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Extracorporeal life support in adult lung transplantation: a survey of Italian lung transplant

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The use of extracorporeal life support (ECLS) during lung transplantation has evolved substantially. Despite recent international consensus recommendations, significant variability persists. We conducted a national survey to describe contemporary practice patterns among Italian lung transplant centres. A 39-item, web-based survey was developed and distributed to all nine Italian lung transplant centres. The survey addressed indications for ECLS, technical aspects of extracorporeal support, anticoagulation and postoperative management. The response rate was 100%. Seven centres (77.8%) reported selective use of ECLS, whereas two (22.2%) routinely used ECLS during bilateral lung transplantations. Veno-arterial extracorporeal membrane oxygenation (VA-ECMO) was the preferred intraoperative support modality in seven centres (77.8%), while two centres (22.2%) preferred cardiopulmonary bypass. Considerable variability was observed in patient selection, anticoagulation, cannulation strategies, postoperative ECLS continuation and weaning practices. Substantial variability remains in ECLS management among Italian lung transplant centres, despite recent international consensus recommendations. These findings provide a contemporary

national overview of ECLS practice and highlight the need for further patient-level and outcome-based evaluation of intraoperative ECLS strategies.

KEYWORDS

ECLS, ECMO, Italian society of organ and tissues transplantation (SITO), lung transplant, survey

Introduction

Lung transplantation (LTx) represents an established surgical treatment option for selected patients with end-stage pulmonary disease [1]. Despite recent international consensus recommendations, limited evidence and reliance on expert opinion, and local feasibility continue to contribute to persistent heterogeneity in practice among centres, encompassing both recipient- and donor-related management [1–3].

The use of extracorporeal life support (ECLS) is one of the most debated aspects of intraoperative LTx management. ECLS may provide haemodynamic stability and facilitate protective ventilation during sequential implantation and reperfusion. However, ECLS may increase transfusion requirements, exposure to systemic anticoagulation, and contribute to systemic inflammatory activation and extrapulmonary complications [4].

Currently International Society for Heart and Lung Transplantation (ISHLT) recommendations state that the criteria for planned intraoperative ECLS versus no ECLS support should consider centre expertise, recipient characteristics, and multidisciplinary intraoperative assessment [4–6]. Recipient-related factors have been proposed as major determinants influencing the planned intraoperative use of ECLS [6]. Unplanned ECLS support is therefore initiated intraoperatively in response to anatomical or physiological deterioration [4, 6]. Despite these recommendations, evidence remains limited regarding the optimal modality and timing of ECLS during lung transplantation. While technical aspects of extracorporeal circuits and cannulation are increasingly standardised, indications for planned ECLS, patient selection, and intraoperative management remain largely based on expert opinion and observational evidence [6–8].

We therefore conducted a national survey whose aim was to provide a contemporary snapshot of lung transplantation management in Italy, highlighting similarities and differences across centres and identifying areas where harmonisation and future shared recommendations may be feasible.

Abbreviations: ACT, activated clotting time; AATS, American Association for Thoracic Surgery; CPB, cardiopulmonary bypass; ECLS, extracorporeal life support; ECMO, extracorporeal membrane oxygenation; ELSO, Extracorporeal Life Support Organization; ICU, intensive care unit; ISHLT, International Society for Heart and Lung Transplantation; LTx, lung transplantation; NIRS, near-infrared spectroscopy; PGD, primary graft dysfunction; RHF, right heart failure; RV, right ventricle; right ventricular; ScvO2, central venous oxygen saturation; SITO, Italian Society for Organ and Tissue Transplantation; sPAP, systolic pulmonary artery pressure; SVR, systemic vascular resistance; SvO2, mixed venous oxygen saturation; TEE, transoesophageal echocardiography; UFH, unfractionated heparin; VA-ECMO, veno-arterial extracorporeal membrane oxygenation; VAV-ECMO, veno-arterial-venous extracorporeal membrane oxygenation; VV-ECMO, veno-venous extracorporeal membrane oxygenation.

Materials and methods

The survey questionnaire was developed by members of the Lung Group of the Italian Society for Organ and Tissue Transplantation (SITO) following a structured multidisciplinary roundtable discussion and internal revision.

No patient data or personally identifiable information were collected. R esponses were provided voluntarily in an aggregated centre-level format. According to applicable institutional and national regulations, informed consent and formal ethical approval were therefore not required.

The survey consisted of 39 questions, collected between October 2024 and January 2025, addressing institutional characteristics, intraoperative management, and ECLS practices.

The survey was distributed via Google Forms by e-mail to representatives from each of the nine Italian lung transplant centres. Each centre submitted a single institutional response. The survey did not prescribe a formal adjudication procedure for disagreements; respondents were asked to reach a consensus within their centre before submitting the institutional response.

Recently published international consensus statements were reviewed and summarised (Supplementary Tables S1,S2, see Supplementary Material) to provide a framework for comparison with survey findings.

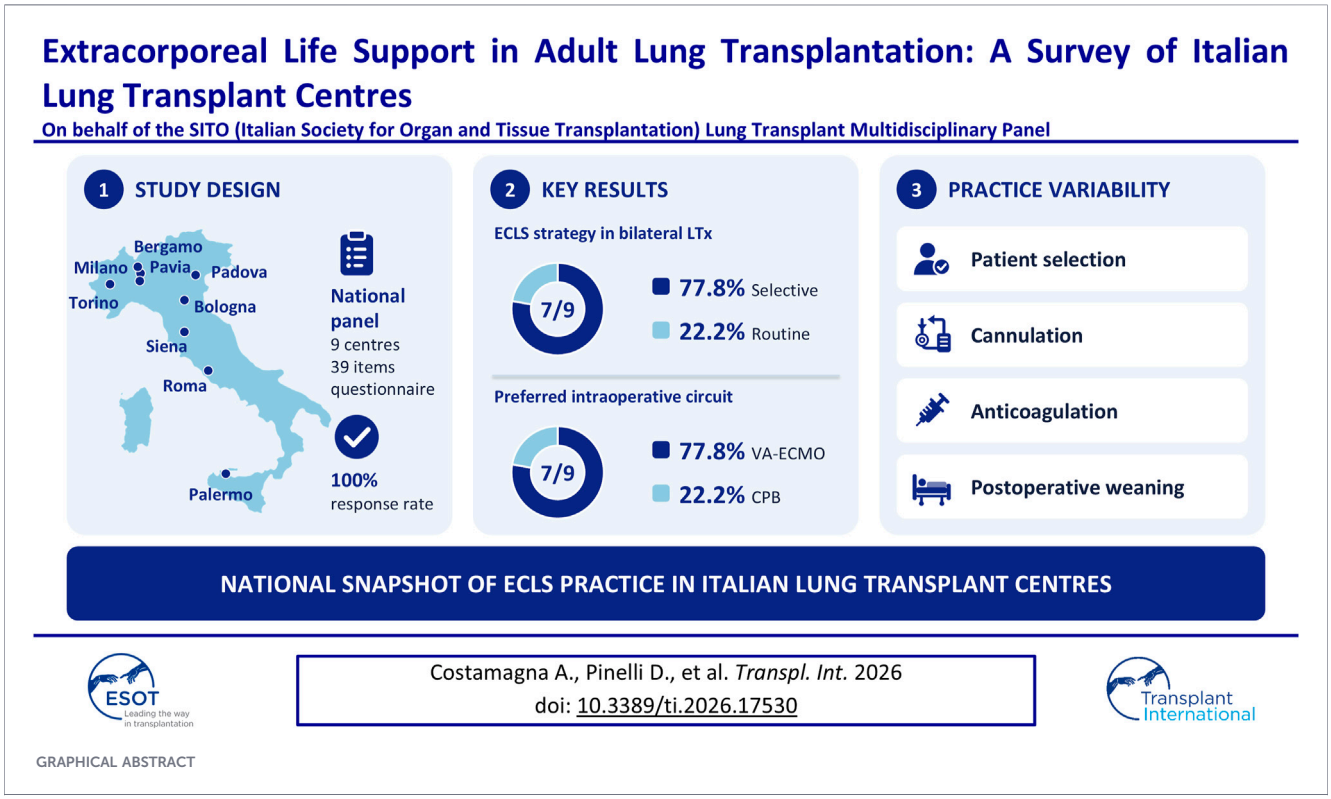
Results

The response rate was 100%. The survey received aggregated responses from all nine Italian transplant centres (Supplementary Figure S1).

Section A - lung transplant team: structural aspects

Annual lung transplant volume varied across centres: two (22.2%) performed more than 30 transplants per year and can therefore be classified as high-volume transplant centres according to the literature [9], one (11.1%) performed 20–30, four (44.4%) performed 10–20, and two (22.2%) performed fewer than 10 procedures (*Q1*).

In most centres, lung transplantation is primarily performed by thoracic surgeons (55.6%), while cardiac surgeons are frequently additional specialists (*Q4*). Anaesthesiologists belong to a dedicated anaesthesia group in seven centres (77.8%), and in six (66.7%) they have a cardiothoracic subspecialty background (*Q5-6*). In four (44.4%) centres, two anaesthesiologists are involved in the management of lung transplantation; in these cases, the second anaesthesiologist was most commonly (77.8%) a cardiothoracic anaesthesiologist (*Q8-9-11*).



The ECMO team was external in only two (22.2%) centres, and the perfusionist is integrated within the cardiac surgical resident team in the vast majority of cases (88.9%) (*Q12*) (Table 1).

Section B - haemodynamic monitoring, vasopressors, and inotropes

All centres routinely use pulmonary artery catheters, transoesophageal echocardiography, and SvO2/ScvO2 monitoring intraoperatively. Four (44.4%) include some form of pulse contour analysis, and eight (88.9%) use near-infrared spectroscopy (NIRS) monitoring during surgery (Figure 2A) (*Q14*).

Reported vasopressor preferences for systemic vascular resistance (SVR) modulation and inotrope preferences for right and left ventricular impairment during lung transplantation are illustrated in Figures 2B,C, respectively (*Q15-16*) (Table 2).

Section C - ECLS in lung transplantation

Among the nine centres, seven (77.8%) reported s elective ECLS. The remaining two centres (22.2%) reported routine ECLS (*Q17*).

In single-lung transplantation, only two centres (22.2%) reported planned ECLS in selected cases. The remaining seven (77.8%) reserved ECLS for severe intraoperative haemodynamic instability or respiratory failure (*Q18*). Selective ECLS is planned preoperatively in 33.3% of centres, whereas in the remaining centres (66.7%) ECLS could be initiated either before or during surgery according to intraoperative clinical evolution (Rescue ECLS) (*Q24*).

Seven centres (77.8%) identified veno-arterial extracorporeal membrane oxygenation (VA-ECMO) as their preferred intraoperative support modality during bilateral lung transplantation, while two (22.2%) preferred conventional extracorporeal circulation (CPB). Central cannulation is favoured in five centres (55.6%), whereas two (22.2%) preferred peripheral cannulation approaches, namely VA and VAV configurations, respectively. No centre identified VV ECMO as the preferred intraoperative support modality (*Q19*).

Centres also rated the relevance of clinical indicators in determining the preferred ECLS modality (*Q20-22*) (Supplementary Figure S2).

Selection of high-risk patients was primarily based on clinical parameters (Figure 3) (*Q25*).

The indicators most frequently rated as highly influential were right ventricular dysfunction, haemodynamic instability, PaO_2 and $PaCO_2$, whereas pH and $ScvO_2$ received lower ratings (*Q27*).

Six centres (66.7%) considered pulmonary hypertension an indication for ECLS only when associated with right ventricular (RV) dysfunction. The remaining three centres (33.3%) identified severe pulmonary hypertension- defined as systolic pulmonary artery pressure (sPAP) ≥ 50% of systolic systemic pressure after cardiovascular optimization–as a standalone indication *(Q26)*.

Transoesophageal echocardiography (TEE) was the preferred modality for assessing RV function (88.9%), followed by Swan-Ganz catheterisation (66.7%) and direct intraoperative visual assessment (44.4%) (*Q28*).

Seven centres (77.8%) reported using an initial bolus of heparin at a dose of 40–100 IU/kg, followed by additional boluses or continuous infusion to maintain an activated clotting time (ACT) between 160 and 220 s during ECLS (*Q23*) (Table 3).

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TABLE 1 Survey results - Section A: Structural aspects of the lung transplant team.

Results	N (%) = 9 (100)
Q01 -annual number of lung transplants performed	-
<10	2 (22)
10–20	4 (44)
20–30	1 (11)
30–50	2 (22)
Q02 -main pathological indication for lung transplantation	-
Pulmonary fibrosis	7 (78)
COPD/emphysema	0 (0)
Pulmonary hypertension	2 (22)
Bronchiectasis (cystic and non-cystic fibrosis)	0 (0)
Q03-most commonly used surgical approach for bilateral lung	-
Transplantation	-
Clamshell incision	8 (89)
Bilateral thoracotomy	1 (11)
Q04 -primary surgeon's specialization	-
General surgeon	2 (22)
Thoracic surgeon routinely performing thoracic procedures	5 (56)
Cardiac surgeon routinely performing cardiac procedures	2 (22)
Q05 -other surgical specialties present in the operating room	-
General surgery	5 (56)
Thoracic surgery	3 (33)
Cardiac surgery	1 (11)
Q06 -presence of an anesthesia team specifically dedicated to lung transplantation	-
Yes	-
No	7 (78)
	2 (22)
Q07 -presence of an ECMO team external to the OR team that provides consultation when needed	-
Yes	-
No	2 (22)
	7 (78)
Q08 - main background of anesthesiologists	-
Cardiac or cardio-thoracic-vascular	6 (67)
Intensive care/ICU anesthesiologist	0 (0)
General OR anesthesiologist	3 (33)
Q09 - number of anesthesiologists involved	-
1	5 (56)
2	4 (44)
Q11 - main background of anesthesiologists managing ECLS	-
Cardiac or cardio-thoracic-vascular	7 (78)
Intensive care/ICU anesthesiologist	0 (0)
General OR anesthesiologist	2 (22)
Q12 -Perfusionist's affiliation in the OR	-
Cardiac surgery OR	8 (89)
External service provider	1 (11)
Q13 - is there an intraoperative anesthetic management protocol for lung transplantation?	-
Yes, without a checklist of medications/devices to be prepared	-
Yes, with a checklist of medications/devices to be prepared	5 (56)
No	4 (44)
	0 (0)

TABLE 2 Survey results - Section B: Hemodynamic Monitoring, Vasopressors, and Inotropes.

Results	N (%) = 9 (100)
Q14 -what hemodynamic monitoring tools are used during lung transplantation? (Multiple answers):	-
Swan-Ganz catheter	-
Transesophageal echocardiography (TEE)	Figure 2A
CO monitoring via pulse contour analysis (e.g., PiCCO)	
NIRS	
$SvO_2/ScvO_2$	
Q15 - which vasopressors are used to increase systemic vascular resistance? (Rank in order of use; assign "0" if not used):	-
Norepinephrine	-
Vasopressin	Figure 2B
Terlipressin	
Phenylephrine	
Ephedrine	
Angiotensin II	
Dopamine	
Q16 - which inotropes are used when needed?	-
(Rank in order of use; assign "0" if not used):	-
Epinephrine	Figure 2C
Dobutamine	
Dopamine	
Ephedrine	
Milrinone	
Enoximone	
Levosimendan	

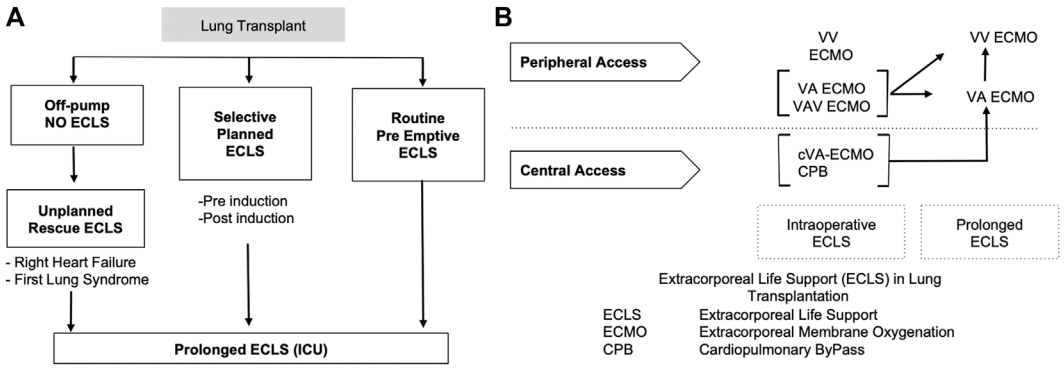


FIGURE 1
(A) The use of mechanical support in lung transplantation has been outlined according to its use as a bridge to transplantation, as intraoperative support and as postoperative support in the ICU (prolonged ECLS). Definitions of routine ECLS, selective ECLS, planned and unplanned ECLS are provided in the text. **(B)** The technical characteristics of the circuit in the various phases are summarised. The different options are dictated by the specific cardiorespiratory clinical picture before, during and after transplantation (ECLS: Extracorporeal Life Support; ECMO: Extracorporeal Membrane Oxygenation; CPB: Cardiopulmonary By-Pass; VV: veno-venous; VA: veno-arterial; VAV: veno-arterial-venous; cVA-ECMO: central access, veno-arterial).

Section D - ECLS technical aspects in lung transplantation

The surgical cut-down technique was reported as the preferred approach for arterial cannulation in 77.8% of centres and venous cannulation in 66.7% of centres. (*Q29-30*) L imb reperfusion was routinely used during peripheral arterial cannulation in six centres (66.7%) (*Q31*). All centres (100%) reported femoral–femoral configuration as the preferred peripheral cannulation strategy for intraoperative VA-ECMO (*Q33*).

Five centres (55.6%) reported maintaining ECMO support postoperatively in patients considered high risk preoperatively or after graft reperfusion. Three centres (33.3%) routinely attempt ECMO weaning regardless of the underlying condition, whereas

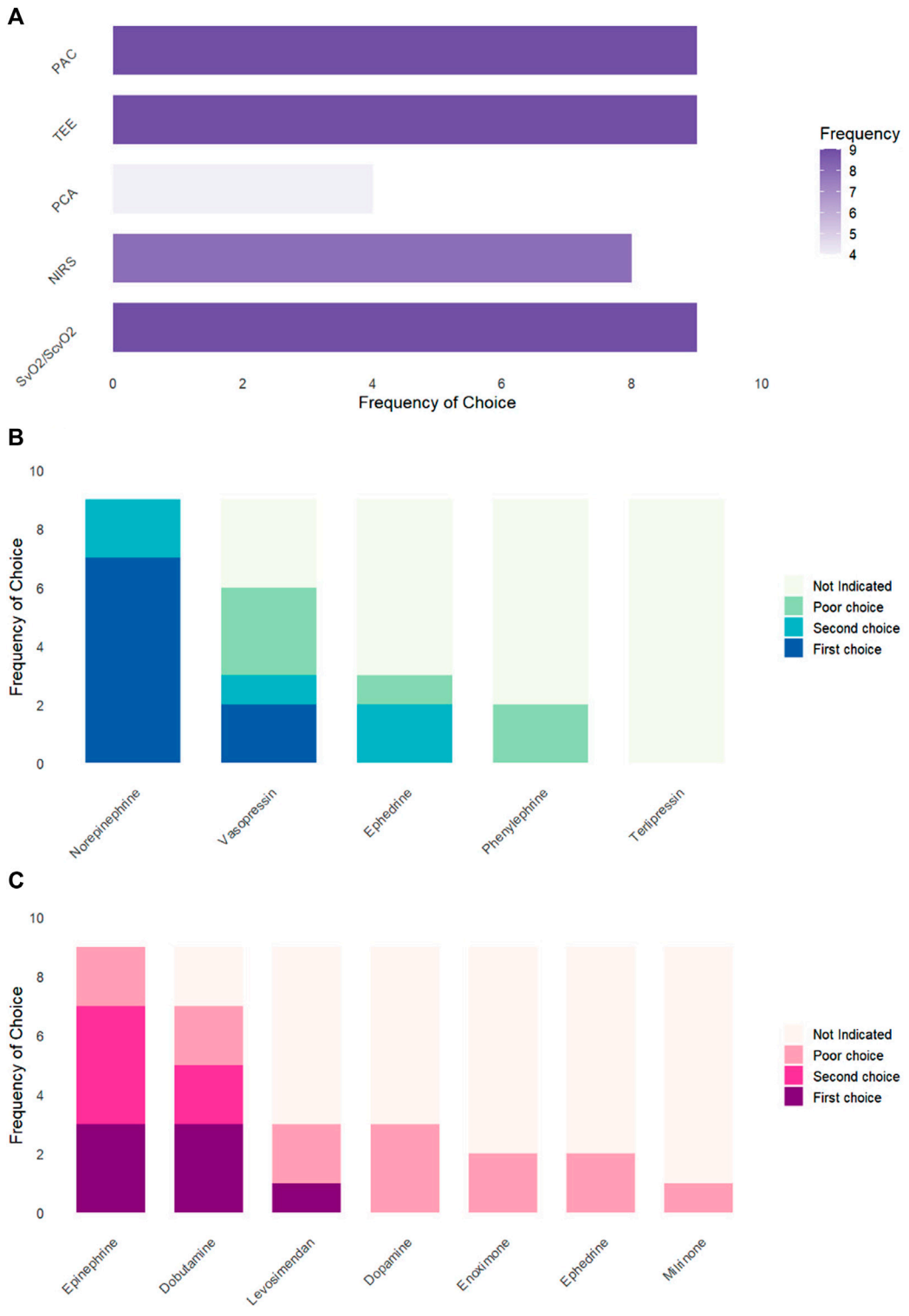


FIGURE 2
Preferences in haemodynamic monitoring, vasopressor, and inotrope selection (Section B). **(A)** Frequency of use of specific haemodynamic monitoring tools (*Q14*). Data are shown as total frequency counts. **(B)** vasopressor preferences for increasing systemic vascular resistance (SVR) (*Q15*). **(C)** Inotrope preferences (*Q16*). Bars reflect how frequently each inotropic agent was chosen across response levels. Stacked bars indicate the distribution of responses categorised as "First choice," "Second choice," "Poor choice," or "Not indicated" for each agent **(B,C)**.

TABLE 3 Survey results - Section C: Indications to extracorporeal support in lung transplant.

Results	N (%) = 9 (100)
Q17 -ECLS planning during bilateral lung transplantation	-
Planned for specific conditions	7 (78)
Routinely used in all cases	2 (22)
Reserved for hemodynamic/respiratory instability	0 (0)
Q18 -ECLS planning during unilateral lung transplantation	-
Planned for specific conditions	2 (22)
Routinely used in all cases	0 (0)
Reserved for hemodynamic/respiratory instability	7 (78)
Q19 -first-line ECLS (for intraoperative assistance)	-
Cardiopulmonary bypass	2 (22)
Central VA ECMO	5 (56)
Peripheral VA ECMO	1 (11)
Hybrid central-peripheral VA ECMO	0 (0)
VAV ECMO	1 (11)
VV ECMO	0 (0)
Q20 -indications for intraoperative VV ECMO (Rank 1–5)	Supplementary Figure S2A
Q21 -indications for intraoperative VA ECMO (Rank 1–5)	Supplementary Figure S2B
Q22 -indications for VAV ECMO (Rank 1–5)	Supplementary Figure S2C
Q23 -intraoperative ECLS anticoagulation protocol	-
UFH(40-100UI/Kg) for ACT 160–220s	7 (78)
UFH single bolus (2500-5000UI), no ACT monitoring	2 (22)
No heparin administered	0 (0)
Q24 -indication for selective support	3 (33)
Before starting surgery	0 (0)
During surgery	6 (67)
Both of the above	
Q25 -if support is selective, how relevant are the following indicators? (Score 1–3)	- Figure 3A
Q26 -selective support: Pulmonary hypertension assessment	-
Predefined cutoff values	0 (0)
PAP >50% of SBP after optimization	3 (33)
Coexistence/emergence of right ventricular dysfunction	6 (67)
Q27 - which factors are assessed in deciding to use extracorporeal support? (Score 1–3)	- Figure 3B
Q28 -RV dysfunction assessment (multiple answers)	-
PAC	6 (67)
TEE	8 (89)
Direct surgical field observation	4 (44)

one (11.1%) did not routinely attempt ECMO weaning in the operating room (*Q34*).

When peripheral ECMO was prolonged postoperatively in the ICU, VA-ECMO was the preferred configuration in 7 (77.8%) centres, whereas 2 (22.2%) preferred conversion to VV-ECMO (*Q35*).

Finally, the preferred weaning strategy was to maintain sedation and invasive mechanical ventilation until ECMO removal (66.7%), rather than pursuing early extubation while continuing ECMO support (33.3%) (*Q37*) (Table 4).

Discussion

This national survey provides a contemporary overview of intraoperative ECLS practices across all nine Italian lung transplant centres. Despite recent international recommendations, substantial variability persists in ECLS selection, cannulation, anticoagulation, postoperative continuation, and weaning. At the same time, the widespread adoption of planned selective VA-ECMO support, use of advanced haemodynamic monitoring, and the integration of

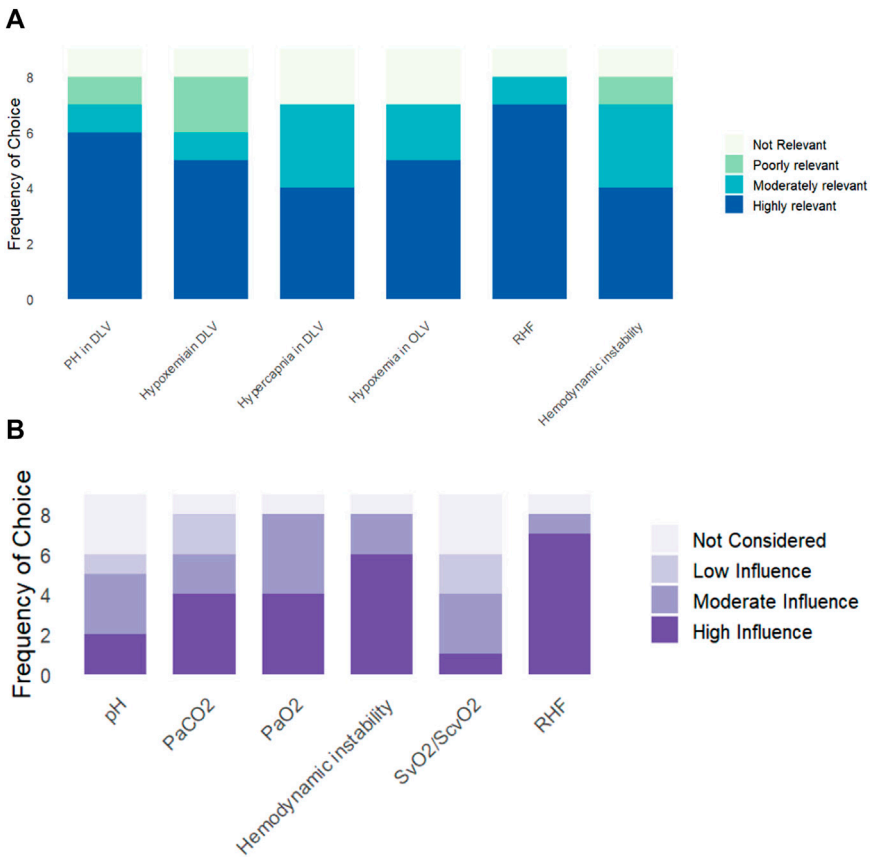


FIGURE 3
Perceived relevance of clinical indicators in support decisions (Section C). Stacked bars show response counts by category; colour intensity reflects increasing relevance or influence. **(A)** Frequency of relevance ratings for indicators used in decisions for selective ECLS support (*Q25*), categorised as Not, Poorly, Moderately, or Highly relevant. **(B)** Influence of clinical factors in deciding to initiate extracorporeal support (*Q27*), rated as Not Considered, Low, Moderate, or High Influence.

multidisciplinary teams, suggest emerging convergence toward individualized extracorporeal support in high-risk recipients.

Annual transplant volume varied substantially across centres, with most centres performing fewer than 30 lung transplants per year, a commonly used threshold for defining a high-volume programme [9]. Despite, previous studies have demonstrated an association between centre volume and post-transplant outcomes, including mortality and hospital readmission rates [9–11], this survey reflects the heterogeneity in structure of the Italian lung transplantation network but was not used to infer differences in ELCS expertise or clinical outcomes (Table 5).

The clamshell incision was the preferred surgical approach in almost all centres, consistent with its widespread use in contemporary bilateral lung transplantation due to the excellent exposure of both pleural cavities provided and the facilitation of central extracorporeal support when required [12, 13]. Bilateral anterolateral thoracotomy, a less invasive approach associated with lower complication rates and faster postoperative recovery [14] was routinely adopted in only one centre.

Regarding team composition, thoracic surgeons represented the primary surgical specialists in most centres (55.6%), while anaesthesiologists frequently had a cardiothoracic subspecialty background (66.7%). Although current international recommendations do not define specific training pathways, they emphasize the importance of multidisciplinary expertise integrating surgical, anaesthetic, perfusion, and intensive care competencies [6].

Haemodynamic monitoring was broadly consistent across centres and with the 2021 international recommendations [4], with pulmonary artery catheterization and TEE widely used for the assessment of ventricular function and for intraoperative decision-making.

NIRS was also frequently used, although its impact on clinically relevant outcomes in this setting remains uncertain [6, 15, 16]. The American Society for Enhanced Recovery and Perioperative Quality Joint Consensus Statement suggests the use of cerebral NIRS monitoring during cardiac surgery to identify acute cerebral malperfusion and support intraoperative management, as well as the implementation of cerebral oximetry-guided intervention algorithms. Nevertheless, these recommendations are supported by low to very low quality evidence [17]. According to a 2018 Cochrane systematic review, the available evidence does not allow firm conclusions regarding the effectiveness of perioperative cerebral NIRS monitoring in preventing early postoperative cognitive dysfunction [18].

Norepinephrine represented the preferred first-line vasopressor in most centres (77.8%), consistent with current recommendations

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TABLE 4 Survey results - Section D: Technical aspects/weaning of extracorporeal support in lung transplant.

Results	N (%) = 9 (100%)
Q29 -peripheral VA-ECMO: Arterial cannulation technique	-
Percutaneous	2 (22)
Surgical cut-down	7 (78)
Interposition graft	0 (0)
Q30 -peripheral VA-ECMO: venous cannulation technique	-
Percutaneous	6 (67)
Surgical	3 (33)
Q31 -distal limb perfusion in peripheral VA-ECMO	-
Always	6 (67)
Never	1 (11)
In selected cases	2 (22)
Q32 -intraoperative VV ECMO, preferred cannulation technique	-
Femoro-femoral	5 (56)
Femoro-jugular	4 (44)
DL jugular cannula	0 (0)
Q33 -peripheral VA ECMO: Access sites	-
Femoral vein and artery	9 (100)
Femoral vein, subclavian artery	0 (0)
Jugular vein, femoral artery	0 (0)
Q34 -at the end of the procedure, is an attempt made to wean the patient off	-
Mechanical support in the operating theatre?	-
Always	3 (33)
Not performed in cases deemed high risk *a priori* or after reperfusion	5 (56)
Never, the patient is always taken to the ICU with peripheral ECMO	1 (11)
Q35 -intraoperative VA/VAV ECMO: Preferred ICU configuration	-
VV ECMO	2(22)
VAV ECMO	0 (0)
VA ECMO	7 (78)
Q36 -prolonged ECMO in ICU: Preferred cannulation technique	-
Hybrid peripheral (percutaneous vein, surgical artery)	2 (22)
Full percutaneous	2 (22)
Full surgical	5 (56)
Q37 –Prolonged ECMO in ICU: weaning strategy	-
Maintain ECMO support and extubate early	3 (33)
Keep patient sedated and intubated until ECMO removal	6 (67)
Q38 -intraoperative ECLS in lung transplant patients	-
<25%	1 (11)
25%–50%	3 (33)
50%–75%	2 (22)
75%	0 (0)
100%, except rare cases	3 (33)
Q39 -would you support specific ECLS training for thoracic/general surgeon?	-
Yes	8 (89)
No	1 (11)

for septic shock [19] and cardiogenic shock [20–22]. Epinephrine and dobutamine emerged as the most frequently selected inotropic agents, in line with the most recent recommendations; whereas levosimendan was reported as first-line inotrope in only one centre, despite the absence of strong recommendation for its routine use in this setting [22, 23].

The main finding of this survey was the predominance of selective planned VA-ECMO during bilateral lung transplantation,

TABLE 5 Types of ECLS performed in lung transplant centres in Italy. The table summarises the responses to questions *Q1, Q17, Q18, Q19, Q34, Q37* and *Q38* in the survey. The centres are listed anonymously in order of caseload.

	Q1	Q17	Q18	Q19	Q34	Q37	Q38
Centre	Annual number of LTx	ECLS planning during bilateral LTx	ECLS planning during unilateral LTx	First-line ECLS	Weaning attempt at the end of surgery	Awake ECMO	Intraoperative ECLS in the last year
1	30–50	Planned for specific conditions	Not planned	Central VA ECMO	Always	Yes	25%–50%
2	30–50	Routine	Planned for specific conditions	Central VA ECMO	Not always	No	100% with exceptions
3	20–30	Planned for specific conditions	Not planned	CPB	Always	Yes	<25%
4	10–20	Planned for specific conditions	Not planned	VAV ECMO	Not always	No	50%–75%
5	10–20	Planned for specific conditions	Not planned	CPB	Not always	No	25%–50%
6	10–20	Planned for specific conditions	Planned for specific conditions	Peripheral VA ECMO	Not always	No	25%–50%
7	10–20	Planned for specific conditions	Not planned	Central VA ECMO	Not always	Yes	50%–75%
8	<10	Routine	Not planned	Central VA ECMO	Never	No	100% with exceptions
9	<10	Planned for specific conditions	Not planned	Central VA ECMO	Always	No	100% with exceptions

List of abbreviations: CPB, cardiopulmonary bypass; ECLS, extracorporeal life support; ECMO, extracorporeal membrane oxygenation; LTx, lung transplantation; VA ECMO, venoarterial extracorporeal membrane oxygenation; VAV ECMO, venoarterial-venous extracorporeal membrane oxygenation.

reported by 77.8% of centres, whereas routine ECLS for all recipients was reported by only two centres. VA-ECMO was preferred over CPB by most centres and central cannulation was more commonly selected than peripheral cannulation. These findings are broadly consistent with recent international consensus recommendations and contemporary North American survey data, which also indicate a growing preference for VA-ECMO over conventional CPB [4, 6–8]. However, current recommendations remain largely based on expert opinion and observational evidence. The present survey therefore describes contemporary institutional practice rather than supporting the superiority of any specific ECLS strategy.

Patient selection for planned intraoperative ECLS remains one of the most debated aspects of lung transplantation. Severe pulmonary hypertension, right ventricular dysfunction, lobar transplantation, re-transplantation, and concomitant cardiac procedures are commonly considered potential indications, whereas intolerance to single-lung ventilation, pulmonary artery clamping, or surgical dissection may lead to unplanned intraoperative ECLS.

Severe pulmonary hypertension as a standalone indication remains controversial. In our survey, t wo-thirds of centres considered pulmonary hypertension an indication for ECLS only when associated with right ventricular dysfunction, highlighting th e importance of integrating pulmonary artery pressures with right ventricular reserve and overall recipient physiology. This supports individualized, multidisciplinary approach to ECLS decision-making rather than reliance on pulmonary pressure thresholds alone (Supplementary Table S2, see Supplementary Material).

The survey further identified RHF and heamodynamic instability ad the main determinant of intraoperative ECLS initiation, with pH, hypoxaemia, and hypercarbia also contributing to decision-making (Figure 3A). These findings reinforce the central role of right ventricular function and heamodynamic tolerance in selecting patients for extracorporeal support | (Figure 3B).

International practice is also evolving toward routine intraoperative ECMO in some programmes. In our survey, two centres reported routine ECLS use (*Q38*). Although published experiences of routine central VA-ECMO suggest potential benefits in selected settings [24], these observations come from highly standardized programmes and cannot be extrapolated to the Italian network as a whole. The present survey does not allow comparison of routine versus selective ECLS strategies.

Technical a spects of ECLS were relatively more homogeneous across centres. TEE and pulmonary artery catheterization were widely used for intraoperative assessment and decision-making, in agreement with contemporary expert recommendations (Supplementary Table S2, see Supplementary Material) [4, 6, 7].

Anticoagulation practices were relatively consistent, with most centres reporting low-dose systemic heparinization and ACT targets of 160–220 s. This approach is within the range reported in contemporary recommendations, although anticoagulation strategies

remain heterogeneous internationally and evidence supporting optimal intraoperative targets is limited (Supplementary Table S1, see Supplementary Material) [6–8].

Peripheral cannulation was generally performed through femoral access, with surgical cut-down preferred for arterial cannulation and distal limb reperfusion routinely used by most centres, consistent with current ELSO technical recommendations [25].

Postoperative continuation and weaning of ECMO remain additional areas of significant variability and remain widely discussed in the literature. Most Italian centres (55.6%) reported maintaining ECLS support postoperatively in selected high-risk recipients, particularly in cases of pulmonary hypertension, right ventricular dysfunction, haemodynamic instability, or early graft dysfunction. This approach is supported by contemporary consensus recommendations (Supplementary Table S1, see Supplementary Material) suggesting that prolonged postoperative mechanical support may facilitate right ventricular remodelling and reduce early graft injury in selected patients (e.g. retransplants, segmental transplants). However, prolonged extracorporeal support also increases exposure to extrapulmonary complications such as vascular, haemorrhagic, infectious, and neurological complications [7, 26, 27].

Despite increasing international interest in awake ECMO and enhanced recovery pathways, most Italian centres (66.7%) still maintain sedation and invasive mechanical ventilation until ECMO removal, indicating these approaches have not yet been widely incorporated into routine practice.

Overall, this survey demonstrates that intraoperative ECLS management during lung transplantation remains characterised by substantial practice variability despite increasing publication of international consensus recommendations.

Limitations and strengths

This survey has several limitations that should be acknowledged. First, although all Italian lung transplant centres participated, the small number of centres precludes formal statistical comparisons and limits extrapolation beyond the Italian setting.

Second, the survey was designed as a descriptive assessment of institutional practices and was not intended to evaluate the efficacy or superiority of specific intraoperative strategies. No patient-level clinical data or postoperative outcomes were collected; therefore the survey cannot determine whether any specific ECLS strategy is associated with improved outcomes.

Third, responses were provided as aggregated institutional answers, which may have masked differences in practice or opinion among clinicians within individual centres.

Finally, the breadth and structure of the questionnaire may have limited the depth with which individual ECLS practices could be characterized, and the rapidly evolving evidence base may result in further changes in practice.

The main strength of the study is its complete national participation, providing a contemporary overview of ECLS practice across the entire Italian lung transplant network. The survey also provides a structured comparison between current institutional practice and recent international recommendations, identifying areas of both convergence and persistent variability. These findings may provide a basis for future multicentre studies incorporating patient-level data and clinical outcomes.

Conclusion

This national survey highlights substantial variability in ECLS management across Italian lung transplant centres, particularly regarding patient selection, cannulation, anticoagulation, and postoperative continuation, and weaning. S elective planned VA-ECMO was the most commonly adopted intraoperative support strategy. These findings provide a contemporary national description of practice and highlight areas in which further patient-level and outcome-based studies are needed to inform future standardisation.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Author contributions

AC: study design, data acquisition and analysis, data interpretation, manuscript writing and revision. DP: study design, data acquisition and analysis, data interpretation, manuscript writing and revision. AL: data analysis and interpretation, manuscript writing and revision. SC: data acquisition and manuscript revision. SN: data acquisition and manuscript revision. FA: data acquisition and manuscript revision. LR: data acquisition and manuscript revision. IR: data acquisition and manuscript revision. AB: data acquisition and manuscript revision. MiS: data acquisition and manuscript revision. McS: data acquisition and manuscript revision. GC: data acquisition and manuscript revision. CP: data acquisition and manuscript revision. AS: data acquisition and manuscript revision. DD: data acquisition and manuscript revision. FV: data acquisition and manuscript revision. LL: data acquisition and manuscript revision. FF: data acquisition and manuscript revision. MB: data acquisition and manuscript revision. MM: data acquisition and manuscript revision. AD: study design, data acquisition and manuscript revision. DB: study design, data acquisition and manuscript revision. All authors have approved the final version of the manuscript to be published and agree to be accountable for all aspects of the work.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontierspartnerships.org/articles/10.3389/ti.2026.17530/full#supplementary-material

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