A synopsis

Extracorporeal life support use in cardiac and circulatory failure: a summary of recently published S3 guidelines

Omer Dzemal[1], Christoph Starck[2], Lukas Wessel[3], Oliver Miera[4], Karl Werdan[5], Marion Burckhardt[6], Ralf Muellenbach[7], Rolf Jaksties[8], Florian Schmidt[9], Karsten Wiebe[10], Christof Schmid[11], Stefan Kluge[12], Kevin Pilarczyk[13], Nils Haake[13], Thomas Schaible[14], Andreas Flemmer[15], Stefan Klotz[16], Alexander Assmann[17], Uwe Janssens[18], Matthias Lubnow[19], Susanne Herber-Jonat[15], Markus Ferrari[20], Dirk Buchwald[21], Stephan Ensminger[22], York Zausig[23], Andreas Beckmann[24], Mark Rosenberg[25], Malte Kelm[26], Marcus Hennersdorf[27], Christiane Hartog[28], Stefan Fischer[29], Ardawan Rastan[30], Daniel Zimpfer[31], Andreas Fründ[32], Sven Maier[33], Elfriede Ruttmann-Ulmer[34], Heinrich Groesdonk[35], Christian Schlensak[36], Monika Nothacker[37], Michael Buerke[38], Harald Köditz[39], Guido Michels[40], Lars Krüger[41], Udo Boeken[17]

[1] Department of Cardiac Surgery, City Hospital of Zurich – Site Triemli, Zurich, Switzerland; [2] German Heart Centre, Department of Cardiothoracic and Vascular Surgery, Berlin, German; [3] Department of Paediatric Surgery, University Hospital Mannheim, Germany; [4] Department of Congenital Heart Disease-Paediatric Cardiology, German Heart Centre Berlin, Germany; [5] Clinic for Internal Medicine III, University Hospital Halle (Saale), Martin-Luther University Halle-Wittenberg, Germany; [6] Department of Health Sciences and Management; Baden-Wuerttemberg Cooperative State University (DHBW), Stuttgart, Germany; [7] Department of Anaesthesiology and Critical Care Medicine, Campus Kassel of the University of Southampton, Kassel, Germany; [8] German Heart Foundation; [9] Department of Paediatric Cardiology and Intensive Care Medicine, Medical School Hannover, Germany; [10] Department of Cardiothoracic Surgery, Münster University Hospital, Münster, Germany; [11] Department of Cardiothoracic Surgery, University Medical Centre Regensburg, Germany; [12] Klinik für Intensivmedizin, Universitätsklinikum Hamburg-Eppendorf, Hamburg, Deutschland; [13]Imland Hospital Rendsburg, Department for Intensive Care Medicine, Rendsburg, Schleswig-Holstein, Germany; [14] Department of Neonatology, University Children's Hospital Mannheim, University of Heidelberg, Mannheim, Germany; [15] Division of Neonatology, Dr. v. Hauner Children's Hospital and Perinatal Centre Munich - Grosshadern, LMU Munich, Germany; [16] Department of Cardiac Surgery, Segeberger Kliniken, Bad Segeberg, Germany; [17]Department of Cardiac Surgery, Heinrich-Heine-University Medical School, Duesseldorf, Germany; [18]Medical Clinic and Medical Intensive Care Medicine, St Antonius Hospital, Eschweiler, Germany; [19]Department of Internal Medicine II, University Hospital Regensburg, Germany; [20] HSK, Clinic of Internal Medicine I, Helios-Kliniken, Wiesbaden, Germany; [21]Department of Cardiothoracic Surgery, University Hospital Bergmannsheil, Ruhr-University, Bochum, Germany; [22] Department of Cardiac and Thoracic Vascular Surgery, University Hospital of Schleswig-Holstein, Lübeck, Germany; [23] Department of Anaesthesiology and Operative Intensive Care Medicine, Aschaffenburg-Alzenau Hospital, Aschaffenburg, Bavaria, Germany; [24] German Society for Thoracic and Cardiovascular Surgery, Langenbeck-Virchow-Haus, Berlin, Germany; [25] Klinikum Aschaffenburg-Alzenau, Medizinische Klinik 1, Aschaffenburg, Germany; [26] Department of Cardiology, Pulmonology and Vascular Medicine, Heinrich-Heine-University Medical School, Duesseldorf, Germany; [27] Department of Cardiology, Pneumology, Angiology and Internal Intensive Care Medicine, SLK-Kliniken Heilbronn, Germany; [28] Department of Anaesthesiology and Operative Intensive Care Medicine, Charité, Humboldt-Universität zu Berlin, and Berlin Institute of Health, Berlin, Germany; [29]Department of Thoracic Surgery and Lung Support, Ibbenbueren General Hospital, Ibbenbueren, Germany; [30] Department of Cardiac and Vascular Thoracic Surgery, Philipps-University Hospital Marburg, Germany; [31]Department of Cardiac Surgery, Medical University of Vienna, Austria; [32] Department of Physiotherapy, Heart- and Diabetes Centre NRW, Ruhr-University, Bochum, Germany; [33] Department of Cardiovascular Surgery, Heart Centre Freiburg University, Freiburg, Germany; [34] Department of Cardiac Surgery, Medical University of Innsbruck, Austria; [35] Department of Intensive Care Medicine, Helios Clinic Erfurt, Germany; [36] Department of Cardio-thoracic and Vascular Surgery, University of Tübingen, Germany; [37] Institute for Medical Knowledge Management, Association of the Scientific Medical Societies (AWMF), Universität Marburg, Germany; [38] Department of Cardiology, Angiology and Internal Intensive Care Medicine, St. Marienkrankenhaus Siegen, Germany; [39] Medical University Children's Hospital, Hannover, Germany; [40] Department of Acute and Emergency Care, St Antonius Hospital Eschweiler, Germany; [41] Division of Thoracic and Cardiovascular Surgery, Heart- and Diabetes Centre NRW, Ruhr-University, Bochum, Germany

Introduction

Extracorporeal life support (ECLS) represents a widely accepted treatment modality for patients with cardiac and/or respiratory failure failing to respond to conventional medical therapy. Through the establishment of a modified cardiopulmonary bypass circuit, ECLS provides a mechanism for temporary cardiac support and gas exchange, allowing patients to recover from existing life-threatening cardiac and/or lung disease. This article summarises the current recommendations for ECLS therapy in adults, which are based on the recently published S3 guidelines entitled "Extracorporeal circulation (ECLS / extracorporeal membrane oxygenation = ECMO), use in cardiac and circulatory failure" (Boeken et al. The Thoracic and Cardiovascular Surgeon. In press).

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Guidelines

A great number of guidelines have been issued in recent years by the association of the scientific medical societies (Arbeitsgemeinschaft der Wissenschaftlichen Medizinischen Fachgesellschaften, AWMF). Medical societies involved in the publication of the current S3 guideline concerning ECLS use in cardiac and circulatory failure are listed in table 1. The level of evidence and the strength of recommendations of ECLS management presented in the current manuscript is high. Detailed description of all S3 guidelines can be found on the AWMF website (www.awmf.org/leitlinien/detail/ll/011-021.html) and were published recently by Boeken and associates (The Thoracic and Cardiovascular Surgeon, in press).

Staffing issues

A multidisciplinary ECLS team should initiate the ECLS (indication and implantation) in adult patients. The implantation should ideally be in an ECLS centre with sufficient expertise by an ECLS team with appropriate skills in terms of implantation [1, 2]. According to the current literature no minimum number of implantations per year can be defined in order to achieve sufficient therapeutic success with the ECLS. However an implantation rate of at least 20 ECLS per year should be aimed for [3–5]. For the ECLS implantation, a standardised procedure adapted to local conditions should be available in written form [6]. For the ECLS initiation, a specific minimum of medical equipment and facilities should be provided [2, 7].

Table 1: Medical societies involved in the publication of current S3 guidelines concerning extracorporeal life support (ECLS) use in cardiac and circulatory failure.

Deutsche Gesellschaft für Thorax-, Herz- und Gefäßchirurgie e.V. (DGTHG)
Deutsche Gesellschaft für Anästhesiologie und Intensivmedizin e.V. (DGAI)
Deutsche Interdisziplinäre Vereinigung für Intensiv- und Notfallmedizin (DIVI)
Deutsche Gesellschaft für Kardiologie - Herz- und Kreislaufforschung e.V. (DGK)
Gesellschaft für Neonatologie und pädiatrische Intensivmedizin e.V. (GNPI)
Deutsche Gesellschaft für Pädiatrische Kardiologie e.V. (DGPK)
Deutsche Gesellschaft für Internistische Intensivmedizin und Notfallmedizin (DGIIN)
Deutsche Gesellschaft für Innere Medizin e.V. (DGIM)
Deutsche Gesellschaft für Kinder- und Jugendmedizin e.V. (DGKJ)
Deutsche Gesellschaft für Kinderchirurgie (DGKCH)
Deutsche Gesellschaft für Thoraxchirurgie (DGT)
Deutsche Gesellschaft für Fachkrankenpflege und Funktionsdienste e. V. (DGF)
Schweizerische Gesellschaft für Herz- und thorakale Gefässchirurgie (SGHC)
Österreichische Gesellschaft für Thorax- und Herzchirurgie (ÖGTHC)
Deutsche Herzstiftung e.V.
Deutscher Verband für Physiotherapie (ZVK)
Akademie für Ethik in der Medizin (AEM)
Deutsche Gesellschaft für Kardiotechnik e.V. (DGfK)

ECLS therapy is to be performed in a centre with a full range of intensive care treatment options in a standardised, multidisciplinary and multimodal approach under the guidance of a specialist experienced in the field of ECLS with an additional qualification in intensive care medicine [2, 8]. Further medical specialists as listed in table 2 should be involved for the management of potential ECLS complications [2, 8].

Table 2: Disciplines that should be available for the management of extracorporeal life support (ECLS) therapy.

	ECLS initiation	ECLS continuation
Cardiac surgery	X	X
Cardiology	X	X
Anaesthesiology	X	X
Intensive care medicine	X	X
Neurology		X
Neurosurgery		X
General surgery		X
Vascular surgery		X
Angiology		X
Radiology		X
Haematology		X
Gastroenterology		X
Nephrology		X
Pulmonology		X
Ethics committee		X

Staff training and continuing education

The processes of initiation, further care, training and employee qualification of the multiprofessional ECLS team should be coordinated by the medical director of the ECLS programme, depending on the institutional structure [2, 7, 8].

A multiprofessional team specially trained in the ECLS therapy process should carry out the multimodal therapy in that field in the intensive care unit (ICU) [7]. Continuing education of the multiprofessional team in the ICU should take place regularly according to a defined internal curriculum. The training requirement depends on the centre-specific ECLS volume and the individual experience of the medical stuff [2].

ECLS circuit and cannulation site

Only centrifugal pumps should be used for ECLS. Heparin-coated components should preferably be used. The selection of the arterial cannulation site should be based on the patient's individual circumstances. In adults, either peripheral (femoral artery) or central (subclavian artery; ascending aorta) cannulation can be performed.

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Patient ICU care and monitoring

Depending on the medical and nursing effort, in the multidisciplinary approach the patient to nurse ratio in the ICU should be determined individually from shift to shift. The patient's individual nursing care in the ICU should be ensured [8]. In addition to medical and nursing treatment, technical checks of the ECLS system should be carried out at least once a day by a perfusionist.

Perfusion, haemodynamics, cardiac unloading, oxygenation, anticoagulation and the functionality of the ECLS system should be continuously monitored in patients on ECLS therapy [6, 9, 10]. (figs 1 and 2). Thus a safety net for early detection of possible complication can be established [11–18].

Every extracorporeal circulation system requires anticoagulation because of contact activation of blood coagulation. Anticoagulation is routinely performed with systemic administration of heparin except in

Parameter	Monitoring interval	Target range
MAP	continuously	>60 mmHg
Arterial pulse curve	continuously	pulsatile
Capillary refill time	1-8 hourly	<3 sec
Extremity perfusion (particularly arterially cannulated extremities)	continuously with NIRS intermittently clinically (once per shift) + 6-hourly with Doppler	similar to contralateral, non-arterially cannulated extremity warm, rosy, detectable pulse
CVP	intermittently as needed	assessment relative to previous values
Cerebral oxygenation	continuously with NIRS	individually different per patient, no significant drops
Diuresis	hourly	>0.5ml/kg bodyweight/h
Venous oxygen saturation	at least 12-hourly	$ScvO_2$≥60% SvO_2≥65%
paO_2	4-hourly	60-90mmHg
SpO_2	continuously	95-98%
Capnography $paCO_2$	continuously 4-hourly	individually, by gap to $paCO_2$
pH	4-hourly	7.35-7.45
Lactate plasma concentration	at least 4-hourly	≤2 mmol/l
ACT	3-hourly (when patient stable, 6-hourly)	160-180 sec
aPTT	4-6 hourly until patient stable, afterwards once-daily	1.5-2 times of reference range
Temperature	continuously (when monitoring intermittent, 4-hourly)	
Echocardiography	once-daily and as needed	
ECG	continuously	no rhythm disturbances, HF >40/min and <120/min

ACT: activated clotting time; aPTT: activated partial thromboplastin time; CVP: central venous pressure; ECG: electrocardiography; HF: heart frequency; MAP: mean arterial pressure; NIRS: near-infrared spectroscopy; paO_2: partial arterial oxygen pressure; $paCO_2$: partial arterial carbon-dioxide pressure; SpO_2: peripheral oxygen saturation; $ScvO_2$: central venous oxygen saturation; SvO_2: mixed venous oxygen saturation.

Figure 1: Patient-related monitoring parameters during extracorporeal life support (ECLS) therapy.

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Parameter	Monitoring interval	Target range
Audiovisual control (tubing, blood-pump, oxygenator)	at least twice-daily	no relevant thrombus formation, no leaks, no abnormal sounds/noises (housing, pump head), no condensed water in gas outlet, no plasma leak, no hemolysis
Control of arterial and venous cannulas	at least twice-daily	correct fixation and position
Electricity and oxygen supply	at least twice-daily	correct electricity and oxygen supply
Oxygenator function	at least once-daily	pressure gradient within manufacturer specifications adequate oxygenation with FiO_2 1.0 O_2/CO_2 transfer similar to previous control D-Dimers low no hyperfibrinolysis "flushing" to remove condensed water
FiO_2: fraction of inspired oxygen.		

Figure 2: Monitoring parameters of the extracorporeal life support (ECLS) system.

cases of heparin-induced thrombocytopenia, where alternative agents such as argatroban, bivalirudin and lepirudin should be used. Coagulation can be monitored with the use of parameters such as partial thromboplastin time (PTT), activated clotting time (ACT), factor Xa or even thromboelastography.

In patients cannulated in a femoral axis, adequate oxygenation should be monitored by measuring the peripheral oxygen saturation in the right upper extremity and through blood gas analysis of blood samples from arteries of the right upper extremity.

A basic clinical-neurological examination should be carried out daily and the pupillary reflex should be checked several times a day.

A basic clinical-neurological examination should be carried out daily and the pupillary reflex should be checked several times a day. Due to the lack of reliable data, no additional apparatus-based method for routine neurological monitoring can be recommended.

In the case of femoral arterial cannulation, a distal perfusion line should be placed to avoid distal limb ischaemia. In the case of peripheral ECLS cannulation, the arterial cannula should be preferably placed contralaterally to the venous cannula.

Management of ventricular distension and central hypoxia

In the case of left ventricular distension, the left ventricle should be actively unloaded after conservative measures have been exhausted. Various techniques have been described for left ventricular unloading, including open surgical placement of a left ventricular vent, percutaneous left atrial venting, transseptal drainage, intra-aortic balloon pump (IABP) and microaxial blood pump placement in the left ventricle. Retrospective studies have shown that the additional use of a microaxial blood pump (Impella®) placed in the left ventricle was associated with a lower 30-day and 1-year mortality compared with the use of ECLS alone without an increase in complication rates. Even though the additional use of Impella during ECLS has shown an improvement in outcomes, further prospective studies should be conducted to confirm the results of the previous retrospective studies [19–21].

Central hypoxia (watershed or Harlequin syndrome) under ECLS therapy with femoral arterial cannulation should be treated immediately after the diagnosis has been established. The following measures are suitable:

- Arterial cannulation of right axillary artery.
- Insertion of another cannula (e.g., via the right internal jugular vein) and change of circuit configuration to veno-arteriovenous (V-AV)

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- Insertion of another venous drainage cannula and change of the configuration to VV-A
- Change from peripheral to central cannulation.

ECLS weaning and explantation

According to the current literature, there is no evidence for levosimendan therapy as part of ECLS weaning [22].
The following criteria should be evaluated before ECLS weaning is initiated according to the standardised protocol:

1. Pulsatile arterial blood pressure and evidence of biventricular contractility on echocardiography
2. Mean arterial blood pressure >60 mm Hg
3. Mixed venous oxygen saturation (SvO_2) ≥65% (central venous oxygen saturation [$ScvO_2$] ≥60%)
4. Lactate values ≤2 mmol/l or falling
5. Vasopressor/inotropic dosage low or falling
6. Sufficient pulmonary oxygenation (Horowitz-index or ratio of arterial oxygen partial pressure (PaO_2 in mmHg) to fraction of inspired oxygen (FiO_2) >200 mm Hg) / CO_2 elimination performance under lung-protective ventilation
7. Compensated end organ functions, especially liver function

In addition, criteria 1–7 should be met with a low ECLS flow (<2.0 l/min) and with a low gas flow (<2 l/min) before ECLS explantation [23, 24]. Pulsatile blood pressure serves as an indication of presence of biventricular contraction, which can be precisely quantified with the help of echocardiography. Furthermore, several retrospective studies have shown that echocardiographic parameters of left and right ventricular function, specifically left ventricular ejection fraction (LVEF), tricuspid annular plane systolic excursion (TAPSE), mitral lateral annular systolic velocity (s'), right ventricle (RV) s' and left ventricular outflow tract (LVOT) velocity time integral (VTI) are predictors of successful weaning from ECLS (25–27). Due to the complexity of the clinical conditions underlying vasopressor/inotropic therapy, it is difficult to define a target vasopressor/inotropic dose, as a prerequisite for initiating ECLS weaning. However, some orientating doses could be <0.1–0.2 µg/kg/min noradrenaline, <0.1–0.2 µg/kg/min adrenaline, <6 µg/kg/min dobutamine and <2.0 mg/h milrinone [28]. Even though the above-mentioned criteria for weaning should be evaluated before initiating weaning from ECLS, further decision to proceed with weaning should be based on the individual judgement of the medical team involved in the patient's treatment and after taking into consideration the patient's general health condition.

During the ECLS weaning process, arterial and central venous blood gas analysis to monitor oxygenation, CO_2 elimination and circulatory function should be performed about 30 minutes after the ECLS blood flow has been reduced [9, 10].
An additional mechanical circulatory support system, such as Impella or IABP, should not be routinely implanted during ongoing ECLS treatment (including weaning) [29–34].
Therapy limitations in ECLS patients should be made as a patient-centered decision with the interprofessional treatment team, taking medical and ethical aspects into account. Such a scenario exists when the desired therapy goal cannot be achieved or the therapy goal is not desired by the patient.
In intensive care patients in the early phase after explantation of an ECLS system, perfusion, haemodynamics (with invasive arterial blood pressure measurement) and oxygenation should be continuously monitored.
Echocardiography should be performed shortly after the ECLS explantation and daily thereafter (early phase after the explantation).
In the early phase after decannulation of a peripherally implanted ECLS system, the cannulation sites should be examined clinically at least once a day.
An ultrasound examination of the cannulated vessels should also be carried out routinely after decannulation.

Normal ward care

As part of the care of patients after ECLS therapy on the normal ward, attention should be given to cardiac deterioration signs and the consequences of cannulation-related complications (infection, thrombosis or ischaemia).

Rehabilitation and follow-up

After ECLS therapy, patients should be rehabilitated in an inpatient setting. Patients should have regular and long-term cardiological follow-up examinations, and depending on the complexity of the underlying disease, in an interdisciplinary special outpatient department.

Omer Dzemali
Heart Centre Triemli
Department of Cardiac Surgery
Birmensdorferstrasse 497
CH-8063 Zürich
omer.dzemali[at]
stadtspital.ch

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