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ORIGINAL ARTICLE

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Effect on the donor lungs of using abdominal normothermic regional perfusion in controlled donation after circulatory death

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Key question

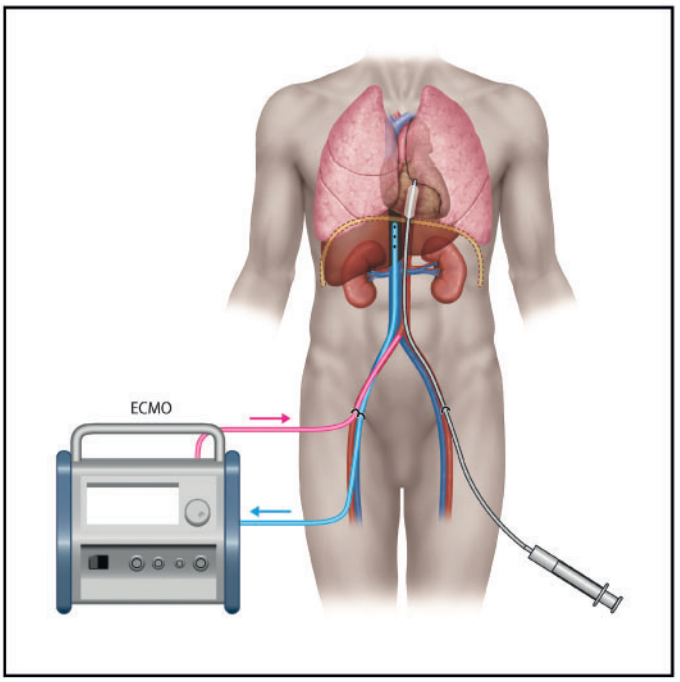
Are outcomes of cDCD LTx affected by the technique used for abdominal (A) organ procurement: A-rapid retrieval (A-RR) versus A-NRP?

Key finding(s)

The A-normothermic regional perfusion (NRP) group had LTx outcomes comparable to those of the A-RR group.

Take-home message

A-NRP did not have a significant impact on lung grafts in our cohort of patients. A-NRP does not preclude safe retrieval of a donor lung.



Abstract

OBJECTIVES: Controlled donation after circulatory death (cDCD) donors are becoming a common source of organs for transplantation globally. However, the graft survival rate of cDCD abdominal organs is inferior to that of organs from brain-dead donors. The rapid retrieval (RR) technique is used by most donor organ procurement teams. The abdominal normothermic regional perfusion (A-NRP) technique has been implemented to minimize warm ischaemic damage to the abdominal organs. However, there is limited information on the

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effect of A-NRP on the quality of the donor lungs. This study aimed to compare lung transplantation outcomes using lungs procured from cDCD donors using the A-NRP and abdominal RR techniques.

METHODS: A single-centre retrospective analysis of consecutive transplant recipients of cDCD lungs from June 2013 to December 2019 was performed. The recipients were divided into 2 cohorts according to the abdominal procurement technique used. The recipient and donor characteristics (age, sex, cause of brain injury, warm ischaemic time, diagnosis, lung allocation score and other factors), incidence of primary graft dysfunction and early survival were monitored.

RESULTS: Twenty-eight consecutive lung transplantation recipients were identified (median age 59 years; 61% male); 14 recipients received lungs using the A-NRP and 14 using abdominal RR for abdominal organ retrieval. There were no significant differences in the baseline characteristics, primary graft dysfunction ($P = 0.70$), hospital mortality ($P = 1.0$) and 1-year survival rate ($P = 1.0$) between the 2 groups.

CONCLUSIONS: No difference was observed in lung transplantation outcomes irrespective of the abdominal organ procurement technique used (A-NRP or abdominal RR).

Keywords: Lung transplantation • Controlled donation after circulatory death • Abdominal normothermic regional perfusion

ABBREVIATIONS

A-RR	Abdominal rapid retrieval
A-NRP	Abdominal normothermic regional perfusion
CA	Cardiac arrest
cDCD	Controlled donation after circulatory death
DBDs	Brain-dead donors
DCD	Donation after circulatory death
ECMO	Extracorporeal membranous oxygenation
FWIT	Functional warm ischaemic time
LOS	Length of stay
LTx	Lung transplantation
PGD	Primary graft dysfunction
RR	Rapid retrieval
WLSTs	Withdrawal of life-sustaining therapies

INTRODUCTION

Lung transplantation (LTx) is an established therapy for end-stage lung disease in selected patients; however, it is limited by the shortage of donor organs [1]. This shortage has led investigators to research ways to increase the donor pool, including the use of extended-criteria donors, donation after circulatory death (DCD), *ex vivo* lung perfusion and evaluation and living lobar LTx. The use of DCD organs can potentially increase LTx rates. In Spain, 18% of all transplanted lungs are procured from DCD; the number of DCD LTx has increased 13-fold from 2012 to 2019 [2].

In most transplant centres, organs in controlled DCD (cDCD) are procured using the rapid retrieval (RR) technique [3]. However, the period of warm ischaemia surrounding cardiac arrest (CA) in these donors causes abdominal organ injury, resulting in retrieval rates 20–50% lower than those in brain-dead donors (DBDs) [4] and a reluctance to use livers and pancreas from these donors. This period of warm ischaemia also results in a higher incidence of primary non-function and delayed graft function in kidney transplantation [5], and causes graft loss and biliary complications after liver transplantation [6]. Published data have shown inferior patient and graft survival rates among recipients of DCD abdominal organs [7]. Therefore, the use of abdominal normothermic regional perfusion (A-NRP) with extracorporeal membranous oxygenation (ECMO) devices to restore blood flow after death and before organ retrieval in cDCD has been the subject of increasing interest. Specifically, A-NRP has been implemented instead of abdominal RR (A-RR) to minimize warm ischaemic damage and improve preservation of abdominal organs, with good applicability and results [8]. The lungs are more tolerant to warm ischaemia than other organs when kept inflated with oxygen [9].

Despite the benefits of A-NRP for abdominal organs, its impact on the quality of the c DCD lungs has not been sufficiently investigated. Currently, lung-RR with A-RR is considered the ideal procurement method as in lung grafts to simplify operative procedures.

Therefore, this study aimed to compare both methods (A-NRP and A-RR) and investigate whether using A-NRP in cDCD donor procurement adversely affects lung grafts.

MATERIALS AND METHODS

This study was approved by the Institutional Review Board of Puerta de Hierro University Hospital (approval date: 15 June 2020, approval PI 133-20). This single-centre retrospective study included all Maastricht category III DCD lung transplants from the start of the DCD program at the Hospital Universitario Puerta de Hierro-Majadahonda from June 2013 to December 2019. We assessed the impact of cDCD lung graft procurement combined with A-NRP on LTx outcomes by focusing on the recipient's early and mid-term mortality and morbidity. Transplant procedures were assigned to one of 2 cohorts based on whether the abdominal organs were procured using A-NRP or A-RR.

Lung procurement and preservation combined with abdominal normothermic regional perfusion

The donor preparation, management and general operative approach have been described previously [10]. When DCD was considered, peripheral femoral cannulation was performed either surgically or percutaneously after heparin administration (30–50 units/kg) for A-NRP. Cannulation was performed at the bedside, in the intensive care unit, before withdrawal of life-sustaining therapies (WLSTs). An aortic balloon inserted into the proximal descending aorta was inflated after the declaration of death,

which prevented re-establishment of cerebral and coronary blood flow during A-NRP. When the balloon could not be correctly positioned, the descending aorta was immediately clamped right below the diaphragm after laparotomy.

WLST occurred in the operating room. Five minutes after the declaration of death, A-NRP was initiated and thoracic surgeons performed a sternotomy and clamped the inferior vena cava. Simultaneously, the donor was reintubated and ventilated with 50% oxygen at a tidal volume of 7 ml/kg ideal body weight and a positive end expiratory pressure value of 5 cm H_2O. The pulmonary artery was cannulated for cold flush perfusion with Perfadex® (Medisan, Uppsala, Sweden) containing prostaglandin E1 and nitroglycerin. Perfadex was infused at a dose of 50–70 ml/kg. The left atrial appendage was amputated to allow free drainage of the pulmonary flush solution. Both pleurae were opened to deliver cold saline into the thoracic cavity for topical cooling. After perfusion, the superior and inferior vena cavae and azygos vein were ligated to separate the thoracic and abdominal compartments. Finally, the donor lungs, which were separated from the heart in the chest cavity, were removed following the procedure as in DBD cases.

Pump flow during A-NRP was maintained for 2 h after lung retrieval at 2–2.4 l/min in order to evaluate liver injury. A continuous pressure of 60–65 mmHg in the femoral arterial cannula and temperature of 37°C were maintained. Bicarbonate was administered immediately after A-NRP initiation to maintain a pH of 7.35–7.45.

Lung procurement and preservation by rapid retrieval

After circulatory arrest and certification of donor death, the thoracic and abdominal teams commenced surgery simultaneously. A median sternotomy was performed, and the pericardium was opened. A cannula was placed in the main pulmonary artery and Perfadex with the same composition and dose as that used in A-NRP was infused. Unlike in A-NRP, the inferior vena cava was partially divided to allow drainage of the liver preservation solution to the pericardial cavity. After perfusion, the donor lungs were removed following the procedure as in DBD cases.

Selecting a donor procurement method

The method depended on the facilities available at the donor hospital and the abdominal organs to be removed. If the donor hospital had an ECMO facility and the liver must be removed, A-NRP was adopted. If only the kidneys were to be removed, RR was selected; however, this depended on the equipment the donor hospital had and the preferences of the kidney transplant team. The appropriate method was determined before WLST, and the ECMO device was attached prior to extubation. Therefore, the choice had no bearing on the donor agonal and warm ischaemic time.

Study design

The following donor demographic characteristics were collected for each recipient: age, sex, cause of brain injury/death, duration of mechanical ventilation, smoking history, partial oxygen pressure over fractional inspired oxygen concentration (PaO_2/FiO_2), WLST-CA time, CA-cold perfusion time, WLST-cold perfusion time, systolic blood pressure <60 mmHg-cold perfusion time and skin incision-cold perfusion time. The following recipient demographic data were collected: age, sex, diagnosis, lung allocation score, secondary pulmonary hypertension, smoking history, cytomegalovirus infection, body mass index, pretransplant medical condition, size mismatch and cardiopulmonary support during the surgery (ECMO/cardiopulmonary bypass). Patients who received a single lung or lung retransplantation were excluded from this study.

Definition of outcomes

The primary outcome of the analysis was 1-year survival. The secondary outcomes were occurrence of primary graft dysfunction (PGD) grade 3, duration of intubation time, incidence of postoperative ECMO, duration of postoperative ECMO support, intensive care unit and hospital length of stay (LOS), rate of acute cellular rejection, airway complication rate, early mortality (<30 days), 1-year graft failure and hospital mortality. The differences in PaO_2/FiO_2 ratio were compared between the A-NRP and A-RR groups at 24, 48 and 72 h after transplantation. The PGD grade was based on the International Society for Heart and Lung Transplantation Working Group document on Primary Dysfunction Report [11]. The functional warm ischaemic time (FWIT) was defined as the duration between when the systolic arterial pressure was <60 mmHg and pulmonary artery flushing.

Statistical analysis

Data analysis was performed using JMP® 11 software (SAS Institute Inc., Cary, NC, USA). Continuous data were expressed as mean ± standard deviation when normally distributed or as median (25–75% interquartile range) when non-normally distributed. Qualitative data were presented as a percentage of the analysed measurements. Comparisons between subgroups were performed using the Mann–Whitney *U*-test or Wilcoxon rank-sum test for continuous data and Fisher's exact test for categorical data. Survival was analysed using the Kaplan–Meier method and compared by the log-rank test. A *P*-value <0.05 was considered statistically significant.

RESULTS

Our retrospective study included 39 cDCD donors attended by the lung retrieval team from the Hospital Universitario Puerta de Hierro-Majadahonda. We set the maximal length of the agonal phase (WLST-CA) at 2 h. However, no donors were excluded by this criterion. Six donors who were considered medically unsuitable by the surgeon were excluded and 3 other donors were excluded after *ex vivo* lung perfusion evaluation. Ultimately, our study consisted of 30 cDCD LTXs performed from June 2013 to December 2019. One single LTx and 1 retransplantation were excluded from the analysis. Of the 28 LTx assessed, half of the DCD donors had A-NRP and the other half had A-RR for abdominal organ retrieval (Figs 1 and 2).

Donor demographic characteristics

Table 1 shows the demographic characteristics of the donors. The most frequent cause of brain injury was cerebrovascular

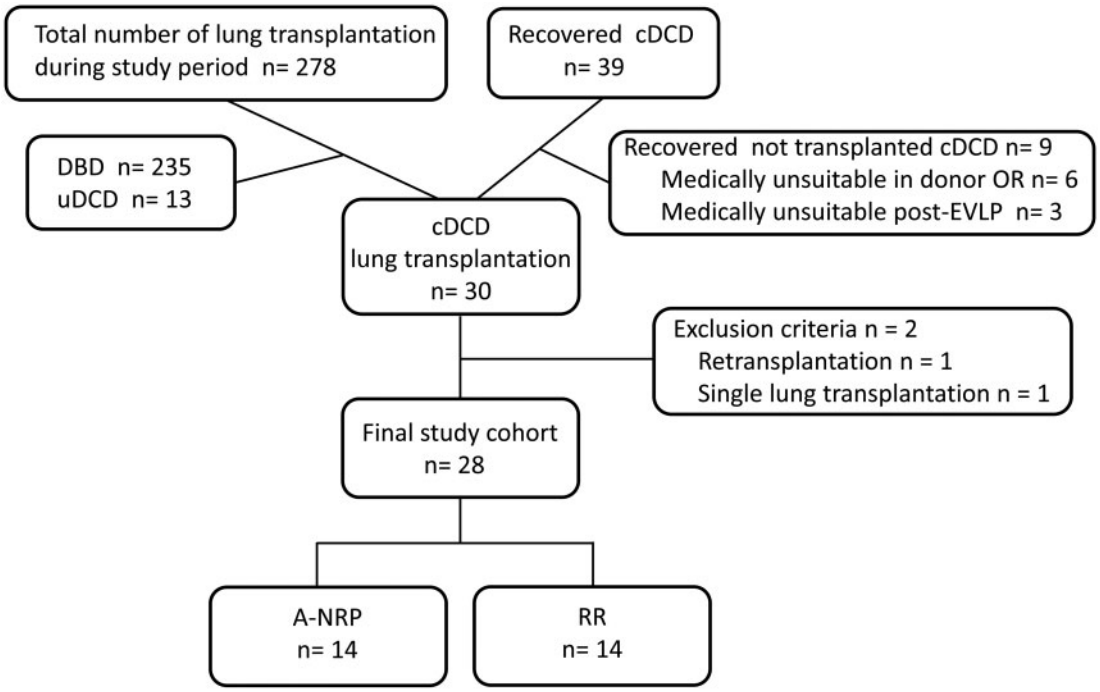

Figure 1: We retrospectively identified 278 consecutive patients who underwent lung transplantation. We excluded lung transplants from uncontrolled circulatory death donors (13 cases) and from brain death donors (235 cases). Moreover, 2 patients were excluded as 1 underwent retransplantation and the other underwent single lung transplantation. A-NRP: abdominal normothermic regional perfusion; A-RR: abdominal rapid retrieval; cDCD: controlled donation after circulatory death.

accident, with the same number in both groups. Before WLST, no significant differences were seen in the final donor PaO_2/FiO_2, smoking histories and duration of mechanical ventilation. The time from skin incision to lung perfusion was similar in both groups (10 vs 9 min, $P = 0.5$). The FWIT of the DCD lungs were not significantly different between groups (A-RR 25 min, A-NRP 21 min, $P = 0.1$). The maximum warm ischaemic time was 55 and 35 min in the A-NRP and A-RR groups, respectively. These times were within the acceptable warm ischaemic times for LTx (90 min) [12], and there was no significant difference between the 2 groups.

Recipient demographic characteristics

Table 2 shows the recipient and transplant-related characteristics. The number of chronic obstructive pulmonary disease recipients was higher in the A-RR group than in the A-NRP group (64% vs 21%). Two patients were bridged to LTx and were treated with ECMO and mechanical ventilation in the A-NRP and A-RR groups, respectively. No significant differences between the 2 groups in secondary pulmonary hypertension (43% vs 64%, $P = 0.26$) or rate of intraoperative extracorporeal life support (57% vs 42%, $P = 0.48$) were noted.

Postoperative characteristics

The incidence of PGD grades is presented in Table 3 and Fig. 3. The incidence of PGD grades 3 at 72 h was the same for both groups (21% vs 21%, $P = 1.0$). The incidence of postoperative ECMO reflects our centre's strategy to continue veno-arterial-ECMO therapy in patients with severe pulmonary hypertension after transplantation and veno-veno ECMO therapy in patients with pulmonary dysfunction without pulmonary hypertension.

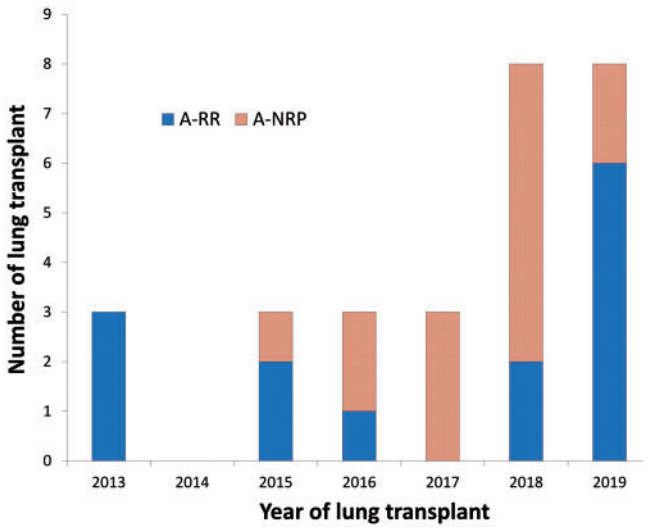

Figure 2: The overall controlled donation after circulatory death lung transplantation experience between 2013 and 2019, according to A-NRP versus A-RR. A-NRP: abdominal normothermic regional perfusion; A-RR: abdominal rapid retrieval.

Seven patients received ECMO according to the eligibility criteria after LTx; 2 of them required postoperative veno-arterial-ECMO support, one of whom died on postoperative day 5. The other was weaned from ECMO on postoperative day 4. The remaining patients were supported by veno-veno ECMO postoperatively and all were successfully weaned from ECMO within 5 days post-surgery.

There were no anastomotic complications requiring surgical repair in either group. Analysis of the relationship between FWIT and PGD (72 h) (Supplementary Material, S1) showed no statistically significant difference ($P = 0.83$).

Table 1: Donor characteristics

Variables	A-NRP (n = 14)	A-RR (n = 14)	P-value
Age (years)	59 (45–69)	58 (50–75)	0.61
Sex			0.7
Male (%)	7 (50)	8 (57)	
Female (%)	7 (50)	6 (43)	
BMI (kg/m^2),	25 (23–27)	27 (25–30)	0.13
Cause of brain injury			0.12
CVA (%)	10 (71)	6 (43)	
Anoxia (%)	3 (21)	8 (57)	
Trauma (%)	1 (7)	0 (0)	
Duration of mechanical ventilation (days)	6 (2–13)	8 (6–13)	0.35
Smoking history (%)	3 (21)	4 (29)	0.66
PaO_2/FiO_2	407 (380–500)	418 (364–497)	0.77
WLST-CA (min)	16 (12–21)	15 (12–22)	0.96
CA-ColdPerf (min)	16 (12–23)	14 (11–19)	0.44
WLST-ColdPerf (min)	33 (27–44)	31 (29–38)	0.8
sBP <60 mmHg-ColdPerf (min)	25 (20–35)	21 (16–24)	0.10
Skin incision-ColdPerf (min)	10 (7–18)	9 (6–14)	0.50

Data are presented as n, median (range) or n (%).

A-NRP: abdominal normothermic regional perfusion; A-RR: abdominal rapid retrieval; BMI: body mass index; CA: cardiac arrest; CVA: cerebrovascular accident; PaO_2/FiO_2: partial oxygen pressure over fractional inspired oxygen concentration; WLST: withdrawal of life-sustaining therapy.

Table 2: Recipient and transplant-related characteristics

Variables	A-NRP (n = 14)	A-RR (n = 14)	P-value
Age (years)	58 (37–62)	60 (54–64)	0.18
Sex			0.25
Male (%)	10 (71)	7 (50)	
Female (%)	4 (29)	7 (50)	
Diagnosis			0.05
COPD (%)	3 (21)	9 (64)	
ILD (%)	4 (29)	4 (29)	
CF (%)	4 (29)	0 (0)	
Other (%)	3 (21)	1 (7)	
LAS, median (range)	36 (34–40)	34 (32–40)	0.32
SPH (%)	6 (43)	9 (64)	0.26
Smoking history (%)	9 (64)	13 (93)	0.11
CMV (%)	12 (86)	11 (79)	0.6
BMI (kg/m^2)	24 (21–27)	26 (23–27)	0.24
Pretransplant medical condition			0.57
ECMO (%)	1 (7)	0 (0)	
Invasive mechanical ventilation (%)	0 (0)	1 (7)	
Non-invasive mechanical ventilation (%)	3 (21)	3 (21)	
Size mismatch (donor pTLC/recipient pTLC)	1.0 (0.9–1.1)	1.1 (1.0–1.25)	0.11
1st graft ischaemic time (min)	318 (300–364)	300 (226–363)	0.49
2nd graft ischaemic time (min)	450 (380–513)	480 (405–518)	0.72
Intraoperative ECLS			0.48
ECMO (%)	6 (43)	3 (21)	
CPB (%)	2 (14)	3 (21)	
No support (%)	6 (43)	8 (57)	

Data are presented as n, median (range) or n (%).

A-NRP: abdominal normothermic regional perfusion; A-RR: abdominal rapid retrieval; BMI: body mass index; CF: cystic fibrosis; COPD: chronic obstructive pulmonary disease; CPB: cardiopulmonary bypass; ECLS: extracorporeal life support; ECMO: extracorporeal membrane oxygenation; ILD: interstitial lung disease; LAS: lung allocation score; pTLC: predicted total lung capacity; SPH: secondary pulmonary hypertension.

Survival and follow-up

The mean follow-up time was 2.2 ± 1.4 and 2.8 ± 2.4 years in the A-NRP and A-RR groups, respectively. Survival in both groups was comparable (Fig. 4). The median intensive care unit LOS was 8 (6–23) vs 7 (6–22) days, respectively (P = 0.9), and postoperative LOS was 46 (33–116) vs 50 (35–121) days, respectively (P = 0.9), in the A-NRP vs A-RR groups. One patient in the A-NRP group died during follow-up (108 days after transplantation) due to pulmonary fungal infection. Another patient in the A-NRP group had acute cellular rejection 118 days after transplantation and a retransplantation was performed using a cDCD donor. One

Table 3: Post-transplant complications and outcomes

Variables	A-NRP ($n = 14$)	A-RR ($n = 14$)	P-value
PGD grade			
24 h			0.89
0 (%)	2 (14)	3 (21)	
1 (%)	5 (36)	4 (29)	
2 (%)	3 (21)	2 (14)	
3 (%)	4 (29)	5 (36)	
48 h			0.65
0 (%)	4 (29)	2 (14)	
1 (%)	6 (43)	5 (36)	
2 (%)	2 (14)	3 (21)	
3 (%)	2 (14)	4 (29)	
72 h			0.09
0 (%)	1 (7)	4 (29)	
1 (%)	9 (64)	3 (21)	
2 (%)	1 (7)	4 (29)	
3 (%)	3 (21)	3 (21)	
PGD 3 (%)	6 (43)	7 (50)	0.7
ECMO postoperatively (%)	3 (21)	4 (29)	0.66
Duration of postoperative ECMO support (days)	4 (3–13)	4 (2–4)	0.49
Rethoracotomy (%)	4 (29)	1 (7)	0.14
Intubation time (h)	24 (24–108)	48 (24–360)	0.52
ICU stay (days)	8 (6–23)	7 (6–22)	0.9
Hospital mortality (%)	1 (7)	1 (7)	1.0
Postoperative length of stay (days)	46 (33–116)	50 (35–121)	0.9
30-Day survival (%)	13 (93)	14 (100)	0.31
1-Year survival (%)	13 (93)	13 (93)	1.0
1-Year graft failure (%)	2 (14)	1 (7)	0.8
Acute cellular rejection (%)	7 (50)	5 (36)	0.55
Airway complications (%)	1 (7)	1 (7)	1.0

Data are presented as *n*, median (range) or *n* (%).

A-NRP: abdominal normothermic regional perfusion; A-RR: abdominal rapid retrieval; ECMO: extracorporeal membrane oxygenation; ICU; intensive care unit; PGD: primary graft dysfunction.

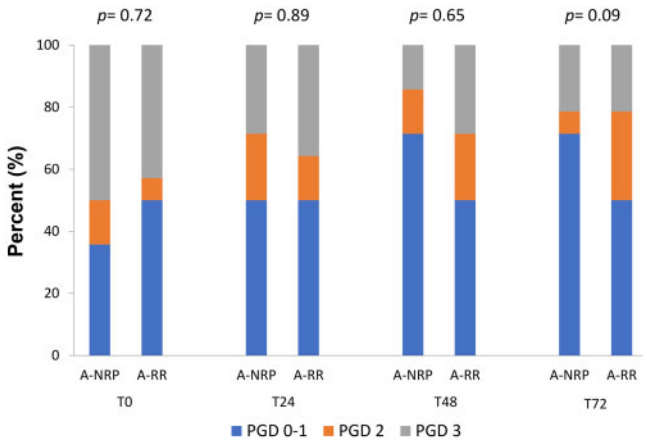

Figure 3: Prevalence and severity of PGD from immediately after reperfusion to 72 h after intensive care unit admission. A-NRP: abdominal normothermic regional perfusion; A-RR: abdominal rapid retrieval; PGD: primary graft dysfunction.

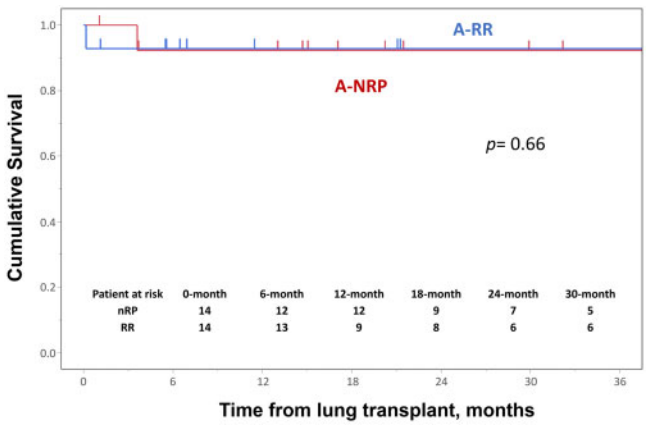

Figure 4: Kaplan–Meier estimates for survival after lung transplantation, according to procedure for the retrieval of abdominal donor organs. A-NRP: abdominal normothermic regional perfusion; A-RR: abdominal rapid retrieval.

patient from the A-RR group died 5 days after transplantation due to severe PGD.

DISCUSSION

This study describes our experience with LTx from cDCD donors who have undergone RR of the lungs combined with either A-NRP or A-RR for the abdominal organs. Our results show that the A-NRP group had comparable postoperative LTx outcomes to the A-RR group. The retrieval technique in cDCD that combines A-NRP for the benefit of abdominal grafts with RR techniques for the lungs had no significant impact on cDCD lungs and is considered safe for thoracic grafts. Overall, A-NRP could potentially be the superior operative procedure for cDCD donors.

The use of ECMO devices for the retrieval of abdominal organs was first proposed by Spanish teams as the ideal approach for

the assessment of uncontrolled DCD procurement [13]. It was associated with high abdominal organ retrieval rates and encouraging clinical results [9]. In cDCD, organ procurement is more commonly performed using the RR technique; however, the outcomes of abdominal DCD organ transplantation are inferior compared to those of the DBD [5, 6]. Hence, the benefits of A-NRP in uncontrolled DCD identified by the Spanish teams attracted interest for the procedure's potential benefits in cDCD, and the technique was explored for cDCD donors in the UK [14] and the United States [15] with superior outcomes to classic cDCD transplantation results [10, 16].

However, this method has the potential to injure lung grafts because of the complex procurement procedure and risk of potential trans-diaphragmatic warming of the flushed lung [17].

Three previous reports have examined LTx patients receiving cDCD donor lungs with A-NRP. Oniscu *et al.* and Mimambres *et al.* [10, 14] reported 3 and 6 cases of LTx using A-NRP with successful outcomes, respectively. However, A-NRP could not be evaluated analytically due to the small number of cases. Minambres *et al.* [18] compared 16 recipients who received DCD donor lungs with A-NRP to 29 recipients who received DBD donor lungs, and both groups showed comparable survival rates. Notably, we compared the outcomes of cDCD LTx between the A-NRP and A-RR groups to better understand A-NRP.

Despite several encouraging reports on the usefulness of A-NRP, it is not a globally adopted technique owing to the potential risk of cerebral perfusion after declaration of death. This can occur when the aorta is not adequately blocked. A specific method to avoid restoring circulation to the brain when using A-NRP and ante-mortem cannulation has been described [10, 19]. In addition, the complexity of the surgical procedure limits the widespread acceptance of A-NRP. Although the complexity of organ procurement with A-NRP is increased, we have not encountered relevant differences in the lung retrieval time; moreover, no cases of abdominal organ loss due to sustained bleeding from either collaterals or the dissection and transection of major vessels in the thoracic cavity have occurred in our series because of careful haemostasis after lung explant; in addition, no negative impact on abdominal organ transplant outcomes has been reported [2].

Our postoperative outcomes were comparable to those of the conventional method, even when we considered the high allowable range of ratio of PGD grade 3 in cDCD [20]. The FWIT was slightly longer in the A-NRP group than that in the RR group; however, the difference was not statistically significant. Moreover, this was not associated with ECMO, which started after the declaration of death. Spain and Belgium allow ante-mortem cannulation and heparinization of a potential DCD donor, which can further decrease the FWIT. However, ante-mortem cannulation is not permitted in other countries where cannulation is completed following the declaration of death. Post-mortem cannulation is complex, and the FWIT may differ from that reported in our study.

Based on our results, there is no negative impact of using A-NRP in thoracic and abdominal DCD donor organ procurement. The procedure appears to be safe for both thoracic and abdominal grafts.

Given the encouraging organ utilization rates and clinical outcomes of A-NRP, the possibility of thoraco-abdominal NRP was recently proposed as a future approach for organ procurement in DCD donations [21, 22]. Thoraco-abdominal NRP has been successfully performed in 1 case in our hospital. In our thoraco-abdominal NRP protocol, which is focused on cardiac retrieval, the patient is cannulated before WLST. After CA and a 5-min hands-off period, a median sternotomy is performed by cardiac surgeons and supra-aortic trunks are clamped in order to avoid cerebral perfusion. Once this step is assured, peripheral veno-arterial-ECMO is started for thoraco-abdominal NRP. Doppler control of middle cerebral arteries is carried out during the perfusion period. After restoration of cardiac function, which is checked by using transoesophageal echocardiography, we start the ECMO support weaning. Once the heart can perfuse all the organs perfusion, the heart, lungs and abdominal organs are carefully assessed. Lung assessment in this scenario is carried out following the same criteria as in DBD. After these manoeuvres, the process of organ procurement is similar to that in DBD. This procedure has several advantages: the ability to assess all donor organs in situ, including DCD heart function, pre-procurement and a methodical surgical dissection that minimizes the risk of organ damage.

Limitations

Our present study has several limitations. First, it is a retrospective study. However, we believe that the effect of A-NRP was successfully investigated due to the extensive collection of detailed demographic information and objective analysis of data. Second, this study was at a relatively small scale and was conducted at a single centre. Nevertheless, we believe that our series of 14 patients (the second-largest patient series published to date) is a significant source of data, with unvarying procurement and perioperative management protocols.

CONCLUSION

In conclusion, NRP for abdominal organs is not a contraindication for simultaneous rapid lung retrieval and does not cause any technical difficulty using standard cold preservation techniques for cDCD lungs. This study adds to the body of evidence that supports the use of A-NRP for cDCD donors during organ retrieval.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *EJCTS* online.

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Conflict of interest: none declared.

Author contributions

Shin Tanaka: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Validation; Visualization; Writing—original draft; Writing—review

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