when the decision of lung acceptance is taken (in our series, only 58% of donors had conclusive results of BAS culture).

Oxygenation ratios have not changed significantly throughout the period of the study. This can be explained in part by the fact that we do not accept donors with PaO2/FiO2 ratio below 300 mmHg. Despite the fact that some investigators have reported good results using donors with oxygenation ratios between 250 and 300 mmHg [9], these are few cases and, currently, there is no sufficient evidence to support the use of donors with PaO2/FiO2 ratio below 300 mmHg. It is true that the 300 mmHg cutoff point of oxygenation ratio was chosen arbitrarily based on a single case described by Harjula et al. [15]. However, it is also true that we are defining a donor lung as optimal with PaO2/FiO2 ratio of 300 mmHg when the ideal lung reaches more than 600 mmHg. In fact, recent experience demonstrated that the use of donors with low oxygenation rates was associated with poor recipient outcomes in terms of 30-day mortality and development of bronchiolitis obliterans syndrome [16]. Therefore, good oxygenation before retrieval (final PaO2/FiO2 above 300 mmHg) is a required criterion in most transplant programmes [5]. More recently, some investigators have highlighted the importance of directly sampling pulmonary vein gases to better assess the lungs individually, tors have highlighted the importance of directly sampling pulmonary vein gases to better assess the lungs individually, and that we used extended donors in selected patients.

Transplant coordination is another issue of concern. In our experience, some donors were not harvested because of instability or cardiac arrest before arrival. In addition, in the early experience, a significant number of grafts were not used by (not offered to) other teams for single-lung transplantation. Taking into account the scarcity of lung donors, this is no longer acceptable, and, currently, up to 30% of lungs from marginal donors and from ideal donors with respect to oxygenation, length of ventilatory support and 30-day survival after LTx. Other large transplant centres have reported comparable short-term outcomes with similarly liberalised donor criteria [10,19,20].

Several limitations must be considered in evaluating the results reported herein. First, the study was retrospective, with the usual limitations of this design. Some missing data such as donor BAS information and smoking habits, the possible subjectivity of the observer in assessing chest X-ray films and bronchoscopic findings and the evolving definitions of what is considered normal or pathological at surgical exploration might have biased the results to some degree but, in our opinion, to an extent to invalidate the main conclusions drawn from the study. In addition, defining criteria of extended donors, even though following the general criteria of previous reports, were chosen arbitrarily.

To summarise, our study suggests that in spite of the high rate of organ donation in our country, the acceptability rate of donor lungs offered for LTx remains low, mainly due to the failure to meet the criteria for acceptance at the early stages of donor-lung assessment. The use of extended donors does not seem to have a negative impact on short-term recipient outcomes. On the basis of these results, some strategies could be started in our setting to expand the lung-donor pool, such as promoting the involvement of ICU staff on the appropriate medical management of the potential lung donor, and the facilitation of direct communication between donor ICU staff and transplant teams.

References

Appendix A. Conference discussion

Dr G.A. Patterson (St. Louis, MO): I would like to congratulate Dr Alvarez for, most importantly, taking a critical look at their own experience over a period of many years. I think we can all learn a lot for ourselves and for others to share when we do take the opportunity to make a critical analysis of our own experience.

I think the most important thing Dr Alvarez’s paper points out is the critical analysis of the different phases of the whole lung-donor organ identification analysis and decision-making, and breaking it up into those three phases I think is actually quite an interesting way to look at it and might be worthy of further study in a much larger experience, for example, through a mechanism like the IHSLT, through the Pulmonary Council of the IHSLT, which might be able to make a broad, very much greater analysis of a huge number of lung donors, because we clearly have a major problem. Dr Alvarez’s experience is not greatly different from ours or any other program: the vast majority of donors get turned down right from the beginning in Phase I. And while we may be able to alter our analysis or our examination of the lungs or become a little more liberal at Phase II at the time of the harvest or postharvest examination of the graft itself, we are really only going to make small incremental increases in the number of donors which we have available by impacting on Phase II and Phase III. So we clearly have to focus on Phase I.

In your paper you have made a comparison between your early experience and your late experience, and I think all that tells you is you are more experienced now than you were before. The rate of abnormal bronchoscopic fell, but I think that is just an observer experience situation. You used more experienced now than you were before. The rate of abnormal bronchoscopy remains an important issue of concern.

Dr W. Weder (Zurich, Switzerland): One group of patients is often difficult to assess and these are the patients who have chest trauma and the brain death is very early after the onset of chest trauma, and it is difficult to assess how the lungs will behave in the next 24 or 48 hours. So what are you doing when you get a lung offered with chest trauma, X-ray looks good, but only a few hours of observation time?

Dr Alvarez: This is also a major problem, because the proportion of traumatic donors, although declining over time, remains a major source of donors. In fact, the assessment of traumatic donors did not differ substantially from other donors. If you have appropriate donor oxygenation without extensive contusion, you cannot expect whether the donor is going to be bad or not only due to the cause of death. Some groups have suggested, like the group of St. Louis, there is some relationship between the traumatic cause of death, with the onset of chronic rejection or the development of acute rejection episodes in the recipient. But it is difficult to assess if the traumatic cause of death itself has a real impact on the recipient outcomes.