Lungs from donation after circulatory death donors: an alternative source to brain-dead donors? Midterm results at a single institution†

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Abstract

OBJECTIVES: Donor organ shortage remains to be the major limitation in lung transplantation, and donation after circulatory death (DCD) might represent one way to alleviate this problem. DCD was introduced to our institution in 2007 and has been a part of our clinical routine since then. Here, we present the mid-term results of lung transplantation from DCD in a single institution and compare the outcomes with the lung recipient cohort receiving lungs from donation after brain death (DBD).

METHODS: Since initiation of the DCD programme in March 2007, of the 157 lung transplantations performed, 26 (16.5%) were retrieved from DCD donors, with 25 double- and 1 single-lung transplants being performed. Results were compared with standard DBD transplantations. Analyses included, amongst others, donor characteristics, survival, prevalence of primary graft dysfunction, acute rejection, lung function tests during follow-up, onset of bronchiolitis obliterans syndrome (BOS) as well as duration of mechanical ventilation, hospital and intensive care unit length of stay.

RESULTS: While there was no significant difference between lung function, BOS and survival between the two groups, lungs from DCD donors had a higher PaO₂ (median; interquartile range) 498.3 (451.5; 525) vs. DBD 442.5 (371.25; 502) kPa before retrieval (P = 0.009). There was also a longer total ischaemic time in the DCD vs. DBD group: 320 min (298.75; 393.25) vs. 285.5 min (240; 373) (P = 0.025). All other parameters were comparable.

CONCLUSIONS: Medium-term results after lung transplantation with organs procured after circulatory death are comparable with those obtained after standard lung transplantation. Therefore, DCD could be used to significantly increase the donor pool.

Keywords: Lung transplantation • Donation after circulatory death • Outcome

INTRODUCTION

Donor shortage remains the major limitation of transplantation. Although advances in procurement and preservation, surgical technique and post surgical intensive care capabilities have lead to an effective doubling of lung transplantations over last decade, still there remains a high percentage of waiting list mortality [1]. Thus, a variety of initiatives have been introduced to increase organ availability and, among them, donation after circulatory death (DCD) seems to be one of the most promising and reproducible. A recently published study by Van De Wauwer et al. [2] indicates that DCD donors might significantly contribute to the donor pool of the transplantation programme. In their experience, 25% of organs were obtained from this category of donors since the introduction of DCD into the clinical routine. De Vleeschauwer and co-workers [3] reported that, in their programme, 12% of lung transplantations (Ltx) were performed after DCD. The idea of DCD is not new, with the first human lung transplantation being performed using the lungs from a non-heart-beating donor (NHBD) [4]. However, once brain death had been defined, the heart-beating donors became the main source of lungs for transplantation [donation after brain death (DBD)].

During the 1990s, when lung transplantation became a real clinical routine procedure with acceptable mid-term results, extensive research was carried out pertaining to ischaemia and reperfusion, which are central problem areas in transplantation in general. Surprisingly at that time, the results suggested that lungs are relatively resistant to ischaemia and tolerate warm ischaemia up to 60-90 min very well [5-7]. It were these findings that paved the way for a new clinical application of organ procurement after cardiac arrest and the concept of DCD. In 1995, Love published the first successful lung transplantation from
DCD donor [8]. In 2001, Steen et al. [9] reported the first LTx after an uncontrolled death due to cardiac arrest followed by DCD donation using ex vivo lung perfusion (EVLP) for assessment of the graft ex situ followed by a number of reports by other groups over the course of the last few years. The vast majority reported good results after controlled Maastricht category III NHBD lung transplantation [2, 3, 10–14]. Only Puri et al. reported results that were inferior compared with standard DBD donor lung transplantation [15].

In 1995, the Maastricht classification was introduced in order to classify non-heart-beating organ and tissue donors [16]. According to this system, potential donors are NHBDs who are grouped as uncontrolled in Groups I and II (I: brought in dead; II: unsuccessful resuscitation) or controlled in Groups III and IV (III: awaiting cardiac arrest; IV: cardiac arrest after brain-stem death); Group V, which is classified as uncontrolled (V: cardiac arrest in a hospital inpatient), has been added in 2000 [17].

Maastricht category I and II DCD donors are relatively rarely utilized as a source of lungs and the series published by de Antonio et al. [18] revealed results inferior to those reported in The International Society for Heart & Lung Transplantation registry. However, the group analysed was small and made the interpretation of the data very difficult. The introduction of a modified EVLP to clinical practice by the Toronto group suggested that the safe and effective evaluation of lungs using ex vivo circuits is clinically feasible and that the results after transplantation of these grafts may be comparable with those obtained after standard transplantation [19]. This method may allow for a change in the approach to uncontrolled DCD donors and was already used by the Madrid group with promising results [20]. Thus, taking into account the number of potential organs from the donors who suffer out-of-hospital or in-hospital cardiac arrest with failed cardiopulmonary resuscitation, the development of EVLP assessment may result in a significant increase in availability of lungs for transplantation.

In this study, we present the early and mid-term results of lung transplantation with organs retrieved from controlled DCD compared with that from standard DBD donors in our institution.

**METHODS**

Lungs were retrieved according to the national protocol with DBD donors being attended by teams allocated to the zone in which procurement took place. All DCD lungs were retrieved by our institutional team. All organs were perfused with Perfadex® solution.

Briefly, organs from DBD donors were inspected in situ after bronchoscopy. If accepted, an antegrade flush perfusion was performed with 4l of solution after cannulation of the proximal pulmonary artery (PA) and incision of the left atrium. After pneumonectomy and back table inspection, an additional retrograde flush with 1000 ml of solution was administered in 118 donors. Six organs were retrieved with antegrade perfusion only and the core cooling technique without pneumoplegia was used in seven cases.

DCD lungs were accepted if the time between withdrawal of treatment and cardiac arrest (agonal time) was <1 h and warm ischaemic time (cardiac arrest to antegrade perfusion) was also <1 h. DCD donors were transferred to the operating theatre for multiorgan retrieval 5 min after complete circulatory arrest, and certification of donor death. Briefly, endotracheal re-intubation was performed simultaneously with median sternotomy and laparotomy. For lung donation, the right ventricle was opened and blood from proximal PA was aspirated. After cannulation of the proximal PA, lungs were flushed with Perfadex® solution supplemented with tromethamine 3.3 ml/l, CaCl2 0.6 ml/l and epoprostenol sodium 2.5 ml/l. Simultaneously, flexible bronchoscopy was performed. Ten minutes after cardiac arrest the lungs were re-inflated and a recruitment manoeuvre was performed in order to recruit any atelectatic regions. As no heparin may be administered prior to cardiac arrest, the first liter of pneumoplegia was supplemented with heparin (20 000 U). After the organ removal, a standard retrograde perfusion was performed. The decision to utilize the lungs for transplantation was taken after completion of retrograde perfusion and final visual and manual inspections of the organ. All procured (DBD and DCD) lungs were stored in Perfadex® solution and placed on ice for transport.

The total ischaemic time was defined as the time between cardiac arrest/aortic cross clamp and reperfusion of the second implanted lung.

**STUDY POPULATION**

**Recipients**

From March 2007 to March 2011, 157 lung transplantations have been performed in Harefield Hospital in 155 recipients: 136 double-lung transplantations (DLTx) and 21 single-lung transplantations (SLTx). Of those, 26 (16.5%) recipients received organs retrieved from DCD donors. Two recipients, one from each group, underwent early redo transplantation with a DLTx in the DCD and lobar SLTx in the DBD group.

**Donors**

DBD and DCD donors were selected using standard ISHLT criteria [21] with extended donor criteria donors being accepted from both groups.

**Donor–recipient matching**

All recipients were consented for either DCD or DBD lungs. The lungs were matched to the recipients according standard criteria: blood group, size, time spent on the waiting list and urgency regardless the type of donor.

**Analysed data**

Before transplantation, recipient demographics, diagnosis, donor demographics, cause of death (COD), history of smoking, last partial oxygen pressure in arterial blood (PaO2) on a fraction of inspired oxygen (FiO2) of 1.0, positive end-expiratory pressure of 5 cmH2O and total ischaemic time were compared between the two groups. For DCD donors, the agonal time and the warm ischaemic time were recorded.

After transplantation, postoperative mechanical ventilation time, intensive care unit (ICU) and hospital length of stay (LOS),
prevalence of primary graft dysfunction (PGD), acute rejection (AR), bronchiolitis obliterans syndrome (BOS) and survival were compared.

**Primary graft dysfunction**

The differences in PaO2/FiO2 ratio were compared between the two groups on arrival to ICU, 24, 48 and 72 h after transplantation. The grade of PGD was defined based on ISHLT Working Group on Primary Dysfunction Report [22]. PaO2/FiO2 <200 mmHg was considered as PGD 3, 200–300 mmHg was considered as PGD 2 and >300 mmHg was considered as PGD 0–1 independent of findings on the chest X-ray.

**Rejection**

Transbronchial biopsies were performed when clinically indicated. AR was graded based on ISHLT Lung Rejection Study Group recommendations [23]. The percentage of patients who developed at least one episode of AR and distribution of rejection grades in DCD and DBD groups were compared.

**Lung function and bronchiolitis obliterans syndrome**

Lung function tests were performed on each hospital admission and transplant outpatient department appointment. The best post-transplant fraction of expired volume in 1 s (FEV1) and number of days after the procedure when achieved were compared as well as FEV1 at 3, 6 months and 1–3 years after transplantation.

The recipient was diagnosed with BOS when the FEV1 dropped permanently >20% of the maximum (the best achieved after transplantation) according ISHLT recommendations [24].

**Airway complications**

Any anastomotic dehiscence or airway complication (e.g. stenosis) requiring surgical or endobronchial intervention (balloon dilatation, cryotherapy, stenting) was considered as an airway complication. The incidence was compared between the study groups.

**Statistical analysis**

Data are presented as a median (interquartile range). Qualitative data are presented as percentage of the analysed group. For comparison of quantitative data, the Mann–Whitney U test was used. Qualitative data were compared using the Fisher’s exact test and \( \chi^2 \) test. The Kaplan–Meier method was used for survival and freedom from BOS estimation. A value of \( P < 0.05 \) was considered to be statistically significant. The analysis was performed using the SPSS version 15.0 for Windows software (IBM®).

**RESULTS**

**Recipients**

Recipient characteristics are presented in Table 1. There were no significant differences in age, gender, diagnosis, percentage procedures under cardiopulmonary bypass (CPB), double- and single-lung transplantation, duration of mechanical ventilation, incidence of postoperative extracorporeal membrane oxygenation (ECMO) use, ICU and hospital LOS.

**Donors**

Between March 2007 and March 2011, a total of 26 controlled Maastricht category III (25–96%) and IV (1–4%) donors donated 1 single and 25 double lungs. During the same period, 130 DBD donors donated 111 double lungs and 20 single organs. Comparison of DCD and DBD donor characteristics is presented in Table 2. There were no statistically significant differences between the groups regarding sex, age, COD, smoking history and duration of mechanical ventilation. Last PaO2 of DCD donors prior to the retrieval was significantly higher when compared with that of DBD donors: 498 mmHg (451.5;525) vs. 442 mmHg (371.25;502) (\( P = 0.009 \)). The total ischaemic time also differed significantly: 320 min (298.75;393.25) for DCD vs. 285.5 min (240;373) for DBD donors (\( P = 0.025 \)). The agonal time in DCD donors was 15 min (12;24) and the warm ischaemic time was 15 min (12;19.25).

**Table 1: Recipient characteristics**

<table>
<thead>
<tr>
<th></th>
<th>DCD (n = 26)</th>
<th>DBD (n = 129)</th>
<th>( P )-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>47 (30; 53.7)</td>
<td>47 (33; 55)</td>
<td>NS</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>13 (50%)</td>
<td>64 (49.6%)</td>
<td>NS</td>
</tr>
<tr>
<td>Female</td>
<td>13 (50%)</td>
<td>65 (50.4%)</td>
<td></td>
</tr>
<tr>
<td>Diagnosis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CF</td>
<td>11 (42%)</td>
<td>43 (33.5%)</td>
<td>NS</td>
</tr>
<tr>
<td>Emphysema</td>
<td>10 (38%)</td>
<td>38 (29.5%)</td>
<td></td>
</tr>
<tr>
<td>α1-Antitrypsin deficiency</td>
<td>2 (8%)</td>
<td>21 (16%)</td>
<td></td>
</tr>
<tr>
<td>PF</td>
<td>1 (4%)</td>
<td>9 (7%)</td>
<td></td>
</tr>
<tr>
<td>LAM</td>
<td>1 (4%)</td>
<td>5 (4%)</td>
<td></td>
</tr>
<tr>
<td>Sarcoidosis</td>
<td>1 (4%)</td>
<td>2 (1.5%)</td>
<td></td>
</tr>
<tr>
<td>PH</td>
<td>0</td>
<td>7 (5.5%)</td>
<td></td>
</tr>
<tr>
<td>OB</td>
<td>0</td>
<td>4 (3%)</td>
<td></td>
</tr>
<tr>
<td>With CPB</td>
<td>21 (80%)</td>
<td>97 (75%)</td>
<td>NS</td>
</tr>
<tr>
<td>Without CPB</td>
<td>5 (20%)</td>
<td>32 (25%)</td>
<td></td>
</tr>
<tr>
<td>DLTx</td>
<td>25 (96%)</td>
<td>109 (85%)</td>
<td>NS</td>
</tr>
<tr>
<td>SLTx</td>
<td>4 (16%)</td>
<td>20 (15%)</td>
<td></td>
</tr>
<tr>
<td>Postoperative ECMO</td>
<td>4 (16%)</td>
<td>6 (5%)</td>
<td>0.066</td>
</tr>
<tr>
<td>Mechanical ventilation (h)</td>
<td>47 (24; 144)</td>
<td>27 (12; 204)</td>
<td>NS</td>
</tr>
<tr>
<td>ICU LOS (d)</td>
<td>5 (3; 33)</td>
<td>5 (3; 21.5)</td>
<td>NS</td>
</tr>
<tr>
<td>Hospital LOS (d)</td>
<td>35.5 (20.5; 79.25)</td>
<td>35 (25; 54)</td>
<td>NS</td>
</tr>
</tbody>
</table>

CF: cystic fibrosis; PF: pulmonary fibrosis; LAM: lymphangioleiomyomatosis; PH: pulmonary hypertension; OB: obliterans bronchiolitis; CPB: cardiopulmonary bypass; DLTx: single lung transplantation; SLTx: single lung transplantation; ECMO: extracorporeal membrane oxygenation.
Survival and follow-up

The median follow-up was 436 days (207.75;823.5) for DCD and 540 (265.5;882) for DBD recipients (P = ns). The survival in both groups was comparable (Figure 1). Four patients from the DCD group (16%) died during follow-up. There were three (12%) in-hospital deaths: one in the operating theatre due to surgical complications, one on Day 15 due to massive pulmonary embolism and one on Day 115 due to multiorgan failure related to sepsis. The last patient died 441 days after transplant due to acute respiratory distress syndrome and chronic renal failure. Twenty-five patients from the DBD group (19%) died during follow-up. There were 14 (11%) in-hospital deaths on Days 1–144 due to pulmonary infections (5), extrapulmonary infections (3), coagulopathy related to prolonged CPB (2), PGD (2), pulmonary embolism (1) and intrapulmonary bleeding (1). Eleven patients died after the initial discharge from hospital due to pulmonary infection (6), BOS (3) and rejection (2).

Primary graft dysfunction

The incidence of PGD graded in for groups is presented in Fig. 2. There were no significant differences between the groups. There was a trend towards higher rate of PGD 3 on arrival to ICU, (P = 0.09) in the DCD group.

Rejection

Seventy-six per cent of DCD and 77% of DBD recipients were free from rejection during follow-up. The incidence and rejection grading is presented in Fig. 3. There were no statistically significant differences between the groups.

Lung function test and bronchiolitis obliterans syndrome

The predicted FEV₁ at different points of measurement was comparable in the analysed groups as well as the time necessary to achieve the best FEV₁ after transplantation (Table 3). The overall incidence of BOS was 9% in the DCD and 13% in the DBD groups (P = ns). Freedom from BOS is presented in Fig. 4. Patients who did not survive the early postoperative period were...
excluded from analysis. There was no difference between the DCD and DBD groups.

Airway complications

There were no anastomotic complications requiring surgical repair in both groups during the study period. The number of patients who developed airway complications treated endobronchially is presented in Fig. 5. The difference is not statistically significant.

Discussion

The number of centres using DCD as a supplemental source of lungs for transplantation is continuously rising. In last few years, several papers evaluating early, mid-term and long-term results of lung transplantation using organs from DCD donors have been published. In the majority of them, DCD lungs are considered an addition to standard DBD organs. In other cases, they have become a vital part of transplantation programme and constitute almost a half of transplantations [2]. In our experience, DCD donors are a significant source of organs. In the beginning—the first 2 years—DCD lungs were used in 12–13% of cases. Over the last year, the percentage increases up to almost 25%. Overall, since we started the programme, 16.5% of transplanted lungs were retrieved from DCD donors. Looking to the future, this may increase even further along with more frequent DCD donor offers with results comparable with standard DBD transplantations.
Experimental studies carried out in 1990s by Egan and Van Raemdonck showed that the warm ischaemic time (from cardiac arrest to PA flush) up to 1 h does not alter lung function significantly [5, 7]. This period may be safely extended up to 90 min, as shown by Loewe et al. [6]. While the gas exchange after transplantation was affected when compared with control groups, the transplanted lung function remained good. Moreover, there was no statistically significant difference in histological examination and wet-to-dry ratio between DCD and DBD lungs [6]. Those findings were confirmed in the clinical settings by other investigators who demonstrated that the prevalence and distribution of various grades of PGD was comparable between DCD and DBD donors [2, 3, 13]. We observed a similar percentage of patients developing PGD in all time points: on arrival to ICU, 24 h, 48 h and 72 h after the procedure. While there was a trend towards higher percentage of recipients with PGD 3 in DCD lungs recipients on arrival to ICU (P = 0.09), this may be overemphasized by the very low incidence of PGD 3 in DBD lung recipients (10%) when compared with the DCD group (25%). The trend disappeared over next 24 h. The use of ECMO support in our group seems to be higher than the reported in the series cited above. The rate was statistically comparable between the evaluated groups; however, there is a trend towards higher incidence in the DCD group (P = 0.066). Only one patient required ECMO due to PGD. In this case, ECMO was successfully explanted and patient was discharged home and currently is doing well. Other three cases required ECMO due to other reasons. All survived and are doing well—one underwent successful early re-transplantation and two were explanted without complications. PGD is a key factor influencing negatively both early and late outcome after lung transplantation. No difference in the incidence of PGD is supportive for DCD lung transplantations.

Along with the PGD rate, other parameters describing the early outcome, including duration of mechanical ventilation and ICU and hospital LOS, were comparable between the DCD and DBD groups, similar to previously published reports.

AR is a common complication after lung transplantation and, according to annual ISHLT report, is observed in 36% of patients over first year after the implantation [1]. Fewer rejection episodes are known as a factor for increasing the chance of long-term survival [25]. De Oliveira et al. [13] reported a lower incidence of A1 rejection in the DCD group in the longest follow-up series published until now. They pointed out that it could be related to lower immunogenicity of the organs retrieved from donors who have not experienced brain death-related pathological changes. This finding has not been confirmed by the Leuven group in a recently published analysis of medium-term outcome of DCD lung transplantation [3]. They reported a comparable rate of rejection in the DCD and DBD groups. Our observation is similar. However, the overall percentage of patients who developed AR in our material is smaller than in Leuven, which might be related to our clinical practice—no routine transbronchial biopsies unless clinically indicated.

BOS is affecting almost 10% of patients in the first year after transplantation and 49% within the first 5 years. It is the most frequent COD beyond the first year after transplantation [1]. The incidence of BOS in our study did not differ in the DCD and DBD groups corroborating the results of Leuven and University of Wisconsin series [3, 13]. The Groningen group reported higher incidence of BOS within the first year after transplantation in the DBD recipients. The authors hypothesize that the decreased inflammatory lung injury before DCD may be responsible for this phenomenon [2].

The number of airway complications in our data is small. We did not observe any anastomotic dehiscence or necrosis requiring surgical repair. Only one patient from the DBD group underwent successful lobectomy due to persistent infection related to bronchial stenosis with failed endoscopic treatment—stenting. The Wisconsin group observed a higher rate of airway complications in the DCD group [13]. The Leuven group reported findings similar to ours with a lack of any serious bronchial complications in the DCD group [13].

There were similar early and late complications after DCD lung transplantations resulting in survival rates comparable with the standard DBD transplantation recipients; as was reported by Wisconsin, Leuven and Groningen groups and is subsequently confirmed by our observations. Analysis of United Network for Organ Sharing data published in 2008 showed better survival in DCD donors (unadjusted P = 0.04) with still existing trend towards better survival after adjustment for propensity score (P = 0.06) [10].

Sub-optimal conditions for lung assessment and recruitment in DCD donors sometimes raise concerns about the suitability of the organ. It may result in declining potentially transplantable lungs and EVLP may present a very useful tool in this situation. It has been implemented in clinical practice by Steen for assessment of uncontrolled DCD donors [9]. The method was modified by Cypel et al. [19] and is used for assessment of so-called high-risk donor lungs. Almost half of the lungs enrolled to a recently published prospective trial were obtained from DCD donors. Out of seven cases of EVLP lung transplantations in our experience, two organs were retrieved from DCD donors. Extensive chest X-ray changes were the reason for EVLP in the first case. The second pair of lungs was obtained from a donor with hypoxic brain injury 9 days after aortic root replacement—he remained ventilated in ICU the whole time after this procedure. Both recipients survived the transplantation have been discharged from hospital and both are doing well at 8- and 18-month follow-up.

The overall number of DCD lung transplantations published is small. We believe that our series of 26 patients—according to our knowledge the second biggest single-centre series published until now—is a significant source of data. We realize that this study has limitations. For instance, DCD donors have had better PaO2 prior to the retrieval which may show a bias towards
rejecting lungs that have less oxygenation capacity. DCD grafts also experience a longer total ischaemic time. We believe that this difference did not influence the outcome. The retrospective nature (some data were missed and excluded from analysis) of the study, the relatively small sample size and relatively short follow-up represent other limitations. However, despite these facts, we conclude that DCD lungs are a valuable source of good quality organs for transplantation, which is mirrored in the increased use of these organs in our clinical practice.

However, these assumptions should be confirmed by prospective studies, especially keeping the cumulative potential of EVLP in mind.

Conflict of interest: none declared.

REFERENCES


APPENDIX. CONFERENCE DISCUSSION

Dr D. Wood (Seattle, WA, USA): This is a fairly large experience with donation after cardiac death. To re- emphasize your last slide to the audience, I think you have accomplished this with really no significant difference in short- or long-term outcomes in either survival, acute or chronic rejection, and other important outcome variables like airway complications. And this is especially important when shortage of donor organs is the main limitation to our patients who are in need of lung transplantation.

So, I have two questions. One relates to the fact that you have used this almost exclusively in Maastricht category III. Now that you have this experience and these results, how do you anticipate perhaps extending this to other categories of cardiac death? And number two is, with experience in ex vivo perfusion, do you see that as a way of helping to extend your criteria for DCD donor utilization even further?

Dr Zych: I will try to answer both questions at the same time because I think it is crucial. DCD donation combined with ex vivo lung perfusion, both of which we are doing in our institution, is an ideal combination. EVLP is a perfect tool for assessment of DCD organs. As we know from our practice, the assessment of the lungs during non-heart-beating retrieval is really difficult, especially the functional assessment. We do not have all that many opportunities to check arterial gases a few times, to check the selective gases from each pulmonary vein, to check the compliance making the deflation test. It is completely different compared to standard beating heart donation.

We can decline the organ when we have doubts. But in reality, we bring the organ to the hospital, place it into the EVLP circuit, and we have enough time for proper assessment. In our group, out of 26 DCD donors, 2 organs were assessed using the EVLP circuit. Both patients who received EVLP lungs are doing well at the moment.

Coming back to your first question, I think that uncontrolled non-heart-beating donors combined with EVLP is the future because we are suffering everywhere from shortage of lungs. The number of possible lungs from the non-heart-beating category I and II donors is very large. If we can assess using EVLP, and transplant just 5 to 10%, the problem of donor shortage will be definitely less than it is now. I want to mention two very important papers: the paper of Professor Stg Steen from Lund published ten years ago, where he transplanted the first uncontrolled non-heart-beating lungs combined with EVLP technique; the second one presented during last ISHLT meeting by colleagues from Spain who are using a similar approach. Results are promising at the moment, but the group is very small. We need to wait for more data.
Dr Wood: Just as a follow-up, you have been able to increase your percentage of DCD donors as a part of your donor pool to approximately 25%. Where do you see this going in the next three to five years in your own group as you consider expanding on your experience? What per cent do you think are actually going to become DCD rather than BDD donors?

Dr Zych: Looking at our progress, we started from around 10–12% increasing to our most recent percentage of 25%. What the dynamics of the process will be, I cannot predict. But as we know from one of the most recent publications from the Groningen group, almost 40–50% of their donations are DCD. Looking at the results, which are good, I think that the trend will be towards a higher percentage.

Dr L. Hamilton (Newcastle-upon-Tyne, UK): We too have an active DCD program, and I thank you for your very important clinical message that these lungs are just as good as DBD donors. But I would like to raise an ethical rather than a clinical question with you. The definition of ‘death’ continues to be controversial. In fact, the President’s group in the States recently produced a 167-page document dealing with the controversies, and that is 40 years after the Harvard group first defined brain death. In your presentation, you referred to DCD as donation after cardiac death and, in fact, there have been some reports in the literature of heart transplants from DCD donors, so clearly the heart is not dead. Do you think the public have concerns about DCD donation, and what can we do as professionals to allay those concerns?

Dr Zych: I am not an expert in ethics, and whatever I say is just what I think. As we know, there is the very difficult process of discussing all the issues about the donation with the family. Everything is discussed with the family; it is carried out in accordance with the law. The donor after cardiac death is a donor who has been certified dead. If somebody expressed the wish, the family or the patient who is in an organ donor registry, that he might be an organ donor after death, I think that we are correct. Of course, I cannot tell you I am right because it is a very sensitive, delicate matter. As we know, donation after cardiac death is not legal in all countries. We in the UK cannot use heparin in the donors which is a common practice in other countries. We are not using heparin. We are not pre-treating the donors. We are not interfering at all with the ICU management. And our results, in fact the Royal Brompton and Harefield results, are very similar to American results which is very promising, and I think we should be satisfied.

Dr Hamilton: In using the term ‘DCD’, we should perhaps refer to donation after circulatory death. It might be easier to reassure/convince the public.

Dr Zych: Yes, I agree.

Dr G. Gerosa (Padova, Italy): A very quick question. When you are referring to ex vivo perfusion, are you referring to the TransMedics OCS, organ care system? If not, do you think that the OCS can play a role in DCD?

Dr Zych: I think yes. Nowadays we are using a different system, not OCS. I think that the advantage with using OCS is that it is a portable machine, very small. You can, in fact, put the lungs into OCS at the donor site, and the cold ischaemia is limited to a few minutes. But we have not used it yet. I wonder whether perhaps it will be possible in the future. Now we are using a different system based in the hospital, not a mobile one.

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**EDITORIAL COMMENT**

**Donation after circulatory death: an important expansion of donor organs for lung transplant patients**

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Donation after circulatory death (DCD) offers a large cohort of new potential lung donors and the possibility of decreasing the waiting list deaths that are the tragic consequence of limited brain death donors (BDDs). Zych et al. [1] have provided an impressive description of a DCD programme at their institution, and their initial and mid-term results. The authors should be congratulated for their report on expanding the donor pool for their end-stage lung disease patients. They demonstrated survival outcomes and incidence of acute chronic rejection that were comparable between the DCD and BDD lungs. However, it is important to note that upon arrival in the ICU the P:F ratios tended to be worse among DCD recipient and the incidence of grade III primary graft dysfunction twice as high. These trends did not reach a statistical significance; however, with a larger sample size, these differences likely would have indeed been significant. Likewise, the incidence of postoperative ECMO support was three times higher among DCD lung recipients. This is despite the fact that the donor PaO<sub>2</sub> levels were significantly higher in the DCD group prior to procurement. Primary graft dysfunction has been shown previously to be associated with a higher incidence of airway complications. The methods by which airway complications were identified and treated is not described in detail, but the incidence of airway complications, while low, is two times higher in the DCD group compared with the BDD group. Therefore, although donation after circulatory death is a meaningful and important source of allograft lungs, the enthusiasm for their use should be qualified and the strategies for their proper utilization need to be well considered.

The authors have stated that an hour of warm ischaemic time is acceptable. However, the literature that they cite to support this is based on dog and rabbit studies alone. At a UNOS-sponsored consensus conference convened in North America to