The 2024 American Association for Thoracic Surgery expert consensus document: Current standards in donor lung procurement and preservation

Jasleen Kukreja, MD,[a] Jose Luis Campo-Canaveral de la Cruz, MD, PhD,[b] Dirk Van Raemdonck, MD,[c] Edward Cantu, MD, MSCE,[d] Hiroshi Date, MD, PhD,[e] Frank D'Ovidio, MD, PhD,[f] Matthew Hartwig, MD,[g] Jacob A. Klapper, MD,[g] Rosemary F. Kelly, MD,[h] Sandra Lindstedt, MD, PhD,[i] Lorenzo Rosso, MD, PhD,[j] Lara Schaheen, MD,[k] Michael Smith, MD,[k] Bryan Whitson, MD,[l] Sahar A. Saddoughi, MD, PhD,[m] and Marcelo Cypel, MD[n]

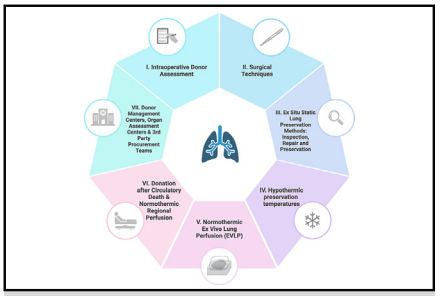
ABSTRACT

Background: Donor lung procurement and preservation is critical for lung transplantation success. Unfortunately, the large variability in techniques impacts organ utilization rates and transplantation outcomes. Compounding this variation, recent developments in cold static preservation and new technological advances with machine perfusion have increased the complexity of the procedure. The objective of the American Association for Thoracic Surgery (AATS) Clinical Practice Standards Committee (CPSC) expert panel was to make evidence-based recommendations for best practices in donor lung procurement and preservation based on review of the existing literature.

Methods: The AATS CPSC assembled an expert panel of 16 lung transplantation surgeons from 14 centers who developed a consensus document of recommendations. The panel was divided into 7 subgroups covering (1) intraoperative donor assessment, (2) surgical techniques, (3) ex situ static lung preservation methods, (4) hypothermic preservation, (5) normothermic ex vivo lung perfusion (EVLP), (6) donation after circulatory death (DCD) and normothermic regional perfusion, and (7) donor management centers, organ assessment centers, and third-party procurement teams. Following a focused literature review, each subgroup formulated recommendation statements for each subtopic, which were reviewed and further refined using a Delphi process until a 75% consensus was achieved on each final statement by the voting group.

Results: The expert panel achieved consensus on 34 recommendations for current best practices in donor lung procurement and preservation both in brain-dead as well as DCD donation. The use of new methods of cold preservation, the role of EVLP, and DCD with and without concomitant heart donation are described in detail.

Conclusions: Consistent and best practices in donor lung procurement and preservation are critical to improve both lung transplantation numbers as well as recipient outcomes. The recommendations described here provide guidance for professionals involved in the care of patients with end-stage lung disease considered for transplantation. (J Thorac Cardiovasc Surg 2025;169:484-504)



Key steps during lung procurement and preservation.

CENTRAL MESSAGE

Consistent and standardized donor lung procurement and preservation strategies are essential to ensure optimal donor lung utilization and transplantation outcomes.

PERSPECTIVE

Significant variability exists in techniques for donor lung procurement and preservation, influencing both organ utilization rates and post-transplantation outcomes. The goal of this expert panel was to offer easily implementable, pragmatic, and uniform recommendations for donor lung procurement and preservation. These recommendations provide insights into current practices while also offering a forward-looking perspective on the future directions of lung procurement and preservation.

From the [a]Department of Surgery, University of California, San Francisco, Calif; [b]Hospital Universitario 12 de Octubre, Madrid, Spain; [c]Department of Thoracic Surgery, University Hospitals Leuven, Leuven, Belgium; [d]Department of Surgery, Hospital of the University of Pennsylvania, Philadelphia, Pa; [e]Department of Surgery, Kyoto University Graduate School of Medicine, Kyoto, Japan; [f]Division of Thoracic Surgery, Columbia University Medical Center, New York, NY; [g]Department of Surgery, Duke University Medical Center, Durham, NC; [h]Division of CardioThoracic Surgery, University of Minnesota, Minneapolis, Minn; [i]Division of Thoracic Surgery, Skane University Hospital, Lund, Sweden; [j]Department of Pathophysiology and Transplantation, Fondazione IRCCS Ospedale Maggiore Policlinico, University of Milan, Milan, Italy; [k]St Joseph's Hospital and Medical Center, Phoenix, Ariz; [l]Division of Cardiac Surgery, Ohio State University Medical Center, Columbus, Ohio; [m]Department of Surgery, Mayo Clinic, Rochester, Minn; and [n]Division of Thoracic Surgery, University of Toronto, Toronto, Ontario, Canada

Funded by the American Association for Thoracic Surgery.

Read at the 104th Annual Meeting of The American Association for Thoracic Surgery, Toronto, Ontario, Canada, April 27-30, 2024.

Abbreviations and Acronyms

AATS	= American Association for Thoracic Surgery
A-NRP	= abdominal-normothermic regional perfusion
CIT	= cold ischemic time
CoR	= class of recommendation
CPSC	= Clinical Practice Standards Committee
DBD	= donation after brain death
DCD	= donation after circulatory death
DMC	= donor management center
EC	= Euro-Collins
ECD	= extended-criteria donor
ECMO	= extracorporeal membrane oxygenation
EVLP	= ex vivo lung perfusion
FiO_2	= fraction of inspired oxygen
ICU	= intensive care unit
LoE	= level of evidence
LPD	= low-potassium dextran
LPP	= lung procurement and preservation
NRP	= normothermic regional perfusion
OCS	= Organ Care Systems
OPTN	= Organ Procurement and Transplantation Network
Organ ARC	= organ assessment and repair center
PA	= pulmonary artery
P/F	= partial pressure of oxygen/fraction of inspired oxygen
PGD	= primary graft dysfunction
SCD	= standard-criteria donor
TA-NRP	= thoracoabdominal-normothermic regional perfusion
uDCD	= uncontrolled donation after circulatory death
UNOS	= United Network for Organ Sharing
UW	= University of Wisconsin
WIT	= warm ischemic time
WLST	= withdrawal of life support therapy

Despite significant progress in the field, the outcomes of lung transplantation continue to lag behind those of other solid organ transplants. This disparity is likely multifactorial, encompassing every stage of the transplant process, including a donor's journey through prerecovery lung optimization to the intraoperative assessment and management of lungs and extending to the postprocurement preservation phase. Yet the processes of donor lung procurement and preservation are characterized by a notable lack of standardization. Variation in intraoperative donor lung assessment, management, perfusion techniques, temperatures, solution composition, and other aspects contribute to the lack of a consistent framework. These inconsistencies become even more relevant for donation after circulatory death (DCD) lung donors. The divergent practices across individuals, institutions and/or regions can significantly impact the overall quality of donor organs and their utilization, ultimately influencing transplant outcomes.

Equally important to the aforementioned inconsistencies, there is considerable variability in the storage conditions for procured lungs. For instance, inflation pressure, fraction of inspired oxygen (FiO_2), and temperature during cold static storage are not standardized. These variations may introduce inconsistencies in organ quality and cellular integrity, potentially influencing the success of the transplantation procedure. Thus, maintaining organ viability during the critical phases of retrieval, flush perfusion, and storage has been the subject of investigations from the early days of lung transplantation. Recent innovations and refinements, such as ex vivo lung perfusion and exploration of warmer temperatures for hypothermic preservation, have brought about significant advancements in the field. Similarly, the emergence of specialized organ recovery centers and third-party recovery teams has the potential to be transformative by concentrating donor and organ optimization and procurement expertise to dedicated facilities and personnel. Of note, most of the data generated on the topic of lung procurement and preservation are derived from retrospective studies, with only a few randomized clinical trials.

The purpose of this expert consensus document from the American Association for Thoracic Surgery (AATS) Clinical Practice Standards Committee (CPSC) is to systematically review the existing literature on donor lung procurement and preservation techniques. The aim is to provide easily implementable, pragmatic, and standardized recommendations that contribute to the enhancement of organ quality, thereby ensuring successful transplantation outcomes. We present a total of 34 recommendations, including intraoperative in situ and ex situ donor lung assessment, management, and preservation; describe the

Received for publication April 15, 2024; revisions received Aug 18, 2024; accepted for publication Aug 25, 2024.

Address for reprints: Jasleen Kukreja, MD, Division of Cardiothoracic Surgery, University of California, San Francisco, 500 Parnassus Ave., MUW 405, Box, 0118, San Francisco, CA 94143 (E-mail: Jasleen.kukreja@ucsf.edu); or Marcelo Cypel, MD, Divison of Thoracic Surgery, University of Toronto, University Health Network, 661 University Ave, Suite 9100E, Toronto, Ontario M5G 1M1, Canada (E-mail: Marcelo.Cypel@uhn.ca).

0022-5223/$36.00

https://doi.org/10.1016/j.jtcvs.2024.08.052

new methods of cold preservation, the role of EVLP, and DCD with and without concomitant heart donation; and briefly discuss specialized donor/organ recovery centers and personnel, providing associated evidence to support those recommendations. The document is intended to serve as a reference for professionals involved in the care of both donors and recipients of lung transplantation.

METHODS

The AATS CPSC and Assembly of Expert Group

The AATS appointed co-chairs and members of the CPSC, who subsequently chose the subject of donor lung procurement and preservation. The co-chairs then curated a writing group comprising renowned experts in lung transplantation, particularly those individuals with expertise in clinical practice guideline development, evidence-based medicine, research, preparation of systematic reviews, or quality improvement. The writing group members were approved by the AATS. All members completed their conflict of interest disclosures.

Formulation of Clinical Topics and Working Groups

Following the assembly of an expert writing group panel of 16 lung transplantation surgeons, the co-chairs and panel members developed an organizational structure and outlined a set of topics for the consensus statement. During group sessions, these topics were refined into a definitive set covering the following topics (Figure 1): (1) intraoperative donor assessment, (2) surgical techniques, (3) ex situ static lung preservation methods, (4) hypothermic preservation, (5) normothermic ex vivo lung perfusion (EVLP), (6) DCD and normothermic regional perfusion (NRP), and (7) donor management centers (DMCs), organ assessment centers (OACs), and third-party procurement teams. The panel was subdivided into smaller working groups, each tasked with addressing specific topics aligned with their published expertise and individual interests.

Development of an Expert Consensus Document

Each working subgroup diligently conducted a systematic literature review tailored to its respective topics, sharing the compiled references for group consideration. Subsequently, these groups formulated recommendation statements specific to their topics, supported by pertinent references when available. The recommendations were then presented to the larger group for evaluation using a Delphi method.

For the evaluation process, the expert consensus panel used a 5-point Likert scale, graded as 1, strongly disagree; 2, disagree; 3, neither agree nor disagree; 4, agree; or 5, strongly agree. A predetermined 80% response rate was mandated for the vote to be considered complete. To establish consensus, a predefined threshold of at least 75% agreement ("agree" or "strongly agree") was required for acceptance of the consensus statement.[1] If the 75% threshold was not achieved, the statement underwent revision after discussion with the writing group and subsequently was resubmitted for repeat voting. This iterative process continued until consensus was achieved on all recommendation statements. The class of recommendation (CoR) and the level of evidence (LoE) supporting it were reported in

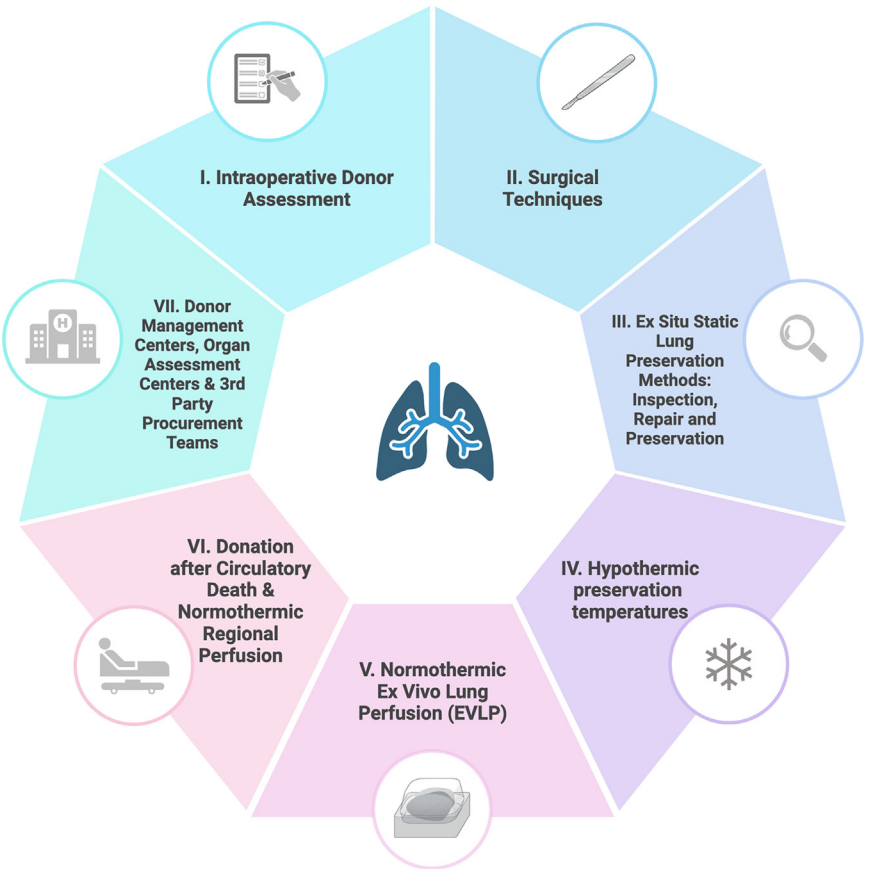


FIGURE 1. Key steps during lung procurement and preservation.

accordance with the terminology adopted by the American College of Cardiology and American Heart Association.[2]

A summary of all sections with their statements, CoR, LoE, and agreement is provided in Table 1.

Section I: Intraoperative Donor Assessment

On arrival at the donor hospital, the procurement surgeon should reassess the donor's medical history, organ-specific function, imaging studies, and other relevant clinical parameters such as blood type compatibility, to

TABLE 1. Table of statements including class of recommendation, level of evidence, and consensus %

Section no.	Statement no.	Section statements	CoR	LoE	Consensus
Intraoperative donor assessment					
I	1	A P/F ratio >300 mm Hg traditionally has been accepted as the threshold for adequate gas exchange in a prospective allograft. Adherence to this ratio is not mandatory and has not been shown to correlate with outcomes. It should be used instead as part of the global intraoperative assessment.	IIa	C-LD	100%
	2	Intraoperative bronchoscopy should be performed routinely to assess for anatomic abnormalities, clear mucus plugging, and ensure ventilation of all lobar segments. Evidence of minor amounts of aspirated gastrointestinal contents or purulent secretions that do not readily reaccumulate should not be considered an absolute contraindication to organ acceptance; rather, these findings should be interpreted in the context of associated friable airways, positive bronchoalveolar lavage cultures, and pneumonia on imaging.	I	C-EO	100%
	3	Fundamentals of gross inspection should include evaluation for lesions, edema, infarcts, contusions, and blebs/bullae, with close attention to ease of recruitment and compliance. Atelectatic pulmonary parenchyma that requires significant inspiratory pressure (ie, 30 mm Hg) to achieve and maintain full recruitment suggests a suboptimal allograft.	I	C-EO	100%
	4	Pulmonary vein gases are a useful adjunct in the overall intraoperative assessment. Their greatest utility may be in assessment of a single lung or when considering lobar transplant.	I	C-LD	100%
Surgical technique					
II	5	Pulmonary vasodilators (eg, prostaglandins) may reduce reactive pulmonary vasoconstriction and should be infused just prior to or with the initial pulmonary flush.	I	C-EO	94%
	6	Donor lungs should be flushed antegrade with cold preservation solution via the pulmonary arteries, while ensuring adequate venting from the left atrial appendage or left atrium while the lungs are gently ventilated. In addition, the lungs should be flushed retrograde via the pulmonary veins in situ after heart extraction or ex situ after lung removal.	I	C-LD	100%
	7	Extracellular fluid type solutions provide superior protection during lung preservation compared to intracellular fluid type solutions and should be used during lung procurement.	I	B-NR	100%
Ex situ lung preservation methods					
III	8	Donor lung inflation with 50% oxygen avoiding hyperinflation prior to cold static storage might be beneficial for outcome after lung transplantation.	IIb	C-LD	100%
	9	Direct contact with ice may result in frost injury of donor lungs. This should be avoided by packing lungs in a first bag filled with cold preservation solution and a second bag with a physiologic liquid solution.	I	C-EO	100%
	10	Intraoperative donor lung injuries to pulmonary vessels and parenchyma may often be repaired on the back table at the time of retrieval or prior to implantation and should not always be a contraindication for transplantation.	IIb	C-LD	100%
	11	Inadvertent and unrecognized transection or ligation of pulmonary vessels may lead to either immediate bleeding and need for a lobectomy or to delayed lobar/segmental infarction after transplantation.	IIb	C-EO	88%

(Continued)

TABLE 1. Continued

Section no.	Statement no.	Section statements	CoR	LoE	Consensus
Hypothermic preservation					
IV	12	Although the optimal temperature for donor lung storage has not yet been determined, studies investigating static cold storage between 4 °C and 10 °C support the use of these warmer temperatures for safe storage of donor lungs.	IIa	B-NR	100%
	13	Intentional extension of the CIT appears to be safe and feasible using preservation temperatures warmer than 0 °C to 4 °C.	IIa	B-NR	93%
Normothermic EVLP					
V	14	EVLP is useful under many conditions, including a P/F ratio <300 mm Hg, evidence of pulmonary edema, poor lung compliance, and in donors with minor to moderate aspiration.	I	B-NR	93%
	15	EVLP is an important option for donor lungs that either cannot be properly evaluated in the donor and/or for logistical reasons.	I	B-NR	100%
	16	EVLP is not recommended in donors with potential signs of irreversible lung injury, such as parenchymal destruction and/or consolidation. EVLP is not performed in cases with signs of severe aspiration. Close examination and communication between organ recovery and the implanting surgeon is recommended to determine the suitability of the graft for EVLP.	III	B-NR	93%
	17	Graft quality assessment on EVLP is based on multiple standard physiologic and objective parameters. One parameter alone is insufficient to assess graft quality.	I	B-NR	100%
	18	Clinical use of EVLP has been driven mainly by 3 major protocols: the Toronto protocol, the Lund protocol, and the OCS protocol.	IIa	C-LD	100%
Donation after circulatory death and normothermic regional perfusion					
VI	19	The decision to pursue organ donation in non-brain-dead donors still leads to controversial ethical questions. Protocols in place throughout the decision to withdraw life-sustaining therapy and the DCD process are critical to ensure an ethical process for the donor that has led to increases in lung transplantation.	I	C-EO	86%
	20	DCD lung donation requires additional financial and educational investment from transplant programs; however, this investment leads to expansion of the donor pool for lung transplantation.	I	C-LD	93%
	21	Use of DCD lungs leads to equivalent long-term survival outcomes and expanded adoption is encouraged.	I	B-NR	100%
	22	In patients not expected to survive withdrawal of life-sustaining treatments and who have given consent (primary or next of kin), premortem heparin administration is recommended for all DCD lung recoveries unless its use will hasten death or is prohibited by local regulations.	I	B-NR	93%
	23	In patients not expected to survive the withdrawal of life-sustaining treatments and who have given consent (primary or next of kin), it is essential to observe a locally and/or legally accepted hands-off period following circulatory arrest and prior to donor procurement to reduce the warm ischemic time and negate the potential for autoresuscitation.	I	B-NR	94%
	24	In patients not expected to survive withdrawal of life-sustaining treatments and who have given consent (primary or next of kin), the functional warm ischemic time should be defined as the interval between systolic blood pressure decline to <50 mm Hg and cold perfusion.	I	B-NR	86%
	25	The use of lungs from DCD organ donors is indicated when the time between withdrawal of support therapy and asystole is <60 min (class I) and reasonable when the time is <180 min.	I & IIa	B-NR	86%

(Continued)

TABLE 1. Continued

Section no.	Statement no.	Section statements	CoR	LoE	Consensus
	26	Evaluation of DCD lungs can be more difficult due to lack of standard tests. If after intraoperative assessment there is still uncertainty regarding lung function, EVLP should be considered prior to organ discard.	I	B-NR	93%
	27	In patients unsuccessfully resuscitated after cardiac arrest, lung donation might be considered despite the logistical complexity.	IIa	B-NR	86%
	28	In the uncontrolled donation after cardiac arrest scenario, further assessment of the grafts using EVLP is advised due to lack of information on donor lung function prior to procurement.	IIa	B-NR	93%
	29	Concomitant recovery of both DCD heart and lungs using direct perfusion and procurement is encouraged and recommended when appropriate.	I	C-LD	94%
	30	There are limited data on the effect of TA-NRP on lung function. The use of DCD lungs after TA-NRP remains controversial, and additional data are required.	IIb	C-EO	86%
	31	The procurement of lungs during A-NRP can be performed safely without adversely impacting lung transplant outcomes.	IIa	C-LD	88%
Organ assessment centers and third-party procurement teams					
VII	32	There may be a role for organ assessment centers where centralized expertise and knowledge can be aggregated to maximize resuscitation and enhance lung organ utilization. These centers would have resources and experience in EVLP to physiologically assess and optimize allografts prior to acceptance.	IIa	B-NR	88%
	33	Recovery centers or donor management centers (hospital- or OPO-based) facilitate overall donor organ recovery through donor optimization, coordination of multiple recovery teams, timely recovery and a focus on honoring the donor and their support people.	IIa	C-EO	92%
	34	Third-party procurement services may be an alternative option to increase organ acceptance and recovery rates at centers where the procurement services may not be readily available.	IIa	C-EO	100%

CoR, Class of recommendation; *LoE*, level of evidence; *P/F*, partial pressure of oxygen/fraction of inspired oxygen; *EVLP*, ex vivo lung perfusion; *DCD*, donation after circulatory death; *TA-NRP*, thoraco-abdominal normothermic regional perfusion; *A-NRP*, abdominal-normothermic regional perfusion; *OPO*, organ procurement organization.

ensure that organs are still acceptable for transplantation. It is important to emphasize that the evaluation process should not rely solely on isolated factors but instead use a more global assessment of the organ's overall suitability for transplantation.

1. A partial pressure of oxygen (PaO_2)/FiO_2 (P/F) ratio >300 mm Hg traditionally has been accepted as the threshold for adequate gas exchange in a prospective allograft. Adherence to this ratio is not mandatory and has not been shown to correlate with outcomes. It should be used instead as part of the global intraoperative assessment. (CoR; Iia; LoE: C-LD)

A preoccupation with blood gas values has persisted over the years and remains a cornerstone of donor lung evaluation. Historical publications in the first decade of successful lung transplant emphasized this metric as an indication of a quality organ. The P/F ratio remains one of the first objective values reported to surgeons and pulmonologists during organ offers[3,4]; however, there is little evidence supporting the outright rejection of an organ based solely on the P/F ratio. Yet reliance on this single numerical parameter likely results in rejection of organs with acceptable quality. For example, a low P/F ratio may be simply a result of atelectasis or the donor's unstable hemodynamics. Thus, the P/F ratio at the time of donor recovery, after bronchoscopy, and after recruitment with visible atelectasis, is the most reliable value. The recent International Society for Heart and Lung Transplantation report on deceased donors clearly demonstrates no discernible difference in either 1-year or 5-year survival rates across various PO_2 quartiles. For instance, 1-year survival when the PO_2 was >500 mm Hg was equivalent to that when the PO_2 was <250 mm Hg.[5]

2. Intraoperative bronchoscopy should be performed routinely to assess for anatomic abnormalities, clear mucus plugging, and ensure ventilation of all lobar segments. Evidence of minor amounts of aspirated gastrointestinal contents or purulent secretions that do not readily reaccumulate should not be considered an absolute contraindication to organ acceptance. Rather, these findings should be interpreted in the context of associated friable airways, positive bronchoalveolar lavage cultures, and pneumonia on imaging. (CoR: I; LoE: C-EO)

Bronchoscopic examination of the airways is a fundamental aspect of donor assessment. Relying solely on the donor's initial bronchoscopy is insufficient, given the likely time lapse between that procedure and the actual procurement. Mucus and debris likely will be seen on examination, a common occurrence in an intubated patient. The focus then should be on evaluating the character of secretions and whether purulent secretions reaccumulate after suctioning, particularly in the lower lobes. This observation may be indicative of a developing or worsening pneumonia. Additionally, it is essential to assess the overall health of the bronchial tree. Friable hyperemic airways may suggest prior instances of aspiration or pneumonia. This observation should be integrated with other findings, including the presence of purulent secretions and infiltrates, and with the findings of a thorough gross inspection and palpation of the lungs to determine suitability for transplantation. In rare instances, donors may exhibit anomalies such as a

bronchus suis (ie, the pig bronchus[6]), in which the bronchus to the right upper lobe comes directly off the trachea or even an endobronchial neoplasm.

3. Fundamentals of gross inspection should include evaluation for lesions, edema, infarcts, contusions, and blebs/bullae, with close attention to ease of recruitment and compliance. Atelectatic pulmonary parenchyma that requires significant inspiratory pressure (ie, 30 cmH_2O) to achieve and maintain full recruitment may suggest a suboptimal allograft. (CoR: I; LoE: C-EO)

Despite the wealth of data available on prospective donors prior to arrival at the procurement site, a diligent and thorough inspection of the lungs remains irreplaceable. Even with the improved resolution of modern imaging, subtle lung abnormalities can elude detection; for example, small bullae in an older donor with a smoking history might signal early emphysema. Similarly, what may seem like atelectasis in the lower lobes on imaging could reflect infarction, significant contusions secondary to trauma, or consolidation due to pneumonia and vice versa.

Lung recruitment is fundamental to assessment of the organ. Procurement teams should establish clear communication with anesthesia prior to the procedure to underscore their intentions. At the time of these maneuvers, careful observation of lung compliance, both during recruitment and following expiratory collapse, is essential. Lungs that do not recruit easily or readily collapse on disconnection from the ventilator can be a cause for concern. This information should be emphasized when communicating with the implanting team.

4. Pulmonary vein gas values are useful adjuncts in the overall intraoperative assessment. Their greatest utility may reside in assessment of a single lung or when considering lobar transplant. (CoR: I; LoE: C-LD)

As mentioned previously, an inordinate amount of emphasis is given to arterial blood gases and PaO_2. Although postrecruitment pulmonary vein gases are not strictly necessary, they can provide additional information as part of a global organ assessment. There are specific scenarios in which vein gases may prove particularly helpful, such as in donors in whom the lower lobes are sluggish to recruit and/or potentially edematous.[7] In such cases, suboptimal gas exchange may warrant intraoperative decline or favor lobar transplantation, especially for smaller recipients. Alternatively, it may justify considering the organ for EVLP. In other instances, procurement teams may choose to incorporate pulmonary vein gases into their assessment of a single allograft.[8]

Section II: Surgical Techniques

Following the intraoperative assessment and acceptance of donor lungs, the subsequent procurement and preservation play critical roles in ensuring cellular viability during cold storage. Although certain steps are universal to all organ procurements, some specific procedures for lung procurement are highly recommended to optimize the process.

5. Pulmonary vasodilators (eg, prostaglandins) may reduce reactive pulmonary vasoconstriction and should be infused just prior to or with the initial pulmonary flush. (CoR: I; LoE: C-EO)

Administration of pulmonary vasodilators such as prostaglandin E1 or prostacyclin I2 before flushing reduces the pulmonary vascular resistance, ensuring a more uniform and effective flush while mitigating ischemia-reperfusion injury.[9] In addition, there may be cytoprotective mechanisms of prostaglandins related to cAMP-mediated vascular protection[10] and shifts in the release of proinflammatory and anti-inflammatory cytokines.[11] The standard approach to lung preservation in most lung transplant programs now involves using an extracellular-type flush preservation solution with a low potassium content after prostaglandin injection.[12] However, the beneficial effects of prostaglandins when using an extracellular-type solution have not been conclusively demonstrated in clinical studies.[13] Of note, owing to its systemic effects, the administration of prostaglandins should be communicated to the other retrieval teams and the anesthesia team in the operating room.

6. Donor lungs should be flushed antegrade with cold preservation solution via the pulmonary arteries while ensuring adequate venting from the left atrial appendage or left atrium (LA) while the lungs are gently ventilated. In addition, the lungs should be flushed retrograde via the pulmonary veins in situ after heart extraction or ex situ after lung removal. (CoR: I; LoE: C-LD)

Once all the procurement teams are ready, the donor is systemically heparinized. A large cannula is then inserted into the pulmonary trunk distal to the pulmonary valve, ensuring a good distance from the valve while avoiding preferential perfusion to only one lung, and then secured with a purse-string suture. Before cross-clamping the aorta, prostaglandin is injected into the pulmonary trunk. For DCD lung donors, prostaglandins could be added into the pulmoplegia flush. The donor lungs are vented through either the left atrial appendage or the LA itself. An antegrade pulmonary flush typically with 3 L of a cold preservation solution is initiated through gravity-dependent flow (30 cm above the level of the heart) while gentle lung ventilation is continued.[14]

In addition to the antegrade flush, a retrograde flush should be performed by administering typically 250 mL of the preservation solution through each pulmonary vein, ideally in situ after heart extraction or, alternatively, ex situ after lung extraction on the back table.[14] The retrograde flush solution is vented through the pulmonary artery (PA). Experimental evidence suggests that addition of a retrograde flush improves lung preservation compared to an antegrade flush alone.[15] This effect has been attributed to a more effective distribution of the flush solution along the tracheobronchial tree,[15,16] less severe impairment of surfactant function,[17] and more effective clearance of red blood cells and/or clots within the capillaries.[18,19]

The clinical application of a retrograde flush was initially reported in 3 patients undergoing heart-lung transplantation.[20] Subsequent studies by Varela and colleagues[21] involving 23 consecutive lung transplantation procedures using retrograde flush demonstrated the feasibility of this technique while simultaneously procuring the heart. Venuta and colleagues[22] conducted a randomized trial comparing antegrade flush with antegrade flush followed by retrograde flush in 14 patients undergoing lung transplantation. The addition of retrograde flush improved intrapulmonary shunt fraction, the indexed alveolar-arterial oxygen tension gradient, mean airway pressure, and chest X-ray score. Following this report, retrograde flush was adopted by the majority of lung transplant centers; however, a retrospective study showed no beneficial effect of late retrograde flush performed at the recipient hospital.[23] Given that pulmonary embolism can be detected in 4.4% of donors,[24] early retrograde flush at the donor hospital appears to be important, particularly in cases of DCD lung donation.[18,19]

7. Extracellular fluid-type solutions provide superior protection during lung preservation compared to intracellular fluid-type solutions and should be used during lung procurement. (CoR: I; LoE: B-NR)

Intracellular-type solutions such as Euro-Collins (EC) solution and University of Wisconsin (UW) solution, which contain low sodium and high potassium levels, have been widely used for solid organ preservation, such as kidney and liver.[25] This preference is rooted in the belief that the sodium-potassium pump activity slows in anaerobic conditions during cold preservation, making intracellular preservation solutions vital for maintaining proper electrolyte balance and preventing cellular swelling. However, the lung is unique in its ability to maintain aerobic metabolism by utilizing oxygen in the alveoli even in the absence of blood circulation,[26] and thus it is conceivable that a more physiologically suitable extracellular preservation solution may be preferable for lung preservation. Fujimura and colleagues[27] reported successful 48-hour preservation using an extracellular-type solution in canine lung transplants. The Toronto group demonstrated that low-potassium dextran (LPD) solution outperformed EC solution in terms of significantly

better immediate function of the preserved lungs in canine[28] and rabbit[29] lung transplant models of 24-hour preservation. In a nonrandomized comparison involving human bilateral lung transplantation, the Toronto group demonstrated that the lung function as assessed by P/F was significantly better in the LPD group (n = 44) compared to the EC group (n = 44) (mean, 370 ± 133 mm Hg vs 310 ± 134 mm Hg; $P = .017$) despite significantly longer total graft ischemic times in the LPD group (mean, 348 ± 69 minutes vs 298 ± 92 minutes; $P = .024$).[12] Similar findings were reported by the Hannover group in a retrospective study comparing LPD (n = 51) and EC (n = 55), highlighting improved airway compliance, shorter mechanical ventilation duration, and superior 30-day graft survival with LPD.[30] A study using the United Network for Organ Sharing (UNOS) database indicated that UW (n = 294) was associated with increased risk of 1-year mortality compared to LPD (n = 4161).[31] Although randomized studies are lacking, these retrospective studies collectively suggest that low-potassium solutions are superior to high-potassium solutions for lung preservation. Other low-potassium preservation solutions, such as Celsior,[32] EP-TU,[33] and ET-Kyoto[34] solutions, also have been used, with acceptable outcomes.

Section III: Ex Situ Static Lung Preservation Methods: Inspection, Repair, and Preservation

Following lung retrieval, thorough inspection of the pulmonary allograft on the back table is imperative prior to their cold storage and transportation to the recipient hospital. In this section, we present 4 recommendations for ex situ preservation based on currently available knowledge. Of note, current practice stems mainly from experimental work in animal models and limited clinical data, supplemented by expert opinion.

8. Donor lung inflation with 50% oxygen avoiding hyperinflation prior to cold static storage might be beneficial for outcome after lung transplantation. (CoR: IIb; LoE: C-LD)

As mentioned in Section I, partial lung collapse is not uncommon in an intubated, mechanically ventilated potential organ donor in the intensive care unit (ICU). Atelectasis is associated with lower alveolar fluid clearance, higher pulmonary vascular resistance, and poorer distribution of preservation solution.[15,35,36] Therefore, recruiting atelectatic areas in the donor lungs through a combination of bronchoscopic suctioning, increased inspiratory pressure, and tidal volume prior to flushing the lungs is essential for optimal outcomes. Additionally, recruitment with the chest open has proven to be an effective strategy. By reversing atelectatic zones, ischemic tolerance during cold storage is prolonged, and immediate post-transplantation lung function is expected to be better.

Level of lung inflation. The optimal degree of lung inflation has been investigated extensively by the group at Washington University in St Louis, Mo. In an early study involving canine left-single lung transplantation, intermittent occlusion of the contralateral PA for 10 minutes, donor lung hyperventilation, and inflation to 30 cmH_2O before hypothermic storage yielded excellent post-transplantation lung function after a 30-hour preservation.[37] In a follow-up study using the same model but with permanent PA occlusion, donor lung hyperinflation during storage increased reperfusion pulmonary edema with worse post-transplantation allograft function.[38] These findings corroborated an earlier study by the group using an ex vivo rabbit lung gravimetric model showing that high tidal volume or a high FiO_2 increased pulmonary capillary permeability on reperfusion.[39]

Similarly, DeCampos and colleagues[40] investigated the optimum inflation volume for hypothermic storage. Comparing rat lungs blocks stored in atelectasis and at 25%, 50%, 75%, and 100% of total lung capacity, the authors found that the optimum inflation volume for lung preservation was 50% of total lung capacity. The importance of full static lung inflation at 26 cmH_2O pressure and during 8 hours of cold lung storage also was demonstrated in a rat double-lung transplantation model by Hausen and colleagues.[41] More recent studies with rat and rabbit lungs confirmed the negative impact of both deflation[36] and hyperinflation[42,43] on lung graft quality.

Van Raemdonck and colleagues[44] investigated the impact of postmortem alveolar expansion in a DCD donor using a rabbit lung flush model and found that the tolerance to warm ischemia could be prolonged by inflating or ventilating donor lungs prior to cold crystalloid flush. Importantly, the beneficial effect of alveolar expansion was not contingent on the presence of oxygen during the warm ischemic period.[45] Various successful methods for preserving DCD lungs postmortem have been reported in clinical series, including topically cooling the lungs with chest drains,[46,47] inflation,[48,49] or ventilaton.[50,51]

Level of oxygen. During cold storage, oxygen is required to support aerobic metabolism, albeit at a reduced rate due to hypothermia.[26] The optimal oxygen concentration during lung preservation was studied in excised rabbit lungs by the group at Washington University in St Louis in the early 1990s. In the absence of alveolar oxygen, lactate accumulated and adenosine triphosphate and phosphocreatine were decreased in lung tissue.[26] In an ex vivo paracorporeal perfused rabbit lung model, lungs preserved with 100% oxygen prior to storage at 10 °C for 24 hours outperformed those with room air, while lungs inflated with 100% nitrogen failed to function.[52] A separate study from Kyoto University in Japan compared various oxygen concentrations (0% O_2, 5% O_2, room air, 50% O_2, and 100% O_2) during inflated storage using an ex vivo rat lung reperfusion model. The findings indicated that hyperoxygenation induces mitochondrial dysfunction and increases lipid peroxidation, resulting in deleterious lung function after reperfusion.[53] Investigators at the University of Texas in Dallas, using a rat lung ventilation and perfusion model after a period of cold storage, demonstrated a shift toward fatty acids as a substrate for oxidative metabolism, particularly with a higher oxygen content.[54] Because fatty acid oxidation occurring after ischemia is deleterious, an FiO_2 >50% may contribute to oxygen toxicity and impaired mitochondrial function on reperfusion, attributed to the production of oxygen free radicals.

Adding carbon monoxide, hydrogen, or a combination of both into the gas mixture on inflation of donor lungs prior to cold storage was reported to be protective against ischemia-reperfusion injury in rat studies.[55,56] Despite these promising results, to date the beneficial effects of using carbon monoxide during lung preservation have not been reported in clinical lung transplantation.

Based on the collective findings from animal research discussed above, one can conclude that the post-transplantation outcome is superior when prior to cold static storage, lungs are inflated with 50% oxygen, at a tidal volume of 6 to 8 mL/kg, a positive end-expiratory pressure of 5 cmH_2O, and airway pressure of 15 to 20 cmH_2O, effectively avoiding hyperinflation. Notably, there is a dearth of prospective comparative clinical studies exploring the optimal oxygen concentration, tidal volume, and airway pressure for inflation prior to clamping or stapling the trachea before donor lung retrieval. The recommended ventilation and oxygen settings are listed in Table 2.

9. Direct contact with ice may result in frost injury of donor lungs. This should be avoided by packing lungs in a first bag filled with cold preservation solution and a second bag with a physiologic liquid solution. (CoR: I; LoE: C-EO)

To maintain a low temperature during transportation, procured organs are typically stored surrounded by ice cubes in a portable container. Studies have shown that the average organ temperature drops below 2 °C during transportation and to ±0 °C after 6 hours.[57] Preservation solution may freeze at temperatures below 0 °C, posing a risk of cryoinjury to the organ and potential post-transplantation primary nonfunction.

A recent study from Japan compared different packing methods for bovine liver grafts to prevent freezing injury during transportation for liver transplantation. The temperature of the ice cubes in the cooler box used for graft transportation was −18 °C instead of 0 °C, at which point livers can freeze. The authors found that maintaining a sufficient amount of lactated Ringer's solution in the second bag acted as a temperature buffer, avoiding

TABLE 2. Current recommendations for lung static preservation and storage

Category	Recommendation
Type of solution	Extracellular type
Volume of flush solution	
Antegrade	50-60 mL/kg in PA
Retrograde	250 mL in each pulmonary vein
PA pressure during flush delivery	30 cm above the level of the heart
Temperature of flush solution	4-8 °C
Lung ventilation settings	V_T: 6-8 mL/kg or 50% TLC; PEEP: 5 cmH_2O
Oxygenation	FiO_2: 50%
Inflation pressure (pre stapling)	15-20 cmH_2O
*Standard storage temperature	0-4 °C

PA, Pulmonary artery; V_T, tidal volume; *TLC*, total lung capacity; *PEEP*, positive end-expiratory pressure; FiO_2, fraction of inspired oxygen. *Results from ongoing clinical trials preserving donor lungs at elevated temperatures (4-10 °C) are awaited.

direct contact between the UW solution in the first bag and the ice cubes in the cooler box. This effectively averted excessive low temperatures and freezing of the UW and grafts.[58]

The authors are not aware of any studies investigating the best method of packing lungs prior to cold storage. Based on individual case experiences, both direct and indirect exposure of lung parenchyma to ice can result in frostbite, observed as frozen perihilar fatty tissue during unpacking and preparation on the back table for subsequent implantation. Therefore, it is advised to pack lungs first in a bag filled with cold extracellular composition solution, avoiding direct ice contact, followed by a second bag filled with a cold physiologic solution. Deairing the bags and sealing with a heavy ribbon ensures complete immersion of donor lungs in the preservation solution. A third empty bag can be used prior to placing the lungs in a cooler for transport.

10. Intraoperative donor lung injuries to pulmonary vessels and parenchyma often may be repaired on the back table at the time of retrieval or prior to implantation and should not always be a contraindication for transplantation. (CoR: IIb; LoE: C-LD)

Cardiothoracic surgical fellows, when trained for donor lung assessment and procurement, should receive instruction from a senior attending surgeon following a standardized protocol before independently performing the procedure at a donor hospital.[59] Injuries to the donor lung should be avoided at the time of retrieval. It is mandatory to carefully inspect the explanted organ on the back table before packing and storage. Any identified injuries should be meticulously documented and communicated to the recipient team to ensure preparation for potential technical challenges during pulmonary graft implantation or for potential complications following transplantation.

Parenchymal abnormalities such as small blebs, an isolated bulla, scar lesions, or peripheral infarcts usually can be resected with a linear stapling device. Similarly, parenchymal lacerations can be sutured or stapled wedge excised before packing. Occasionally, a lobectomy in an otherwise healthy donor lung may be necessary to address larger or more centrally located abnormalities, as seen in significant lobar contusion or pneumonia.

Intraoperative injuries to pulmonary vessels may occur inadvertently during the dissection, splitting, or extraction of the heart-lung block. Most injuries result from leaving an excessively short arterial or left atrial cuff to the double-lung block. Such incidents may occur during a hurried cardiectomy in which careful attention to anatomic landmarks is neglected. A thorough inspection of pulmonary vessels on the back table is essential to promptly recognize and address such injuries. Several techniques for repairing a short arterial or atrial cuff before implantation[60-66] or when standard hilar clamping is no longer possible[62,67] have been described; however, no large series comparing different repair techniques are available, with most of the literature based on individual case reports or small case series.[68-70]

11. Inadvertent and unrecognized transection or ligation of pulmonary vessels may lead to either immediate bleeding and need for lobectomy or to delayed lobar/segmental infarction after transplantation. (CoR: IIb; LoE: C-EO)

Inadvertent and unrecognized injury to pulmonary vessels may result in serious complications. Immediate bleeding in the lung hilum, at a distance from the vascular anastomoses, may occur during reperfusion if an arterial or venous branch is injured at procurement. The bleeding vessel can be ligated, clipped, or sutured, whereas a bleeding parenchymal laceration or staple line usually can be controlled with a local hemostatic agent, such as a biological glue or adhesive.

Ligation of a side branch of a PA or pulmonary vein in the donor lung can result in a segmental or lobar infarction that might not become apparent until a week after transplantation. A lobectomy is often necessary to solve the problem and to save patient's life.[71,72] The authors have seen cases where a right upper lobe artery was mistakenly ligated for the azygos vein in the donor. A right upper lobectomy was needed at 1 week post-transplantation when upper lobe infarction became apparent on chest computed tomography. Likewise, in an ex situ donor right lower lobectomy on the back table, the anomalous origin of the right middle lobe pulmonary vein from right inferior pulmonary vein resulted in infarction of the right middle lobe, necessitating a return to the operating room for a subsequent right middle lobectomy. Rarely, the right upper lobe pulmonary vein may atypically drain into the superior vena cava. Consequently, meticulous attention is imperative during lung retrieval.

Clinical experience with injured pulmonary vessels and management of anastomotic complications owing to either an excessive cuff length with kinking or a too-short cuff resulting in restrictive suture is limited to individual case reports or small case series.[68,69,73-76]

Section IV: Hypothermic Preservation on 0 °C to 4 °C versus 4 °C to 10 °C Temperature

Hypothermic preservation stands as a cornerstone in organ preservation, offering a pivotal strategy to slow metabolic processes and diminish oxygen demand, thereby maintaining organ viability, curtailing ischemic injury, and extending the time window for transplantation. In lung preservation, a combination of antegrade and retrograde cold flush perfusion through the pulmonary vessels, coupled with topical cooling and cold static storage, has been the accepted standard technique.[77] With emerging evidence, this section delves into the optimal lung preservation temperatures.

12. Although the optimal temperature for donor lung storage has not yet been determined, studies investigating static cold storage between 4 °C and 10 °C support the use of these warmer temperatures for safe storage of donor lungs. (CoR: IIa; LoE: B-NR)

A cold static preservation of donor lungs at 0 °C to 4 °C on ice has been the gold standard for decades. However, as outlined in the preceding section, the use of ice for storage has been noted to result in uneven cooling of the lungs, often causing temperatures to drop below freezing. Previous experimental research identified superior lung graft preservation efficacy at 10 °C.[78,79] For instance, more recent animal studies demonstrated better mitochondrial metabolic and inflammatory profiles in lung grafts preserved at 10 °C compared to those preserved on ice.[77] Encouraged by these results, a safety clinical study[80] and a subsequent multicenter nonrandomized clinical trial were conducted, revealing comparable outcomes between recipients transplanted with lungs preserved at 10 °C at long ischemic times (∼14 hours) and those with lungs stored on ice (∼7 hours) in terms of

primary graft dysfunction (PGD), perioperative mortality, and in 1-year survival.[80] Similarly, outcomes from a multicenter registry have been reported, wherein lungs preserved in a device designed to maintain stable temperatures between 4 °C and 8 °C showed a trend toward a reduced PGD rate at 72 hours.[81]

In conclusion, while the current standard for static cold preservation involves ice at temperatures between 0 °C and 4 °C, recently published studies demonstrate the feasibility and safety of cold storage at temperatures warmer than the conventional range. Ongoing trials challenge the existing paradigm, potentially influencing the standard of care for the transportation and storage of lung grafts.

13. Intentional extension of the CIT appears to be safe and feasible using preservation temperatures warmer than 0 °C to 4 °C. (CoR: IIa; LoE: B-NR)

Some studies examining the optimal temperature for cold static storage also have explored the concept of intentionally prolonging the cold ischemic time (CIT) of the lung grafts.[77] In a safety study by the Toronto group, 5 patients underwent transplantation after preserving the lung grafts at 10 °C and extending the CIT up to 16 hours with no reported instances of PGD grade 3 at 72 hours.[77] Subsequently, in a multicenter nonrandomized clinical trial from the Madrid, Vienna, and Toronto group, 70 patients underwent transplantation using this preservation technique and then matched to a contemporary cohort using the standard static preservation on ice. The median CIT was approximately 11 hours for the first lung and nearly 14 hours in second lung in the 10 °C preservation cohort, versus 6 hours and 8 hours, respectively, in the ice cold preservation cohort. There were no significant differences between the 2 cohorts in terms of the key postoperative outcomes such us PGD grade, ventilation time, hospital and ICU length of stay (LOS), and early mortality. After 1 year, overall survival also was comparable in the 2 groups.[80] This study sheds light on the feasibility and safety of intentionally prolonging CIT significantly, challenging previous notions in the field. The results of the ongoing 4 °C versus 10 °C randomized clinical trial (NCT 05898776) are awaited, which also is evaluating intentional extension of CIT in the 10 °C arm.

Section V: Normothermic Ex Vivo Lung Perfusion (EVLP)

Normothermic EVLP represents an established clinical practice that has significantly increased donor lung utilization rates. It serves as a valuable platform for preserving lungs under physiologic conditions, affording meticulous organ quality assessment for extended-criteria donors (ECDs) and logistical problem-solving for standard-criteria donors (SCDs) or ECDs. Additionally, based on preclinical studies, EVLP may serve as an innovative modality for precise pharmaceuticals and molecular treatments.[82-88] However, proof of feasibility in human clinical lung transplantation is not yet evident.

In this section, we present 5 recommendations on the use of EVLP for lung transplantation based on single-center retrospective studies, experimental work in animal model, and few prospective randomized and nonrandomized controlled clinical trials.[89-93]

14. EVLP is useful under many conditions, including donor lungs with a P/F ratio <300 mm Hg, evidence of pulmonary edema, or poor lung compliance, and in donors with minor to moderate aspiration. (CoR: I; LoE: B-NR)

EVLP serves as a useful intermediary phase between donor lung retrieval and subsequent transplantation into the recipient, particularly for "high-risk" organs. It provides a valuable opportunity for the reassessment and optimization of these organs, addressing the unique challenges they pose to lung transplantation.[94-100]

As highlighted in Section I, despite evidence to the contrary, the P/F ratio remains a criterion for assessing and accepting donor lungs. Lungs with a P/F < 300 mm Hg often are rejected owing to concerns about suboptimal organ function.[101] In such instances, EVLP proves particularly invaluable, enabling a comprehensive evaluation of organs and potential improvement of the P/F before transplantation. Interventions during EVLP, such as mucus clearance through ex vivo bronchoscopy and the gentle, gradual recruitment of the atelectatic lungs outside of the rigid confines of the pleural cavity, ensure the selection of organs with acceptable quality for transplantation.[93,99]

Neurogenic and hydrostatic pulmonary edema is prevalent in both brain-dead and DCD donors, significantly compromising lung function and oxygen exchange.[102] EVLP can be a useful tool to tackle this issue, allowing removal of excess fluid using cellular or acellular perfusate, depending on the specific EVLP platform used. The response to treatment is assessed methodically by careful monitoring of the perfusate level, evaluating gross appearance of the lungs, and assessing various lung functional parameters, such as P/F ratio, peak pressure, pulmonary vascular resistance, lung compliance, and deflation test. Additional evaluations include bronchoscopy, lung X-ray, perfusate biomarkers, and histologic evaluations of any abnormal findings. Hence, EVLP serves as a pivotal tool for optimizing and assessing the suitability of lungs for transplantation.[103,104]

Aspiration of gastric contents into the lungs occurs frequently in organ donors, often resulting in rejection of these lungs over concerns about compromised organ quality and function and the potential development of post-transplantation PGD. In cases where donors have incurred minor to moderate aspiration injuries, EVLP provides a valuable platform for assessment, offering insights into the effective management of injuries and determining the suitability of these lungs for transplantation.[103,104]

15. EVLP is an important option for donor lungs that cannot be properly evaluated in the donor and/or for logistical reasons. (CoR: I; LoE: B-NR)

EVLP has a crucial role beyond reevaluating discarded donor lungs, especially in scenarios with logistical complexities or challenges assessing donor lungs within the donor's body.[93-95] Such factors as time constraints, donor medical history, and specific medical conditions can hinder comprehensive evaluations, particularly in cases involving venoarterial ECMO or DCD donors.[105] The prolonged agonal time (>60 minutes) during DCD lung retrieval can pose a risk of lung injury, potentially jeopardizing transplant outcomes. EVLP provides an opportunity to reevaluate these lungs for transplantation.[96,97,100] Donor organ challenges may be more pronounced in donor hospitals with lower volumes, in which local medical professionals may have limited experience and expertise. In such cases, EVLP emerges as a solution, offering a thorough and controlled assessment of lung functionality and viability.

16. EVLP is not recommended in donors with potential signs of irreversible lung injury, such as parenchymal destruction and/or consolidation. EVLP is not performed in cases with signs of severe aspiration. Close examination and communication between organ recovery and the implanting surgeon is recommended to determine the suitability of the graft for EVLP. (CoR: III; LoE: B-NR)

Although EVLP is recommended for salvaging discarded donor lungs, in certain situations its use is not advisable with current methods and treatment options—for instance, when there is evidence of irreversible lung injury and permanent damage to the lung parenchyma, such as substantial parenchymal destruction, lacerations with hemorrhage resulting from trauma that cannot be easily staple-resected, or consolidation due to lobar pneumonia. In such cases, EVLP has proven ineffective in improving the condition of the donor lungs and potentially can exacerbate underlying pathology.[89,90,92,93,97,99,100,104,106] Similarly, in cases of severe aspiration resulting in severe secondary pneumonitis and the persistence of substantial gastric contents within the lungs despite bronchoscopy with suction and clearance attempts, EVLP might not yield favorable outcomes.

17. Graft quality assessment on EVLP is based on multiple standard physiologic and objective parameters. One parameter alone is not sufficient to assess graft quality. (CoR: I; LoE: B-NR)

When evaluating donor lungs for transplantation, it is crucial to consider a diverse array of physiologic and objective parameters. Lung function is influenced by numerous factors, and relying on a single parameter alone is insufficient for determining suitability for transplantation.[104] Assessing multiple parameters can provide a more comprehensive and precise assessment of the donor lung. These physiologic and objective parameters encompass measures of lung oxygenation, PA pressures, airway pressures, compliance, lung resistance, lung weight, and changes in volume in the reservoir, among others.[107-109]

Objective parameters, identified through such modalities as bronchoscopy, lung X-ray, ultrasound, and gross lung evaluation, are pivotal in this assessment process.[89-91] Bronchoscopy findings, including edema fluid, hemorrhagic fluid, purulent secretions, and signs of aspiration, among others, provide insight into the condition of the lung. The management of parenchymal edema in EVLP has garnered considerable attention, as it influences decisions regarding lung discarding. Conventionally, lungs in EVLP are positioned supine, increasing the risk of fluid accumulation in posterior-dependent regions. Preclinical and human studies suggest that prone positioning during EVLP is feasible, promoting a more homogeneous distribution of interstitial fluid and potentially reducing edema and mitigating ischemia-reperfusion injury.[110] Additionally, gross lung evaluation involves visually inspecting the lungs for such characteristics as bogginess (indicative of fluid accumulation), infarcts, nodules, masses, and other abnormalities that may impact lung functionality and suitability for transplantation.

Several assessment systems have been developed for lungs during EVLP to assist clinicians in making an informed decision about a lung's transplantability. For instance, there is growing attention on biomarkers in the perfusate, particularly interleukins (IL-6 and IL-8) and cell-free DNA, which could differentiate between favorable and unfavorable grafts and predict transplant outcomes.[111,112] The EXPIRE regression model, which integrates donor characteristics, gas exchange, and mechanical parameters on EVLP, has demonstrated the ability to predict lung suitability within just 4 hours into EVLP.[113] Machine-learning algorithms, like the InsighTx AUROC model based on clinical and biochemical data on EVLP, yielded good results when assessing the suitability of donor lungs for transplant.[114] The majority of these assessment systems are not yet used in routine clinical practice, however. Lung weight also has been described as a surrogate marker for lung edema during EVLP.[115]

18. Clinical use of EVLP has been driven mainly by 3 major protocols: the Toronto protocol, the Lund protocol, and the Organ Care System (OCS) protocol. (CoR: Iia; LoE: C-LD)

The clinical application of EVLP has witnessed significant advancements, driven primarily by 3 major protocols: the Toronto protocol, the Lund protocol, and the OCS protocol.[90,91,98] These protocols represent pivotal milestones in the field of lung transplantation, transforming how donor lungs are assessed, optimized, and ultimately transplanted. All 3 protocols have been used successfully in clinical trials.[89,116] Determining the superiority of these protocols over one another is challenging owing to a lack of randomized controlled clinical trials comparing them. Nonetheless, their adoption has expanded the donor pool for lung transplantation.[92]

There are distinct differences among the protocols. The Lund protocol uses STEEN solution (XVIVO Perfusion AB), a buffered extracellular solution with colloid osmotic pressure for the prevention of pulmonary edema, together with red blood cells, and maintains a target flow rate of 100% of cardiac output in continuous flow with an open LA. The Toronto protocol uses an acellular STEEN perfusate and 40% cardiac output in continuous flow against a closed LA with pressure of 5 mm Hg. With the Toronto protocol, extended EVLP with preservation times up to 12 hours has been reported. The OCS, developed by Transmedics, uses its own OCS lung solution together with red blood cells and a pulsatile flow at 2 to 2.5 L/minute with an open LA.

Several multicenter studies have investigated the safety and outcomes of EVLP for both SCD and ECD lungs. Among these, the NOVEL trial, the first prospective, multicenter trial, published its findings in 2014.[117] This study revealed no statistically significant differences in PGD3 rates, ICU duration, or 1-year survival between ECDs and SCDs. In 2018, the INSPIRE trial, the first prospective multicenter randomized controlled trial, explored the use of OCS's portable EVLP system for SCD lungs[98] demonstrating a decrease in PGD3 rates within the first 72 hours following transplantation and no differences in survival after 24 months.

The subsequent OCS EXPAND trial, applying a similar protocol to ECD lungs, likewise reported no differences in survival at the 24-month post-transplant period.[107] However, higher than anticipated rates of PGD3 were observed. Similarly, the DEVELOP-UK trial, using a modified Lund protocol on ECD lungs, was terminated prematurely because of elevated initial PGD3 rates and the requirement for ECMO within the first 3 days post-transplantation in the EVLP arm.[106] Intriguingly, in the EXPAND trial, PGD3 rates peaked during the initial post-transplantation hours but normalized after 72 hours, exerting no adverse impact on survival.[107] This phenomenon possibly suggests a distinct PGD phenotype. These findings were corroborated by other multicenter trials, including one by Nilsson and colleagues[99] focusing on ECD-EVLP cases at 2 Scandinavian centers using the Lund protocol. These studies detected no differences in long-term survival, although initial P/F ratios were lower and ICU stays were longer for the EVLP cases.[118]

Additionally, investigations into the use of initially rejected donor lungs on EVLP have reported notable conversion rates, some exceeding 80%.[119,120] The introduction of EVLP has led to an 18% increase in transplantation volume in Germany and increases of up to 70% in highly experienced centers like Toronto. Several other centers have reported significant reductions in waitlist times following EVLP adoption. These findings collectively underscore the evolving landscape of lung transplantation, with EVLP playing an important role in expanding donor lung utilization.[121]

Section VI: Donation After Circulatory Death (Controlled and Uncontrolled) and Normothermic Regional Perfusion

Despite a resurgence in the use of DCD lung donors, this pool remains underutilized globally owing to resource constraints, logistical challenges, and legislative factors. Additionally, the lack of consensus on definitions and workup surrounding DCD recovery, including the start of warm ischemic time (WIT), maximum tolerable ischemic time, placement of nasogastric tube to prevent aspiration before extubation, premortem bronchoscopy, and heparin before withdrawal of life support therapy (WLST), among others, further complicates the issue. The recent introduction of NRP, a technique to resuscitate organs in a DCD donor using a modified ECMO device, has increased the DCD heart recovery rates. However, the impact of NRP on donor lung utilization remains unclear, owing to limited available data. This section addresses controversies surrounding DCD donation, provides guidelines for approaching DCD donors, and discusses the role of NRP in DCD lung donation.

19. The decision to pursue organ donation in non–brain-dead donors still leads to controversial ethical questions. Protocols in place throughout the decision to withdraw life-sustaining therapy and the DCD process are critical to ensure an ethical process for the donor, which has led to increases in lung transplantation. (CoR: I, LoE: C-EO)

The adoption of DCD has increased the donor pool for lung transplantation, although controversy persists regarding WLST.[122,123] Ethical guidelines governing DCD organ procurement include separation of the decision

to withdraw life-sustaining therapy from the decision to proceed with organ donation.[124] During the DCD process, the declaration of death is performed by physicians not involved in the organ procurement process, ensuring an impartial assessment. Furthermore, a dedicated "stand off" period is mandated after circulatory arrest before initiating organ procurement, reinforcing the ethical principles and safeguarding the integrity of the donation process.[124,125]

20. DCD lung donation requires additional financial and educational investment from transplant programs; however, this investment leads to expansion of the donor pool for lung transplantation. (CoR: I; LoE: C-LD)

DCD lungs expand the donor pool for lung transplantation but remain underutilized in some countries, including the United States. Currently, only 4% to 5% of lung transplants performed in the US are from DCD donors, indicating untapped potential for a more extensive application of these organs.[126] In contrast, international use of DCD lungs is notably higher at 30% to 40%.[126] DCD lung procurement requires specialized training for assessment and procurement. Additionally, lung transplant programs must make a financial investment, considering the possibility that a donor may not pass within the allotted time, resulting in an increase in costly dry runs.[127]

21. The use of DCD lungs leads to equivalent long-term survival outcomes, and expanded adoption is encouraged. (CoR: I; LoE: B-NR)

Multicenter studies have demonstrated that survival outcomes are similar between DCD and donation after brain death (DBD) lung donors with or without EVLP.[100,128-130] As noted in Section V, EVLP is a valuable tool for evaluating organ function prior to transplant in circumstances where concern persists and/or there is inadequate in situ and ex situ assessment.[97,131]

22. In patients not expected to survive WLST and who have given consent (primary or next of kin), premortem heparin administration is recommended for all DCD lung recoveries unless it will hasten death or is prohibited by local regulations. (CoR: I; LoE: B-NR)

Many countries advocate for premortem heparin administration for all DCD organ recoveries, except when its use may hasten death or is prohibited by local regulations.[124,132] Despite this recommendation, only 91% of US organ procurement organizations (OPOs) mandate heparin administration.[133] Among the 5 countries in which antemortem administration of heparin is not allowed, this restriction is attributed in part to a lack of professional guidance.[132] Similarly, premortem bronchoscopy is recommended to assess and optimize lungs for transplant as in DBD donors. Standardizing practices and providing clear professional guidance may mitigate confusion and improve organ utilization while upholding ethical standards.

23. In patients not expected to survive WLST and who have given consent (primary or next of kin), it is essential to observe locally and/or legally accepted hands-off period following circulatory arrest and prior to donor procurement to negate the potential for autoresuscitation. (CoR: I; LoE: B-NR)

The hands-off period is observed to reduce the potential for autoresuscitation after circulatory arrest. Recommended durations ranging from 2 to 5 minutes have been endorsed by the American Society of Transplant Surgeons, Society of Critical Care Medicine, and Institute of Medicine.[124] Among OPOs in the United States, only ~20% opt for hands-off periods of <5 minutes.[127] Globally, a 5 minute hands-off period is the most commonly applied standard.[132]

24. In patients not expected to survive WLST and who have given consent (primary or next of kin), the functional WIT should be defined as the interval between systolic blood pressure decline to <50 mm Hg until cold perfusion. (CoR: I; LoE: B-NR)

Since the introduction of DCD organ transplantation, numerous reports have consistently confirmed the safety and efficacy of using organs from DCD donors.[124,128-130,134] Concern over WIT is due to reports of worse organ outcomes.[133] However, the period of WIT has been variably defined and difficult to standardize. Recently, WIT has been defined to start after systolic blood pressure declines to <50 mm Hg or 60 mm Hg.[128,135] Standardizing the definition of WIT, akin to determining a standardized definition for PGD, will facilitate further studies and improve the understanding of WIT's impact on organ outcomes. Moreover, it will provide clear guidance for donor hospital and donation experts when communicating with donor families regarding the potential time requirements for successful donation.

25. The use of lungs from DCD organ donors is indicated when the time between WLST and asystole is < 60 minutes (class I) and reasonable when the time is < 180 minutes. (CoR: I and IIa; LoE: B-NR)

Standardization of definitions and experience in DCD lung transplant have expanded with reported success of lung transplant within 180 minutes of WLST.[130,136-142] Despite work suggesting that prolonged WIT may be tolerated in DCD lung transplant, the International Society for Heart and Lung Transplantation DCD registry data suggest that 99% of reported DCD lung transplants involve a WIT <60 minutes.[130] It is important to note that different countries and different institutions within a country (ie, United States) have different thresholds and definitions for maximal allowable WIT following WLST. Therefore, the distinction between WLST and WIT is critical for the continued understanding and optimization of DCD lung transplant. For example, it is entirely possible that a 3-hour interval may be seen after WLST with only a 20-minute WIT, the latter based on the foregoing definition of functional WIT.

26. Evaluation of DCD lungs can be more difficult owing to a lack of standard tests. If after intraoperative assessment there is still uncertainty regarding lung function, EVLP should be considered prior to organ discard. (CoR: I; LoE: B-NR)

In the evaluation of DCD lung offers, certain standard tests commonly available during the evaluation of brain-dead donors, such as bronchoscopy and computed tomography scans, might not be available. Consequently, when procuring DCD lungs without some of these data, intraoperative organ assessment becomes critical in determining the suitability of a lung for transplantation. This will necessitate reintubation in the operating room for bronchoscopic evaluation to assess the airway for signs of infection, inflammation, and indications of aspiration and to ensure airway clearance for recruitment. The intraoperative assessment encompassing in situ palpation of the lungs, their recruitability, and deflation test to evaluate for lung edema, consolidation, recoil, and overall function, as well as their ex situ evaluation, are crucial (Table 3). If concerns persist regarding the quality of the lungs, the EVLP platform serves to further evaluate DCD lungs and mitigate worries related to organ injury during the DCD lung transplant process.[97,131] A checklist for DCD lung procurement is shown in Table 3.

27. In patients unsuccessfully resuscitated after cardiac arrest, lung donation might be considered despite the logistic complexity. (CoR: IIa; LoE: B-NR)

Uncontrolled DCD (uDCD) lung transplants have been reported in Spain, Italy, and Canada.[143] While the potential for expanding the donor pool is substantial, widespread adoption is limited owing to logistical complexities, resource requirements, potential ethical dilemmas and nonstandard organ assessment needs.[143] Despite these challenges, uDCD lung transplant has demonstrated comparable outcomes to DBD lung transplant, underscoring its potential to contribute significantly to organ transplantation efforts.[143]

28. In the uncontrolled donation after cardiac arrest scenario, further assessment of the grafts using EVLP is advised owing to a lack of information on donor lung function before procurement. (CoR: IIa; LoE: B-NR)

TABLE 3. DCD checklist before and during procedure

Checklist for DCD procurement prior to withdrawal of life support
1. Determine location of withdrawal
a. If not in the operating room, determine who will be transporting patient to the OR
2. Discuss heparin administration prior to withdrawal
3. Nasogastric tube insertion prior to extubation to avoid aspiration
4. Review who will be performing the declaration of death
5. Determine length of standoff period
6. Discuss who will be reintubating the patient after the standoff period
7. Confirm availability of the bronchoscopy equipment
8. Confirm all surgical instruments are present on a separate sterile table
Checklist for intraoperative evaluation of DCD lungs
1. Once intubated, perform bronchoscopy to evaluate the airway.
2. Confirm appropriate vent settings: FiO_2, 50%; PEEP, 5 cmH_2O; tidal volume, 6-8 mL/kg.
3. Sternotomy.
4. Cannulate the main PA.
5. Inject prostaglandin into the main PA and manually compress the heart to circulate or in the pulmoplegia solution.
6. Start flush with extracellular type perfusate.
7. Amputate the left atrial appendage and cut the IVC to vent the heart.
8. During flush, begin recruiting lungs with gentle pressure.
9. Manually palpate and inspect all lobes of the lung in situ.
10. Temporarily disconnect the lungs from the ventilator to check deflation.
11. Begin standard lung procurement.
12. Palpate and inspect lungs ex situ.
13. If concern for function persists, consider ex vivo lung perfusion.

DCD, Donation after circulatory death; *FiO_2*, fraction of inspired oxygen; *PEEP*, positive end-expiratory pressure; *PA*, pulmonary artery; *IVC*, inferior vena cava.

uDCD has the potential to be an additional source of donors, yet fewer than 100 cases have been reported from 2001 to the present. Beyond logistical complexities, a significant hindrance to widespread adoption is the lack of standardized assessment of organ function for previously unknown uDCD grafts. The most frequently used approach for in situ functional organ assessment entails topical cooling using chest tubes and gas analysis corrected by temperature, using the effluent of the LA. For this assessment, preservation solution is infused through the PA and drained through the left atrial appendage. Subsequently, 300 mL of previously retrieved donor blood is infused, and the theoretically oxygenated effluent is sampled for gas analysis.[50,144-146] Similar outcomes to other donor sources, such as controlled DCD or DBD, have been reported.[144-146]

On the other hand, EVLP has a key role in uDCD programs, enabling a much more comprehensive evaluation and validation of grafts. In the uDCD scenario, there is a lack of functional information on grafts before the recovery; thus, the EVLP platform has been advocated as a crucial method for further functional assessment of these unique grafts.[48,49,147]

29. Concomitant recovery of both DCD heart and lungs using direct perfusion and procurement is encouraged and recommended when appropriate. (CoR: I; LoE: C-LD)

The use of DCD hearts is on the rise with the implementation of two novel methods aimed at limiting cold ischemia of the heart: normothermic machine perfusion and normothermic regional perfusion (NRP), the latter of which is described in detail below.[148] When normothermic machine perfusion is used for heart preservation, donor blood must be collected before cross-clamping and flushing of donor organs. Apart from this brief delay in the organ flushing process, the procurement strategy for concomitant heart and lung DCD procurement is not significantly different from these procurements are performed in isolation.[148,149] The importance of communication between the heart and lung teams for concomitant recovery cannot be overstated.

30. There are limited data on the effect of thoraco-abdominal normothermic regional perfusion (TA-NRP) on lung function. The use of DCD lungs after TA-NRP remains controversial, and additional data are needed. (CoR: Iib; LoE: C-EO)

TA-NRP limits organ ischemia during DCD procurement.[150] After declaration of death and the "no touch" period, sternotomy is performed, and the donor is cannulated via the aorta and right atrium. The patient is placed on circulatory support, restoring blood flow, while cross-clamping the head vessels to eliminate cerebral blood flow (Figure 2). This allows the reanimation of the heart and heart function is evaluated in real time after exposure to warm ischemia through the DCD process. Similar to traditional DCD lung procurement, it is important that the donor is reintubated and that ventilation of the lungs is maintained during NRP. One significant advantage of NRP is that by restarting the heart and circulation, once the donor is weaned off bypass, the procurement strategy is similar to a traditional brain death protocol. Now arterial blood gases can be obtained to assess lung function. Typically, NRP will last for 30 to 60 minutes.

Controversy remains whether NRP leads to lung damage. Most recent data on the subject suggest that after "standard" lung evaluation, transplantation can proceed, with outcomes comparable to standard DCD lungs.[151-157] However, the rate of lung declines after TA-NRP is not well documented, and many centers have noted unpredictable results.[158] The lack of standardization of TA-NRP with inconsistent venting practices may lead to lung edema, accounting for variable outcomes. Furthermore, long-term survival studies for the use of lungs following TA-NRP need further evaluation. Another strategy involves performing peripheral venoarterial cannulation prior to WLST. In this scenario, after peripheral cannulation, WLST is carried out. Following declaration of death, the subsequent steps mirror those described above: a sternotomy is performed, followed by cross-clamping of the head vessels to eliminate cerebral blood flow.[159] Subsequently, ventilation is restored and TA-NRP is started, facilitating heart recovery and enabling evaluation of both heart and lung grafts.

Owing to a lack of data comparing direct perfusion and procurement with TA-NRP, the panel cannot currently recommend one method over the other for lung recovery. Future studies are awaited to provide clearer insights.

31. The procurement of lungs during abdominal-normothermic regional perfusion (A-NRP) can be performed safely without adversely impacting lung transplant outcomes. (CoR: Iia; LoE: C-LD)

Although direct lung procurement can be performed safely during A-NRP with favorable transplant outcomes,[160-162] the variability in techniques underscores the need for standardization to ensure consistently reproducible results (Table 4). The most common published method for A-NRP includes peripheral femoral cannulation either percutaneously or via a surgical cut down before WLST. At the same time, an occlusive balloon is placed in the descending aorta through the contralateral femoral artery (Figure 3). It is inflated once circulatory arrest is declared and before the initiation of A-NRP, precluding cerebral perfusion during NRP. After circulatory arrest and a predetermined no-touch period, NRP is initiated. The donor is reintubated and ventilated using the parameters described in Table 2. A median sternotomy is performed simultaneously. The venous return to the heart through the superior and inferior vena cava is eliminated by ligating these vessels. The cessation of venous return from the upper half of the body may result in reduced blood flow to the pump. Consequently, the controlled DCD donor is administered 1 to 1.5 L of saline to mitigate this effect. Lung perfusion, preservation, graft macroscopic evaluation, and subsequent retrieval are then performed in the standard fashion, as described in Section II. Meticulous attention must be paid to hemostasis, such as ligating

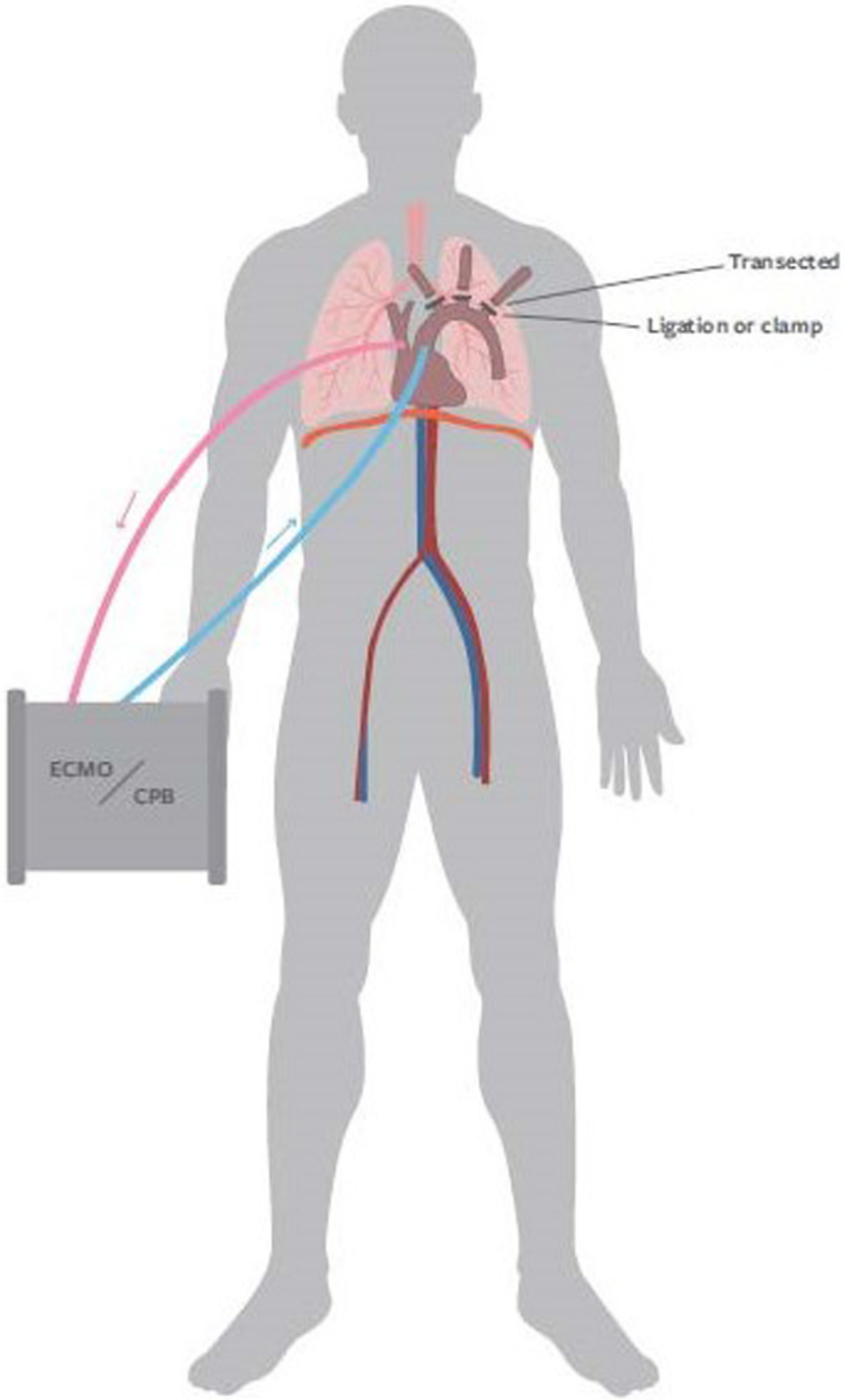


FIGURE 2. Central cannulation approach for thoracoabdominal normothermic regional perfusion (*TA-NRP*). *ECMO*, Extracorporeal membrane oxygenation; *CPB*, cardiopulmonary bypass.

the azygous vein prior to its transection, to mitigate the risk of excessive blood loss, which potentially could lead to A-NRP malfunction, compromising abdominal organ viability.

It is particularly important to observe local legislative policies that may or may not allow cannulation before WLST. In scenarios in which cannulation before WLST is restricted, either peripheral or direct cannulation in the abdomen can be performed following the no-touch period. Evaluation and perfusion of lungs are then performed after initiating A-NRP, adhering to the same methodology as described above.

TABLE 4. Checklist for perioperative management of DCD lungs using A-NRP

1. Donor is usually peripherally cannulated for VA-ECMO before WLST.
2. Introduce an occlusive intra-aortic balloon through the contralateral femoral artery and inflate it at the level of the descending aorta.
3. Carry out WLST according to hospital protocol.
4. After intubation, perform bronchoscopy to evaluate the airway.
5. Confirm appropriate ventilator settings: FiO_2, 50%; PEEP, 5 cmH_2O; tidal volume, 6-8 mL/kg.
6. Start A-NRP; the occlusive balloon in the descending aorta precludes retrograde perfusion of the brain.
7. Sternotomy.
8. Cross-clamp the IVC, mobilizing the venous cannula if necessary.
9. Ligate the SVC.
10. Cannulate the PA.
11. Start flush with extracellular type solution primed with prostaglandin.
12. Cut the left atrial appendage and IVC above the clamp.
13. During flush, begin recruiting lungs with gentle pressure.
14. Manually palpate and inspect all lobes of the lung.
15. Disconnect from the ventilator to evaluate deflation of the lungs.
16. Begin standard lung procurement: ligate the azygos vein prior to division to avoid excessive bleeding.

DCD, Donor after circulatory death; *A-NRP*, abdominal-normothermic regional perfusion; *VA-ECMO*, venoarterial extracorporeal membrane oxygenation; *WLST*, withdrawal of life-sustaining therapy; *FiO_2*, fraction of inspired oxygen; *PEEP*, positive end-expiratory pressure; *IVC*, inferior vena cava; *SVC*, superior vena cava; *PA*, pulmonary artery.

Section VII: Donor Management Centers, Organ Assessment Centers, and Third-Party Procurement Teams

In solid organ transplantation, a new interest in donor management and pretransplant donor allograft optimization has led to rapid, marked changes in workflow. The emergence of specialized entities, such as DMCs, OACs, and third-party (ie, fee-for-service or nonimplanting center) procurement teams has begun to revolutionize the field.[163-166] These changes have been led in large part by lung transplantation professionals.

While these innovations are still evolving, their impact on organ recovery safety and cost considerations (monetary, time, and personnel) are yet to be completely assessed.[167] These dynamic processes are unfolding in tandem with donor hospitals, transplant centers, United Network for Organ Sharing (UNOS)/Organ Procurement and Transplantation Network (OPTN) collaboration, guidance, and federal statutes in the United States.

32. There may be a role for OACs in which centralized expertise and knowledge can be aggregated to maximize resuscitation and enhance lung organ utilization. These OACs would have resources and experience in EVLP to physiologically assess and optimize allografts prior to acceptance. (CoR: Iia; LoE: B-NR)

Just as with many endeavors that benefit from economies of scale, a concentration of experience, specifically in terms of number of donors managed and organs assessed, inherently contributes to improvement in organ recovery yield and quality of organs available for transplantation. This trend is notably observed in OACs.[168] A higher concentration of lung allografts managed within OACs enables the local staff to gain greater competency and efficiency as has been demonstrated with centralized ex vivo machine perfusion facilities in North America.[163] The individualized attention given to lung allograft at OAC can result in improved outcomes. While concerns have been raised about the 2 CITs inherent in centralized EVLP centers, a multicenter study demonstrated the feasibility of remote EVLP for declined lung allograft with a resultant increase in number of transplants without compromising short or long term outcomes.[105] The repetition and accumulated expertise gained in such environments can contribute to the success and efficiency of organ recovery and transplantation processes.[104]

33. Recovery centers or donor management centers (either hospital or OPO based) facilitate overall donor organ recovery through donor optimization, coordination of multiple recovery teams, timely recovery and a focus on honoring the donor and their support people. (CoR: IIa, LoE: C-EO)

A DMC facilitates enhanced donor allograft utilization. The colocalization and a higher concentration of donors managed within DMCs enables the local staff to gain greater competency and efficiency. This centralization brings the nuances of effective donor management from hospitals or centers that, individually, may perform very few recoveries to centers of expertise. Hence, the concentration of expertise and resources directed toward DBD donor at DMC can result in improved outcomes, which in turn can result in higher overall organ recovery yield and a better lung allograft quality.[168] However, rigorous prospective studies are needed for validation.

Furthermore, the relocation of DBD donor from local hospitals allows for a more thoughtful allocation of the organ, removing external constraints imposed by the donor's hospital, including staffing issues, elective case load, overall capacity, and ICU bed occupancy. Removing these constraints allows time to perform prospective crossmatching and facilitates broader organ sharing, among other benefits, enhancing the overall efficiency and effectiveness of the transplantation process.[169]

34. Third-party procurement services may be an alternative option to increase organ acceptance and recovery rates at centers in which the procurement services might not be readily available. (CoR: Iia; LoE: C-EO)

Expanding lung transplant access and volume could be achieved by delegating procurements to other qualified teams. Whether using a loco-regional recovery team from a transplant center or adopting a fee-for-service model, such an approach would optimize (implanting) surgeon resources, increase safety, and improve program sustainability.[170] Although challenging to quantify owing to a lack of prospective multicenter studies, the impact of the donor organ procurement team on the transplant center surgeon's quality of life and workforce health can be significant without impacting lung transplant outcomes. Although the widespread adoption of third-party procurement raises financial concerns for transplant centers regarding professional fee collection, it potentially can offset these concerns by reducing the travel-related time, cost, and safety risks for the transplant center surgeons.[171,172]

CONCLUSIONS

Lung procurement and preservation techniques have evolved significantly over the past decade, including the adoption of EVLP, DCD, NRP, temperature-controlled devices, and the establishment of organ recovery teams and centers. Although these innovations hold promise for expanding the donor pool, significant variability in these practices exists among centers and regions. Therefore, this expert panel has endeavored to present easily implementable, pragmatic, and uniform recommendations for donor lung procurement and preservation, with the overarching goal of increasing organ utilization rates and enhance post-transplantation outcomes.

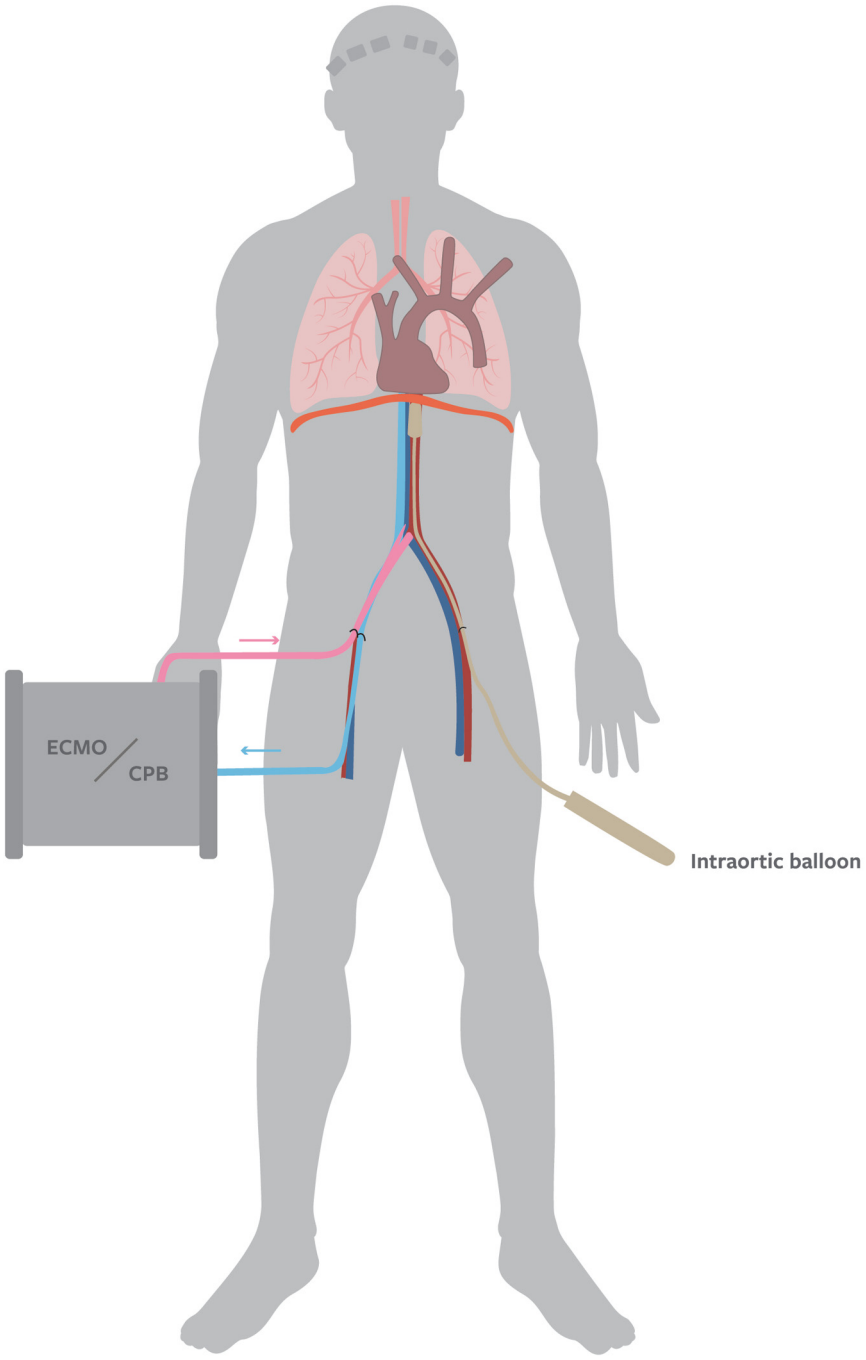


FIGURE 3. Peripheral cannulation approach for abdominal normothermic regional perfusion (*A-NRP*). *ECMO*, Extracorporeal membrane oxygenation; *CPB*, cardiopulmonary bypass.

Conflict of Interest Statement

Dr Kukreja: Guidepoint consultant, University of Washington for expert testimony; American Society of Transplantation Fellows meeting, travel and room/board; UNOS DCD Lung collaborative meeting, room/board; LUng Bioengineering, data monitoring committee; Dr Cypel: consultant, Lung Bioengineering/United Therapeutics; consultant, Incyte; consultant, Avivo; founder and shareholder, Traferox Technologies Inc. Dr Van Raemdonck: Broere Charitable Foundation. Dr Cantu: United Therapeutics, consulting; Lung Bioengineering, consulting; CSL Behring, consulting; ISHLT, Board of Directors, Chair Education oversight Committee, Chair Membership and Outreach Committee; UNOS/OPTN Lung Committee FDA Device committee. Dr Date: Adachi, Tri-Med: research grants; Johnson and Johnson: lecture fee. Dr

D'Ovidio: research grants from NIH, Cystic Fibrosis Foundation. Dr Hartwig: Transmedics, consulting and grant funding; CSL Behring, advisory board; Biomedinnovations, research support. Dr Kelly: Leadership/Board AATS and AATS Foundation, travel support for meetings. Grant: Regenerative Medicine Minnesota 2023-2024. Dr Lindstedt: XVIVO, speakers bureau. Dr Smith: consultant: United Therapeutics, Transmedics, Transplant Solutions. Dr Whitson: National Institutes of Health Grant R01HL143000, Clinical Events Committee of TransMedics OCS; speaking honoraria for Medtronic, UNOS/OPTN Board of Directors American Society of Artificial Internal Organs Board of Trustees. All other authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

References

1. Bakaeen FG, Svensson LG, Mitchell JD, Keshavjee S, Patterson GA, Weisel RD. The American Association for Thoracic Surgery/Society of Thoracic Surgeons position statement on developing clinical practice documents. *J Thorac Cardiovasc Surg*. 2017;153(4):999-1005. https://doi.org/10.1016/j.jtcvs.2017.01.003
2. Jacobs AK, Anderson JL, Halperin JL. The evolution and future of ACC/AHA clinical practice guidelines: a 30-year journey: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. *J Am Coll Cardiol*. 2014;64(13):1373-1384. https://doi.org/10.1016/j.jacc.2014.06.001
3. Botha P. Extended donor criteria in lung transplantation. *Curr Opin Organ Transplant*. 2009;14(2):206-210. https://doi.org/10.1097/mot.0b013e328326c834
4. Urlik M, Stącel T, Latos M, et al. Donor-related risk factors associated with increased mortality after lung transplant. *Transplant Proc*. 2020;52(7):2133-2137. https://doi.org/10.1016/j.transproceed.2020.03.044
5. Chambers DC, Zuckermann A, Cherikh WS, et al. The International Thoracic Organ Transplant Registry of the International Society for Heart and Lung Transplantation: 37th adult lung transplantation report - 2020; focus on deceased donor characteristics. *J Heart Lung Transplant*. 2020;39(10):1016-1027. https://doi.org/10.1016/j.healun.2020.07.009
6. Boehm PM, Sinn K, Schwarz S, Kollmann D, Berlakovich G, Hoetzenecker K. Oblique carinal end-to-end anastomosis for pig bronchus in organ donor and lung transplant recipient. *Ann Thorac Surg*. 2022;113(3):e195-e197. https://doi.org/10.1016/j.athoracsur.2021.05.029
7. Botha P, Trivedi D, Searl CP, Corris PA, Schueler SVB, Dark JH. Differential pulmonary vein gases predict primary graft dysfunction. *Ann Thorac Surg*. 2006;82(6):1998-2002. https://doi.org/10.1016/j.athoracsur.2006.07.026
8. Costa J, Sreekanth S, Kossar A, et al. Donor lung assessment using selective pulmonary vein gases. *Eur J Cardiothorac Surg*. 2016;50(5):826-831. https://doi.org/10.1093/ejcts/ezw179
9. Sasaki S, Yasuda K, McCully JD, LoCicero J. Does PGE1 attenuate potassium-induced vasoconstriction in initial pulmonary artery flush on lung preservation? *J Heart Lung Transplant*. 1999;18(2):139-142. https://doi.org/10.1016/s1053-2498(98)00003-5
10. Naka Y, Roy DK, Liao H, et al. cAMP-mediated vascular protection in an orthotopic rat lung transplant model. Insights into the mechanism of action of prostaglandin E1 to improve lung preservation. *Circ Res*. 1996;79(4):773-783. https://doi.org/10.1161/01.res.79.4.773
11. de Perrot M, Fischer S, Liu M, et al. Prostaglandin E1 protects lung transplants from ischemia-reperfusion injury: a shift from pro- to anti-inflammatory cytokines. *Transplantation*. 2001;72(9):1505-1512. https://doi.org/10.1097/00007890-200111150-00006
12. Fischer S, Matte-Martyn A, de Perrot M, et al. Low-potassium dextran preservation solution improves lung function after human lung transplantation. *J Thorac Cardiovasc Surg*. 2001;121(3):594-596. https://doi.org/10.1067/mtc.2001.109703
13. Puskas JD, Cardoso PFG, Mayer E, Shi S, Slutsky AS, Alexander Patterson G. Equivalent eighteen-hour lung preservation with low-potassium dextran or Euro-Collins solution after prostaglandin E1 infusion. *J Thorac Cardiovasc Surg*. 1992;104(1):83-89. https://doi.org/10.1016/s0022-5223(19)34839-1
14. Munshi L, Keshavjee S, Cypel M. Donor management and lung preservation for lung transplantation. *Lancet Respir Med*. 2013;1(4):318-328. https://doi.org/10.1016/S2213-2600(12)70064-4
15. Baretti R, Bitu-Moreno J, Beyersdorf F, Matheis G, Francischetti I, Kreitmayr B. Distribution of lung preservation solutions in parenchyma and airways: influence of atelectasis and route of delivery. *J Heart Lung Transplant*. 1995;14(1 Pt 1):80-91.
16. Wittwer T, Fehrenbach A, Meyer D, et al. Retrograde flush perfusion with low-potassium solutions for improvement of experimental pulmonary preservation. *J Heart Lung Transplant*. 2000;19(10):976-983. https://doi.org/10.1016/s1053-2498(00)00189-3
17. Strüber M, Hohlfeld JM, Kofidis T, et al. Surfactant function in lung transplantation after 24 hours of ischemia: advantage of retrograde flush perfusion for preservation. *J Thorac Cardiovasc Surg*. 2002;123(1):98-103. https://doi.org/10.1067/mtc.2002.119063
18. Hayama M, Date H, Oto T, Aoe M, Andou A, Shimizu N. Improved lung function by means of retrograde flush in canine lung transplantation with non-heart-beating donors. *J Thorac Cardiovasc Surg*. 2003;125(4):901-906. https://doi.org/10.1067/mtc.2003.296
19. Van De Wauwer C, Neyrinck AP, Geudens N, et al. Retrograde flush following warm ischemia in the non-heart-beating donor results in superior graft performance at reperfusion. *J Surg Res*. 2009;154(1):118-125. https://doi.org/10.1016/j.jss.2008.06.007
20. Sarsam MA, Yonan NA, Deiraniya AK, Rahman AN. Retrograde pulmonary-plegia for lung preservation in clinical transplantation: a new technique. *J Heart Lung Transplant*. 1993;12(3):494-498.
21. Varela A, Cordoba M, Serrano-Fiz S, et al. Early lung allograft function after retrograde and antegrade preservation. *J Thorac Cardiovasc Surg*. 1997;114(6):1119-1120. https://doi.org/10.1016/s0022-5223(97)70029-1
22. Venuta F, Rendina EA, Bufi M, et al. Preimplantation retrograde pneumoplegia in clinical lung transplantation. *J Thorac Cardiovasc Surg*. 1999;118(1):107-114. https://doi.org/10.1016/s0022-5223(99)70149-2
23. Gohrbandt B, Warnecke G, Fischer S, et al. Retrograde in situ versus antegrade pulmonary preservation in clinical lung transplantation: a single-centre experience. *Eur J Cardiothorac Surg*. 2015;49(1):55-62. https://doi.org/10.1093/ejcts/ezv108
24. Terada Y, Gauthier JM, Pasque MK, et al. Clinical outcomes of lung transplants from donors with unexpected pulmonary embolism. *Ann Thorac Surg*. 2021;112(2):387-394. https://doi.org/10.1016/j.athoracsur.2020.08.040
25. Belzer FO, Southard JH. Principles of solid-organ preservation by cold storage. *Transplantation*. 1988;45(4):673-676. https://doi.org/10.1097/00007890-198804000-00001
26. Date H, Matsumura A, Manchester JK, Cooper JM, Lowry OH, Cooper JD. Changes in alveolar oxygen and carbon dioxide concentration and oxygen consumption during lung preservation. The maintenance of aerobic metabolism during lung preservation. *J Thorac Cardiovasc Surg*. 1993;105(3):492-501. https://doi.org/10.1016/s0022-5223(19)34232-1
27. Fujimura S, Handa M, Kondo T, Ichinose T, Shiraishi Y, Nakada T. Successful 48-hour simple hypothermic preservation of canine lung transplants. *Transplant Proc*. 1987;19(1 Pt 2):1334-1336.
28. Keshavjee SH, Yamazaki F, Cardoso PF, McRitchie DI, Patterson GA, Cooper JD. A method for safe twelve-hour pulmonary preservation. *J Thorac Cardiovasc Surg*. 1989;98(4):529-534. https://doi.org/10.1016/s0022-5223(19)34354-5
29. Yamazaki F, Yokomise H, Keshavjee SH, et al. The superiority of an extracellular fluid solution over Euro-Collins' solution for pulmonary preservation. *Transplantation*. 1990;49(4):690-694. https://doi.org/10.1097/00007890-199004000-00007
30. Strüber M, Wilhelmi M, Harringer W, et al. Flush perfusion with low potassium dextran solution improves early graft function in clinical lung transplantation. *Eur J Cardiothorac Surg*. 2001;19(2):190-194. https://doi.org/10.1016/s1010-7940(00)00631-x

31. Arnaoutakis GJ, Allen JG, Merlo CA, Baumgartner WA, Conte JV, Shah AS. Low potassium dextran is superior to University of Wisconsin solution in high-risk lung transplant recipients. *J Heart Lung Transplant*. 2010;29(12):1380-1387. https://doi.org/10.1016/j.healun.2010.05.031
32. Gohrbandt B, Simon AR, Warnecke G, et al. Lung preservation with perfadex or celsior in clinical transplantation. *Transplantation*. 2015;99(9):1933-1939. https://doi.org/10.1097/tp.0000000000000578
33. Okada Y, Matsumura Y, Date H, et al. Clinical application of an extracellular phosphate-buffered solution (EP-TU) for lung preservation: preliminary results of a Japanese series. *Surg Today*. 2012;42(2):152-156. https://doi.org/10.1007/s00595-011-0052-1
34. Ikeda M, Bando T, Yamada T, et al. Clinical application of ET-Kyoto solution for lung transplantation. *Surg Today*. 2014;45(4):439-443. https://doi.org/10.1007/s00595-014-0918-0
35. Stevens GH, Sanchez MM, Chappell GL. Enhancement of lung preservation by prevention of lung collapse. *J Surg Res*. 1973;14(5):400-405. https://doi.org/10.1016/0022-4804(73)90045-0
36. Sakuma T, Tsukano C, Ishigaki M, et al. Lung deflation impairs alveolar epithelial fluid transport in ischemic rabbit and rat lungs. *Transplantation*. 2000;69(9):1785-1793. https://doi.org/10.1097/00007890-200005150-00010
37. Puskas JD, Hirai T, Christie N, Mayer E, Slutsky AS, Patterson GA. Reliable thirty-hour lung preservation by donor lung hyperinflation. *J Thorac Cardiovasc Surg*. 1992;104(4):1075-1083. https://doi.org/10.1016/s0022-5223(19)34694-x
38. Aoe M, Okabayashi K, Cooper JD, Patterson GA. Hyperinflation of canine lung allografts during storage increases reperfusion pulmonary edema. *J Thorac Cardiovasc Surg*. 1996;112(1):94-102. https://doi.org/10.1016/s0022-5223(96)70182-4
39. Haniuda M, Hasegawa S, Shiraishi T, Dresler CM, Cooper JD, Patterson GA. Effects of inflation volume during lung preservation on pulmonary capillary permeability. *J Thorac Cardiovasc Surg*. 1996;112(1):85-93. https://doi.org/10.1016/s0022-5223(96)70181-2
40. DeCampos KN, Keshavjee S, Liu M, Slutsky AS. Optimal inflation volume for hypothermic preservation of rat lungs. *J Heart Lung Transplant*. 1998;17(6):599-607.
41. Hausen B, Ramsamooj R, Hewitt CW, et al. The importance of static lung inflation during organ storage: the impact of varying ischemic intervals in a double lung rat transplantation model. *Transplantation*. 1996;62(12):1720-1725. https://doi.org/10.1097/00007890-199612270-00004
42. Patel MR, Laubach VE, Tribble CG, Kron IL. Hyperinflation during lung preservation and increased reperfusion injury. *J Surg Res*. 2005;123(1):134-138. https://doi.org/10.1016/j.jss.2004.07.017
43. Ikeyama K, Sakai H, Omasa M, et al. Influence of inflated lung pressure on lung mechanical properties during cold storage in rats. *Eur Surg Res*. 2006;38(1):48-53. https://doi.org/10.1159/000091596
44. Van Raemdonck DEM, Jannis NCP, Rega FRL, De Leyn PRJ, Flameng WJ, Lerut TE. Extended preservation of ischemic pulmonary graft by postmortem alveolar expansion. *Ann Thorac Surg*. 1997;64(3):801-808. https://doi.org/10.1016/s0003-4975(97)00627-9
45. Van Raemdonck DE, Jannis NC, De Leyn PR, Flameng WJ, Lerut TE. Alveolar expansion itself but not continuous oxygen supply enhances postmortem preservation of pulmonary grafts. *Eur J Cardiothorac Surg*. 1998;13(4):431-441. https://doi.org/10.1016/s1010-7940(98)00046-3
46. Steen S, Sjöberg T, Pierre L, Liao Q, Eriksson L, Algotsson L. Transplantation of lungs from a non-heart-beating donor. *Lancet*. 2001;357(9259):825-829. https://doi.org/10.1016/S0140-6736(00)04195-7
47. Gomez-de-Antonio D, Campo-Cañaveral JL, Crowley S, et al. Clinical lung transplantation from uncontrolled non-heart-beating donors revisited. *J Heart Lung Transplant*. 2012;31(4):349-353. https://doi.org/10.1016/j.healun.2011.12.007
48. Valenza F, Citerio G, Palleschi A, et al. Successful transplantation of lungs from an uncontrolled donor after circulatory death preserved in situ by alveolar recruitment maneuvers and assessed by ex vivo lung perfusion. *Am J Transplant*. 2016;16(4):1312-1318. https://doi.org/10.1111/ajt.13612
49. Healey A, Watanabe Y, Mills C, et al. Initial lung transplantation experience with uncontrolled donation after cardiac death in North America. *Am J Transplant*. 2020;20(6):1574-1581. https://doi.org/10.1111/ajt.15795
50. Suberviola B, Mons R, Ballesteros MA, et al. Excellent long-term outcome with lungs obtained from uncontrolled donation after circulatory death. *Am J Transplant*. 2019;19(4):1195-1201. https://doi.org/10.1111/ajt.15237
51. Palleschi A, Zanella A, Citerio G, et al. Lung transplantation from controlled and uncontrolled donation after circulatory death (DCD) donors with long ischemic times managed by simple normothermic ventilation and ex-vivo lung perfusion assessment. *Transpl Int*. 2023;36:10690. https://doi.org/10.3389/ti.2023.10690
52. Weder W, Harper B, Shimokawa S, et al. Influence of intraalveolar oxygen concentration on lung preservation in a rabbit model. *J Thorac Cardiovasc Surg*. 1991;101(6):1037-1043. https://doi.org/10.1016/s0022-5223(19)36621-8
53. Fukuse T, Hirata T, Ishikawa S, et al. Optimal alveolar oxygen concentration for cold storage of the lung. *Transplantation*. 2001;72(2):300-304. https://doi.org/10.1097/00007890-200107270-00024
54. Meyer PE, Jessen ME, Patel JB, Chao RY, Malloy CR, Meyer DM. Effects of storage and reperfusion oxygen content on substrate metabolism in the isolated rat lung. *Ann Thorac Surg*. 2000;70(1):264-269. https://doi.org/10.1016/s0003-4975(00)01538-1
55. Meng C, Ma L, Niu L, et al. Protection of donor lung inflation in the setting of cold ischemia against ischemia-reperfusion injury with carbon monoxide, hydrogen, or both in rats. *Life Sci*. 2016;151:199-206. https://doi.org/10.1016/j.lfs.2016.03.015
56. Fujiwara A, Hatayama N, Matsuura N, et al. High-pressure carbon monoxide and oxygen mixture is effective for lung preservation. *Int J Mol Sci*. 2019;20(11):2719. https://doi.org/10.3390/ijms20112719
57. Horch DF, Mehlitz T, Laurich O, et al. Organ transport temperature box: multicenter study on transport temperature of organs. *Transplant Proc*. 2002;34(6):2320. https://doi.org/10.1016/s0041-1345(02)03253-0
58. Kurihara K, Ito T, Aida N, Kenmochi T, Kusaka M, Egawa H. An examination of packing methods for grafts to prevent freezing injury during transportation for liver transplantation. *J Clin Med*. 2023;12(14):4703. https://doi.org/10.3390/jcm12144703
59. Smail H, Saxena P, Wallinder A, et al. Donor lung procurement by surgical fellow with an expectation of high rate of lung utilisation. *Heart Lung Circ*. 2018;27(8):961-966. https://doi.org/10.1016/j.hlc.2017.12.007
60. Hammond GL, Franco KL, Baldwin JC. Method of single-lung transplantation in the absence of a left atrial cuff. *Ann Thorac Surg*. 1992;54(2):379-380. https://doi.org/10.1016/0003-4975(92)91410-b
61. Casula RP, Stoica SC, Wallwork J, Dunning J. Pulmonary vein augmentation for single lung transplantation. *Ann Thorac Surg*. 2001;71(4):1373-1374. https://doi.org/10.1016/s0003-4975(00)02369-9
62. Parekh K, Patterson GA. Technical considerations in adult lung transplantation. *Semin Thorac Cardiovasc Surg*. 2004;16(4):322-332. https://doi.org/10.1053/j.semtcvs.2004.09.013
63. Gamez P, Alvarez R, Hernández H, Córdoba M, De Pablo A. Lung transplantation: how to do the venous anastomosis when the pulmonary graft has no auricular cuff. *J Heart Lung Transplant*. 2005;24(8):1123-1125. https://doi.org/10.1016/j.healun.2004.09.011
64. Oto T, Rabinov M, Negri J, et al. Techniques of reconstruction for inadequate donor left atrial cuff in lung transplantation. *Ann Thorac Surg*. 2006;81(4):1199-1204. https://doi.org/10.1016/j.athoracsur.2005.11.057
65. Yarbrough WM, Bates MJ, Deuse T, et al. Alternative technique for salvage of donor lungs with insufficient atrial cuffs. *Ann Thorac Surg*. 2009;88(4):1374-1376. https://doi.org/10.1016/j.athoracsur.2008.11.031
66. Yokoyama Y, Chen-Yoshikawa TF, Nakajima D, Ohsumi A, Date H. Various techniques for anastomosis of pulmonary arteries with size mismatch during lung transplantation. *JTCVS Tech*. 2021;9:192-194. https://doi.org/10.1016/j.xjtc.2021.06.009
67. Robert JH, Murith N, de Perrot M, Bednarkiewicz M, Licker MJ, Spiliopoulos A. Lung transplantation: how to perform the venous anastomosis when clamping is too distal. *Ann Thorac Surg*. 2000;70(6):2164-2165. https://doi.org/10.1016/s0003-4975(00)01758-6
68. Griffith BP, Magee MJ, Gonzalez IF, et al. Anastomotic pitfalls in lung transplantation. *J Thorac Cardiovasc Surg*. 1994;107(3):743-754. https://doi.org/10.1016/s0022-5223(94)70330-2
69. Clark SC, Levine AJ, Hasan A, Hilton CJ, Forty J, Dark JH. Vascular complications of lung transplantation. *Ann Thorac Surg*. 1996;61(4):1079-1082. https://doi.org/10.1016/0003-4975(96)00003-3
70. Siddique A, Bose AK, Özalp F, et al. Vascular anastomotic complications in lung transplantation: a single institution's experience. *Interact Cardiovasc Thorac Surg*. 2013;17(4):625-631. https://doi.org/10.1093/icvts/ivt266
71. Fitton TP, Bethea BT, Borja MC, et al. Pulmonary resection following lung transplantation. *Ann Thorac Surg*. 2003;76(5):1680-1686. https://doi.org/10.1016/s0003-4975(03)00975-5

72. Souilamas R, Saueressig M, Boussaud V, Amrein C, Guillemain R, Sonett J. Pulmonary resection after lung transplantation in cystic fibrosis patients. *Asian Cardiovasc Thorac Ann*. 2011;19(3-4):202-206. https://doi.org/10.1177/0218492311409242
73. Banerjee SK, Santhanakrishnan K, Shapiro L, Dunning J, Tsui S, Parmar J. Successful stenting of anastomotic stenosis of the left pulmonary artery after single lung transplantation. *Eur Respir Rev*. 2011;20(119):59-62. https://doi.org/10.1183/09059180.00009610
74. Jing L, Chen W, Zhai Z, et al. Pulmonary vein stenosis after lung transplantation: a case report and literature review. *Ann Transl Med*. 2021;9(2):181. https://doi.org/10.21037/atm-20-3972
75. Orlitová M, Gewillig M, Van Slambrouck J, et al. Endovascular transatrial stenting of pulmonary vein stenosis after lung transplantation. *Am J Transplant*. 2023;23(1):111-114. https://doi.org/10.1111/ajt.17202
76. Schulman LL, Anandarangam T, Leibowitz DW, et al. Four-year prospective study of pulmonary venous thrombosis after lung transplantation. *J Am Soc Echocardiogr*. 2001;14(8):806-812. https://doi.org/10.1067/mje.2001.111855
77. Ali A, Wang A, Ribeiro RVP, et al. Static lung storage at 10°C maintains mitochondrial health and preserves donor organ function. *Sci Transl Med*. 2021;13(611) https://doi.org/10.1126/scitranslmed.abf7601
78. Wang LS, Yoshikawa K, Miyoshi S, et al. The effect of ischemic time and temperature on lung preservation in a simple ex vivo rabbit model used for functional assessment. *J Thorac Cardiovasc Surg*. 1989;98(3):333-342. https://doi.org/10.1016/s0022-5223(19)34378-8
79. Date H, Lima O, Matsumura A, Tsuji H, d'Avignon DA, Cooper JD. In a canine model, lung preservation at 10° C is superior to that at 4° C. *J Thorac Cardiovasc Surg*. 1992;103(4):773-780. https://doi.org/10.1016/s0022-5223(19)34961-x
80. Ali A, Hoetzenecker K, Luis Campo-Cañaveral de la Cruz J, et al. Extension of cold static donor lung preservation at 10°C. *NEJM Evid*. 2023;2(6):EVIDoa2300008. https://doi.org/10.1056/evidoa2300008
81. Haney J, Hartwig M, Langer N, Sanchez P, Bush E. Not too warm, not too cold: real-world multi-center outcomes with elevated hypothermic preservation of donor lungs. *J Heart Lung Transplant*. 2023;42(4):S39-S40. https://doi.org/10.1016/j.healun.2023.02.084
82. Nykänen AI, Keshavjee S, Liu M. Creating superior lungs for transplantation with next-generation gene therapy during ex vivo lung perfusion. *J Heart Lung Transplant*. 2024;43(5):838-848. https://doi.org/10.1016/j.healun.2024.01.016
83. Niroomand A, Hirdman G, Pierre L, et al. Proteomic changes to immune and inflammatory processes underlie lung preservation using ex vivo cytokine adsorption. *Front Cardiovasc Med*. 2023;10:1274444. https://doi.org/10.3389/fcvm.2023.1274444
84. Wang A, Ribeiro RVP, Ali A, et al. Ex vivo enzymatic treatment converts blood type A donor lungs into universal blood type lungs. *Sci Transl Med*. 2022;14(632):eabm7190. https://doi.org/10.1126/scitranslmed.abm7190
85. Ribeiro RVP, Ku T, Wang A, et al. Ex vivo treatment of cytomegalovirus in human donor lungs using a novel chemokine-based immunotoxin. *J Heart Lung Transplant*. 2022;41(3):287-297. https://doi.org/10.1016/j.healun.2021.10.010
86. Lindstedt S, Eyjolfsson A, Koul B, et al. How to recondition ex vivo initially rejected donor lungs for clinical transplantation: clinical experience from lund university hospital. *J Transplant*. 2011;2011:754383. https://doi.org/10.1155/2011/754383
87. Nakajima D, Cypel M, Bonato R, et al. Ex vivo perfusion treatment of infection in human donor lungs. *Am J Transplant*. 2016;16(4):1229-1237. https://doi.org/10.1111/ajt.13562
88. Machuca TN, Hsin MK, Ott HC, et al. Injury-specific *ex vivo* treatment of the donor lung: pulmonary thrombolysis followed by successful lung transplantation. *Am J Respir Crit Care Med*. 2013;188(7):878-880. https://doi.org/10.1164/rccm.201302-0368LE
89. Cypel M, Yeung JC, Liu M, et al. Normothermic ex vivo lung perfusion in clinical lung transplantation. *N Engl J Med*. 2011;364(15):1431-1440. https://doi.org/10.1056/NEJMoa1014597
90. Lindstedt S, Hlebowicz J, Koul B, et al. Comparative outcome of double lung transplantation using conventional donor lungs and non-acceptable donor lungs reconditioned ex vivo. *Interact Cardiovasc Thorac Surg*. 2011;12(2):162-165. https://doi.org/10.1510/icvts.2010.244830
91. Cypel M, Yeung JC, Machuca T, et al. Experience with the first 50 ex vivo lung perfusions in clinical transplantation. *J Thorac Cardiovasc Surg*. 2012;144(5):1200-1207. https://doi.org/10.1016/j.jtcvs.2012.08.009
92. Valenza F, Rosso L, Coppola S, et al. Ex vivo lung perfusion to improve donor lung function and increase the number of organs available for transplantation. *Transpl Int*. 2014;27(6):553-561. https://doi.org/10.1111/tri.12295
93. Sage E, Mussot S, Trebbia G, et al. Lung transplantation from initially rejected donors after ex vivo lung reconditioning: the French experience. *Eur J Cardiothorac Surg*. 2014;46(5):794-799. https://doi.org/10.1093/ejcts/ezu245
94. Tikkanen JM, Cypel M, Machuca TN, et al. Functional outcomes and quality of life after normothermic ex vivo lung perfusion lung transplantation. *J Heart Lung Transplant*. 2015;34(4):547-556. https://doi.org/10.1016/j.healun.2014.09.044
95. Divithotawela C, Cypel M, Martinu T, et al. Long-term outcomes of lung transplant with ex vivo lung perfusion. *JAMA Surg*. 2019;154(12):1143-1150. https://doi.org/10.1001/jamasurg.2019.4079
96. Luc JGY, Jackson K, Weinkauf JG, Freed DH, Nagendran J. Feasibility of lung transplantation from donation after circulatory death donors following portable ex vivo lung perfusion: a pilot study. *Transplant Proc*. 2017;49(8):1885-1892. https://doi.org/10.1016/j.transproceed.2017.04.010
97. Machuca TN, Mercier O, Collaud S, et al. Lung transplantation with donation after circulatory determination of death donors and the impact of ex vivo lung perfusion. *Am J Transplant*. 2015;15(4):993-1002. https://doi.org/10.1111/ajt.13124
98. Warnecke G, Van Raemdonck D, Smith MA, et al. Normothermic ex-vivo preservation with the portable Organ Care System Lung device for bilateral lung transplantation (INSPIRE): a randomised, open-label, non-inferiority, phase 3 study. *Lancet Respir Med*. 2018;6(5):357-367. https://doi.org/10.1016/s2213-2600(18)30136-x
99. Nilsson T, Wallinder A, Henriksen I, et al. Lung transplantation after ex vivo lung perfusion in two Scandinavian centres. *Eur J Cardiothorac Surg*. 2019;55(4):766-772. https://doi.org/10.1093/ejcts/ezy354
100. Van Raemdonck D, Keshavjee S, Levvey B, et al. Donation after circulatory death in lung transplantation-five-year follow-up from ISHLT Registry. *J Heart Lung Transplant*. 2019;38(12):1235-1245. https://doi.org/10.1016/j.healun.2019.09.007
101. Whitford H, Kure CE, Henriksen A, et al. A donor PaO2/FiO2 < 300 mm Hg does not determine graft function or survival after lung transplantation. *J Heart Lung Transplant*. 2020;39(1):53-61. https://doi.org/10.1016/j.healun.2019.08.021
102. Busl KM, Bleck TP. Neurogenic pulmonary edema. *Crit Care Med*. 2015;43(8):1710-1715. https://doi.org/10.1097/CCM.0000000000001101
103. Fumagalli J, Rosso L, Gori F, et al. Early pulmonary function and mid-term outcome in lung transplantation after ex-vivo lung perfusion – a single-center, retrospective, observational, cohort study. *Transplant Int*. 2020;33(7):773-785. https://doi.org/10.1111/tri.13606
104. Mallea JM, Hartwig MG, Keller CA, et al. Remote ex vivo lung perfusion at a centralized evaluation facility. *J Heart Lung Transplant*. 2022;41(12):1700-1711. https://doi.org/10.1016/j.healun.2022.09.006
105. Palleschi A, Inci I, Van Raemdonck DE, et al. Lung transplantation from donation after brain death donors on extracorporeal support. *Transplantation*. 2022;106(7):e356-e357. https://doi.org/10.1097/TP.0000000000004145
106. Fisher A, Andreasson A, Chrysos A, et al. An observational study of donor ex vivo lung perfusion in UK lung transplantation: DEVELOP-UK. *Health Technol Assess*. 2016;20(85):1-276. https://doi.org/10.3310/hta20850
107. Loor G, Warnecke G, Villavicencio MA, et al. Portable normothermic ex-vivo lung perfusion, ventilation, and functional assessment with the Organ Care System on donor lung use for transplantation from extended-criteria donors (EXPAND): a single-arm, pivotal trial. *Lancet Respir Med*. 2019;7(11):975-984. https://doi.org/10.1016/s2213-2600(19)30200-0
108. Ghaidan H, Fakhro M, Andreasson J, Pierre L, Ingemansson R, Lindstedt S. Ten year follow-up of lung transplantations using initially rejected donor lungs after reconditioning using ex vivo lung perfusion. *J Cardiothorac Surg*. 2019;14(1):125. https://doi.org/10.1186/s13019-019-0948-1
109. Slama A, Schillab L, Barta M, et al. Standard donor lung procurement with normothermic ex vivo lung perfusion: a prospective randomized clinical trial. *J Heart Lung Transplant*. 2017;36(7):744-753. https://doi.org/10.1016/j.healun.2017.02.011
110. Niikawa H, Okamoto T, Ayyat KS, Sakanoue I, Yun JJ, McCurry KR. Successful lung transplantation after acellular ex vivo lung perfusion with prone positioning. *Ann Thorac Surg*. 2020;110(4):e285-e287. https://doi.org/10.1016/j.athoracsur.2020.02.045

111. Sage AT, Richard-Greenblatt M, Zhong K, et al. Prediction of donor related lung injury in clinical lung transplantation using a validated ex vivo lung perfusion inflammation score. *J Heart Lung Transplant*. 2021;40(7):687-695. https://doi.org/10.1016/j.healun.2021.03.002
112. Kanou T, Nakahira K, Choi AM, et al. Cell-free DNA in human ex vivo lung perfusate as a potential biomarker to predict the risk of primary graft dysfunction in lung transplantation. *J Thorac Cardiovasc Surg*. 2021;162(2):490-499.e2. https://doi.org/10.1016/j.jtcvs.2020.08.008
113. Di Nardo M, Del Sorbo L, Sage A, et al. Predicting donor lung acceptance for transplant during ex vivo lung perfusion: the EX vivo lung PerfusIon pREdiction (EXPIRE). *Am J Transplant*. 2021;21(11):3704-3713. https://doi.org/10.1111/ajt.16616
114. Sage AT, Donahoe LL, Shamandy AA, et al. A machine-learning approach to human ex vivo lung perfusion predicts transplantation outcomes and promotes organ utilization. *Nat Commun*. 2023;14(1):4810. https://doi.org/10.1038/s41467-023-40468-7
115. Okamoto T, Ayyat KS, Sakanoue I, et al. Clinical significance of donor lung weight at procurement and during ex vivo lung perfusion. *J Heart Lung Transplant*. 2022;41(6):818-828. https://doi.org/10.1016/j.healun.2022.02.011
116. Cypel M, Rubacha M, Yeung J, et al. Normothermic ex vivo perfusion prevents lung injury compared to extended cold preservation for transplantation. *Am J Transplant*. 2009;9(10):2262-2269. https://doi.org/10.1111/j.1600-6143.2009.02775.x
117. Sanchez PG, Davis RD, D'Ovidio F, et al. The NOVEL lung trial one-year outcomes. *J Heart Lung Transplant*. 2014;33(4):S71-S72. https://doi.org/10.1016/j.healun.2014.01.226
118. Fildes JE, Archer LD, Blaikley J, et al. Clinical outcome of patients transplanted with marginal donor lungs via ex vivo lung perfusion compared to standard lung transplantation. *Transplantation*. 2015;99(5):1078-1083. https://doi.org/10.1097/tp.0000000000000462
119. Ingemansson R, Eyjolfsson A, Mared L, et al. Clinical transplantation of initially rejected donor lungs after reconditioning ex vivo. *Ann Thorac Surg*. 2009;87(1):255-260. https://doi.org/10.1016/j.athoracsur.2008.09.049
120. Wierup P, Haraldsson Å, Nilsson F, et al. Ex vivo evaluation of nonacceptable donor lungs. *Ann Thorac Surg*. 2006;81(2):460-466. https://doi.org/10.1016/j.athoracsur.2005.08.015
121. Cypel M, Yeung JC, Donahoe L, et al. Normothermic ex vivo lung perfusion: does the indication impact organ utilization and patient outcomes after transplantation? *J Thorac Cardiovasc Surg*. 2020;159(1):346-355.e1. https://doi.org/10.1016/j.jtcvs.2019.06.123
122. Thiessen C, Gordon EJ, Kelly B, Wall A. The ethics of donation after circulatory death organ recovery: an overview of new considerations arising from procurement practice and policy changes. *Curr Opin Organ Transplant*. 2022;28(2):133-138. https://doi.org/10.1097/mot.0000000000001046
123. Nielsen Busch EJ, Mjaaland MT. Does controlled donation after circulatory death violate the dead donor rule? *Am J Bioeth*. 2022;23(2):4-11. https://doi.org/10.1080/15265161.2022.2040646
124. Reich DJ, Mulligan DC, Abt PL, et al. ASTS Recommended Practice Guidelines for controlled donation after cardiac death organ procurement and transplantation. *Am J Transplant*. 2009;9(9):2004-2011. https://doi.org/10.1111/j.1600-6143.2009.02739.x
125. Holm AM, Courtwright A, Olland A, Zuckermann A, Van Raemdonck D. ISHLT position paper on thoracic organ transplantation in controlled donation after circulatory determination of death (cDCD). *J Heart Lung Transplant*. 2022;41(6):671-677. https://doi.org/10.1016/j.healun.2022.03.005
126. Furukawa M, Noda K, Chan EG, Ryan JP, Coster JN, Sanchez PG. Lung transplantation from donation after circulatory death, evolution, and current status in the United States. *Clin Transplant*. 2023;37(3):e14884. https://doi.org/10.1111/ctr.14884
127. Costa J, Shah L, Robbins H, et al. Use of lung allografts from donation after cardiac death donors: a single-center experience. *Ann Thorac Surg*. 2018;105(1):271-278. https://doi.org/10.1016/j.athoracsur.2017.07.023
128. Cypel M, Levvey B, Van Raemdonck D, et al. International Society for Heart and Lung Transplantation donation after circulatory death registry report. *J Heart Lung Transplant*. 2015;34(10):1278-1282. https://doi.org/10.1016/j.healun.2015.08.015
129. Krutsinger D, Reed RM, Blevins A, et al. Lung transplantation from donation after cardiocirculatory death: a systematic review and meta-analysis. *J Heart Lung Transplant*. 2015;34(5):675-684. https://doi.org/10.1016/j.healun.2014.11.009
130. Levvey B, Keshavjee S, Cypel M, et al. Influence of lung donor agonal and warm ischemic times on early mortality: analyses from the ISHLT DCD Lung Transplant Registry. *J Heart Lung Transplant*. 2019;38(1):26-34. https://doi.org/10.1016/j.healun.2018.08.006
131. Charles EJ, Huerter ME, Wagner CE, et al. Donation after circulatory death lungs transplantable up to six hours after ex vivo lung perfusion. *Ann Thorac Surg*. 2016;102(6):1845-1853. https://doi.org/10.1016/j.athoracsur.2016.06.043
132. Lomero M, Gardiner D, Coll E, et al. Donation after circulatory death today: an updated overview of the European landscape. *Transplant Int*. 2020;33(1):76-88. https://doi.org/10.1111/tri.13506
133. Choubey AP, Siskind EJ, Ortiz AC, et al. Disparities in DCD organ procurement policy from a national OPO survey: a call for standardization. *Clin Transplant*. 2020;34(4):e13826. https://doi.org/10.1111/ctr.13826
134. Mason DP, Thuita L, Alster JM, et al. Should lung transplantation be performed using donation after cardiac death? The United States experience. *J Thorac Cardiovasc Surg*. 2008;136(4):1061-1066. https://doi.org/10.1016/j.jtcvs.2008.04.023
135. Manara AR, Murphy PG, O'Callaghan G. Donation after circulatory death. *Br J Anaesth*. 2012;108:i108-i121. https://doi.org/10.1093/bja/aer357
136. Levvey BJ, Harkess M, Hopkins P, et al. Excellent clinical outcomes from a national donation-after-determination-of-cardiac-death lung transplant collaborative. *Am J Transplant*. 2012;12(9):2406-2413. https://doi.org/10.1111/j.1600-6143.2012.04193.x
137. Cypel M, Sato M, Yildirim E, et al. Initial experience with lung donation after cardiocirculatory death in Canada. *J Heart Lung Transplant*. 2009;28(8):753-758. https://doi.org/10.1016/j.healun.2009.05.009
138. Snell GI, Levvey BJ, Oto T, et al. Early lung transplantation success utilizing controlled donation after cardiac death donors. *Am J Transplant*. 2008;8(6):1282-1289. https://doi.org/10.1111/j.1600-6143.2008.02231.x
139. Egan TM, Lambert CJ, Reddick R, Ulicny KS, Keagy BA, Wilcox BR. A strategy to increase the donor pool: use of cadaver lungs for transplantation. *Ann Thorac Surg*. 1991;52(5):1113-1121. https://doi.org/10.1016/0003-4975(91)91290-c
140. Levvey BJ, Westall GP, Kotsimbos T, Williams TJ, Snell GI. Definitions of warm ischemic time when using controlled donation after cardiac death lung donors. *Transplantation*. 2008;86(12):1702-1706. https://doi.org/10.1097/tp.0b013e3181901f24
141. Reeb J, Keshavjee S, Cypel M. Successful lung transplantation from a donation after cardiocirculatory death donor taking more than 120 minutes to cardiac arrest after withdrawal of life support therapies. *J Heart Lung Transplant*. 2016;35(2):258-259. https://doi.org/10.1016/j.healun.2015.10.010
142. Santos PARD, Teixeira PJZ, Moraes Neto DM, Cypel M. Donation after circulatory death and lung transplantation. *J Bras Pneumol*. 2022;48(2):e20210369. https://doi.org/10.36416/1806-3756/e20210369
143. Coll E, Miñambres E, Sánchez-Fructuoso A, Fondevila C, Campo-Cañaveral de la Cruz JL, Domínguez-Gil B. Uncontrolled donation after circulatory death: a unique opportunity. *Transplantation*. 2020;104(8):1542-1552. https://doi.org/10.1097/tp.0000000000003139
144. Valdivia D, Gómez de Antonio D, Hoyos L, Campo-Cañaveral de la Cruz JL, Romero A, Varela de Ugarte A. Expanding the horizons: uncontrolled donors after circulatory death for lung transplantation—first comparison with brain death donors. *Clin Transplant*. 2019;33(6):e13561. https://doi.org/10.1111/ctr.13561
145. Campo-Cañaveral de la Cruz JL, Crowley Carrasco S, Tanaka S, et al. Lung transplantation from uncontrolled and controlled donation after circulatory death: similar outcomes to brain death donors. *Transplant Int*. 2021;34(12):2609-2619. https://doi.org/10.1111/tri.14120
146. Gámez P, Díaz-Hellín V, Marrón C, Meneses JC, de Pablo A, Martín de Nicolás JL. Development of a non-heart-beating lung donor program with «Bithermia Preservation», and results after one year of clinical experience. *Arch Bronconeumol*. 2012;48(9):338-341. https://doi.org/10.1016/j.arbres.2011.11.006
147. Musso V, Mendogni P, Scaravilli V, Morlacchi LC, Croci GA, Palleschi A. Extended-criteria uncontrolled DCD donor for a fragile recipient: a case report about a challenging yet successful lung transplantation. *Int J Surg Case Rep*. 2020;77S(Suppl):S67-S71. https://doi.org/10.1016/j.ijscr.2020.09.051
148. Copeland H, Hayanga JWA, Neyrinck A, et al. Donor heart and lung procurement: a consensus statement. *J Heart Lung Transplant*. 2020;39(6):501-517. https://doi.org/10.1016/j.healun.2020.03.020

149. Kwon JH, Ghannam AD, Shorbaji K, et al. Early outcomes of heart transplantation using donation after circulatory death donors in the United States. *Circ Heart Fail*. 2022;15(12):e009844. https://doi.org/10.1161/circheartfailure.122.009844
150. Truog RD, Flescher A, Ladin K. Normothermic regional perfusion—the next frontier in organ transplants? *JAMA*. 2023;329(24):2123. https://doi.org/10.1001/jama.2023.9294
151. Spencer PJ, Saddoughi SA, Choi K, et al. Heart-lung transplantation from donation after circulatory death using mobile normothermic regional perfusion. *ASAIO J*. 2024;70(1):e13-e15. https://doi.org/10.1097/mat.0000000000002029
152. Schwarz S, Gökler J, Moayedifar R, et al. Prioritizing direct heart procurement in organ donors after circulatory death does not jeopardize lung transplant outcomes. *JTCVS Tech*. 2022;16:182-195. https://doi.org/10.1016/j.xjtc.2022.08.032
153. Gao Q, Pontula A, Alderete IS, et al. Impact of simultaneous heart procurement on outcomes of donation after circulatory death lung transplantation. *Am J Transplant*. 2024;24(1):79-88. https://doi.org/10.1016/j.ajt.2023.08.012
154. Zhou AL, Ruck JM, Casillan AJ, et al. Early United States experience with lung donation after circulatory death using thoracoabdominal normothermic regional perfusion. *J Heart Lung Transplant*. 2023;42(6):693-696. https://doi.org/10.1016/j.healun.2023.03.001
155. Urban M, Castleberry AW, Markin NW, et al. Successful lung transplantation with graft recovered after thoracoabdominal normothermic perfusion from donor after circulatory death. *Am J Transplant*. 2022;22(1):294-298. https://doi.org/10.1111/ajt.16806
156. Ribeiro RVP, Reynolds FA, Sarrafian TL, et al. Impact of normothermic regional perfusion during DCD recovery on lung allograft function: a preclinical study. *JHLT Open*. 2023;2:100009. https://doi.org/10.1016/j.jhlto.2023.100009
157. Cain MT, Park SY, Schäfer M, et al. Lung recovery utilizing thoracoabdominal normothermic regional perfusion during donation after circulatory death: the Colorado experience. *JTCVS Tech*. 2023;22:350-358. https://doi.org/10.1016/j.xjtc.2023.09.027
158. Choi K, Spadaccio C, Ribeiro RVP, et al. Early national trends of lung allograft use during donation after circulatory death heart procurement in the United States. *JTCVS Open*. 2023;16:1020-1028. https://doi.org/10.1016/j.xjon.2023.08.014
159. Royo-Villanova M, Miñambres E, Sánchez JM, et al. Maintaining the permanence principle of death during normothermic regional perfusion in controlled donation after the circulatory determination of death: results of a prospective clinical study. *Am J Transplant*. 2024;24(2):213-221. https://doi.org/10.1016/j.ajt.2023.09.008
160. Tanaka S, Luis Campo-Cañaveral de la Cruz J, Crowley Carrasco S, et al. Effect on the donor lungs of using abdominal normothermic regional perfusion in controlled donation after circulatory death. *Eur J Cardiothorac Surg*. 2020 ezaa398; https://doi.org/10.1093/ejcts/ezaa398
161. Mora V, Ballesteros MA, Naranjo S, et al. Lung transplantation from controlled donation after circulatory death using simultaneous abdominal normothermic regional perfusion: a single center experience. *Am J Transplant*. 2022;22(7):1852-1860. https://doi.org/10.1111/ajt.17057
162. Campo-Cañaveral de la Cruz JL, Miñambres E, Coll E, et al. Outcomes of lung and liver transplantation after simultaneous recovery using abdominal normothermic regional perfusion in donors after the circulatory determination of death versus donors after brain death. *Am J Transplant*. 2023;23(7):996-1008. https://doi.org/10.1016/j.ajt.2023.04.016
163. Bery A, Ali A, Cypel M, Kreisel D. Centralized organ recovery and reconditioning centers. *Thorac Surg Clin*. 2022;32(2):167-174. https://doi.org/10.1016/j.thorsurg.2021.11.003
164. Bery A, Marklin G, Itoh A, et al. Specialized donor care facility model and advances in management of thoracic organ donors. *Ann Thorac Surg*. 2022;113(6):1778-1786. https://doi.org/10.1016/j.athoracsur.2020.12.026
165. Keshavjee S. Human organ repair centers: fact or fiction? *JTCVS Open*. 2020;3:164-168. https://doi.org/10.1016/j.xjon.2020.05.001
166. Whitson BA, Black SM. Organ assessment and repair centers: the future of transplantation is near. *World J Transplant*. 2014;4(2):40-42. https://doi.org/10.5500/wjt.v4.i2.40
167. Gauthier JM, Doyle MBM, Chapman WC, et al. Economic evaluation of the specialized donor care facility for thoracic organ donor management. *J Thorac Dis*. 2020;12(10):5709-5717. https://doi.org/10.21037/jtd-20-1575
168. Marsolais P, Durand P, Charbonney E, et al. The first 2 years of activity of a specialized organ procurement center: report of an innovative approach to improve organ donation. *Am J Transplant*. 2017;17(6):1613-1619. https://doi.org/10.1111/ajt.14139
169. Chang SH, Kreisel D, Marklin GF, et al. Lung focused resuscitation at a specialized donor care facility improves lung procurement rates. *Ann Thorac Surg*. 2018;105(5):1531-1536. https://doi.org/10.1016/j.athoracsur.2017.12.009
170. Englesbe MJ, Merion RM. The riskiest job in medicine: transplant surgeons and organ procurement travel. *Am J Transplant*. 2009;9(10):2406-2415. https://doi.org/10.1111/j.1600-6143.2009.02774.x
171. Olaso DG, Halpern SE, Krischak MK, et al. Same-teams versus different-teams for long distance lung procurement: a cost analysis. *J Thorac Cardiovasc Surg*. 2023;165(3):908-919.e3. https://doi.org/10.1016/j.jtcvs.2022.05.040
172. Yang Z, Gerull WD, Shepherd HM, et al. Different-team procurements: a potential solution for the unintended consequences of change in lung allocation policy. *Am J Transplant*. 2021;21(9):3101-3111. https://doi.org/10.1111/ajt.16553

Key Words: lung preservation, ex vivo lung perfusion, normothermic regional perfusion, lung transplantation