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Extracorporeal membrane oxygenation (ECMO) during the COVID-19 pandemic

This document provides the framework to support provision of ECMO during an escalating pandemic. It should be used to inform local policies and procedures which should be current and reviewed regularly.

Introduction

Extracorporeal membrane oxygenation (ECMO) is an advanced form of life support – targeted at the heart and lungs. It may be indicated in cases of acute severe cardiac or pulmonary failure that is both potentially reversible and unresponsive to conventional management. Usually delivered in an intensive care unit (ICU), there are two main types of ECMO – veno-venous (V-V) and veno-arterial (V-A).

Both types provide respiratory support, but only V-A ECMO provides haemodynamic support. NSW adult patients who require ECMO can currently receive treatment at eight of the 38 tertiary adult ICUs in metropolitan Sydney as well as John Hunter Hospital. Infants and children who require ECMO receive this at the paediatric intensive care units at Children's Hospital, Westmead and Sydney Children's Hospital, Randwick. NSW has a well-established adult ECMO retrieval service which has been operational for more than 10 years, supported by clinicians on a dedicated roster from Royal Prince Alfred and St Vincent's Hospitals. The Kids ECMO Referral Service (KERS) is currently being implemented for paediatric and neonatal ECMO referrals and retrievals in NSW.

Acute respiratory failure is the predominant feature of severe COVID-19. Mortality due to severe COVID-19 associated acute respiratory distress syndrome (ARDS) is similar to severe ARDS from non-COVID-19 causes.[1] As such, V-V ECMO may have a role in the management of these critically ill patients.

In a pandemic, the use of ECMO needs to take into consideration whether ECMO is the best treatment option based on the normal ECMO criterion, the patient's ability to benefit from this modality and current system capacity. In NSW, the decision to initiate ECMO follows a multidisciplinary discussion led by an ECMO intensivist. In neonates and children all ECMO discussions will be conducted through KERS after referral to newborn and paediatric emergency transport service (NETS).

International experience

The World Health Organization currently recommends that patients with ARDS who have refractory hypoxaemia despite optimised conventional management and are in settings with access to expertise in ECMO, should be referred for consideration of ECMO. Significant international (and some smaller Australian) experience exists in the use of V-V ECMO for COVID-19. An international cohort study published by the Lancet in October 2020 looked at data from the Extracorporeal Life Support Organisation (ELSO). The study looked at 1,035 patients from 213 hospitals in 36 countries with confirmed COVID-19 who had ECMO support. At 90 days post ECMO initiation there was a 36% mortality rate whilst 30% were able to be discharged from hospital. A multicentre French study of 302 patients with a median age of 52 revealed 46% of patients were alive at 90 days with a mortality rate of 54%.[2]

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A similar survival rate for COVID-19 and non-COVID-19 respiratory failure patients on V-V ECMO has been demonstrated.[3] The duration on V-V ECMO for COVID-19 patients appears to be six or more days longer than non-COVID-19 V-V ECMO patients. Hospital length of stay is also very long.[4] Similarly good survival has been demonstrated in other health systems.[5]

The overwhelming majority of COVID-19 cases in children do not require hospitalisation and respiratory failure is rare. Nevertheless, ECMO has been used to manage a small number of cases with severe SARS-CoV-2-associated paediatric ARDS in immunocompetent and immunosuppressed older children and adolescents.[6, 7] Children who present with paediatric inflammatory multisystem syndrome temporally related to SARS-CoV-2 (PIMS-TS), are at risk of acutely developing refractory shock with cardiac and coronary dysfunction and may benefit from VA-ECMO in extreme cases.[8]

Considerations during COVID-19 pandemic in NSW

It is important to optimise conventional therapy prior to consideration of ECMO. This includes but is not limited to immunomodulating drugs, neuromuscular blockade, judicious fluid management, optimised lung protective ventilation, appropriate positive end expiratory pressure (PEEP) and most importantly prone ventilation. Hence, ECMO is not recommended as first-line therapy.

ECMO is contraindicated in patients with preexisting conditions which are incompatible with recovery (e.g. severe cardiac or baseline respiratory disease or severe neurological injury, end stage malignancy) with the exception of bridge to transplant for a few patients.

V-V ECMO may be utilised for patients with COVID-19 and severe respiratory failure with expected outcomes comparable to patients supported with V-V ECMO pre-pandemic.[4]

V-A ECMO may be utilised for patients with COVID-19 and severe cardiac failure; however, the experience is more limited, and outcomes are worse than respiratory ECMO.[4]

The usual contraindications to all ECMO apply to the COVID-19 patient group as they do to non-COVID-19 patients.

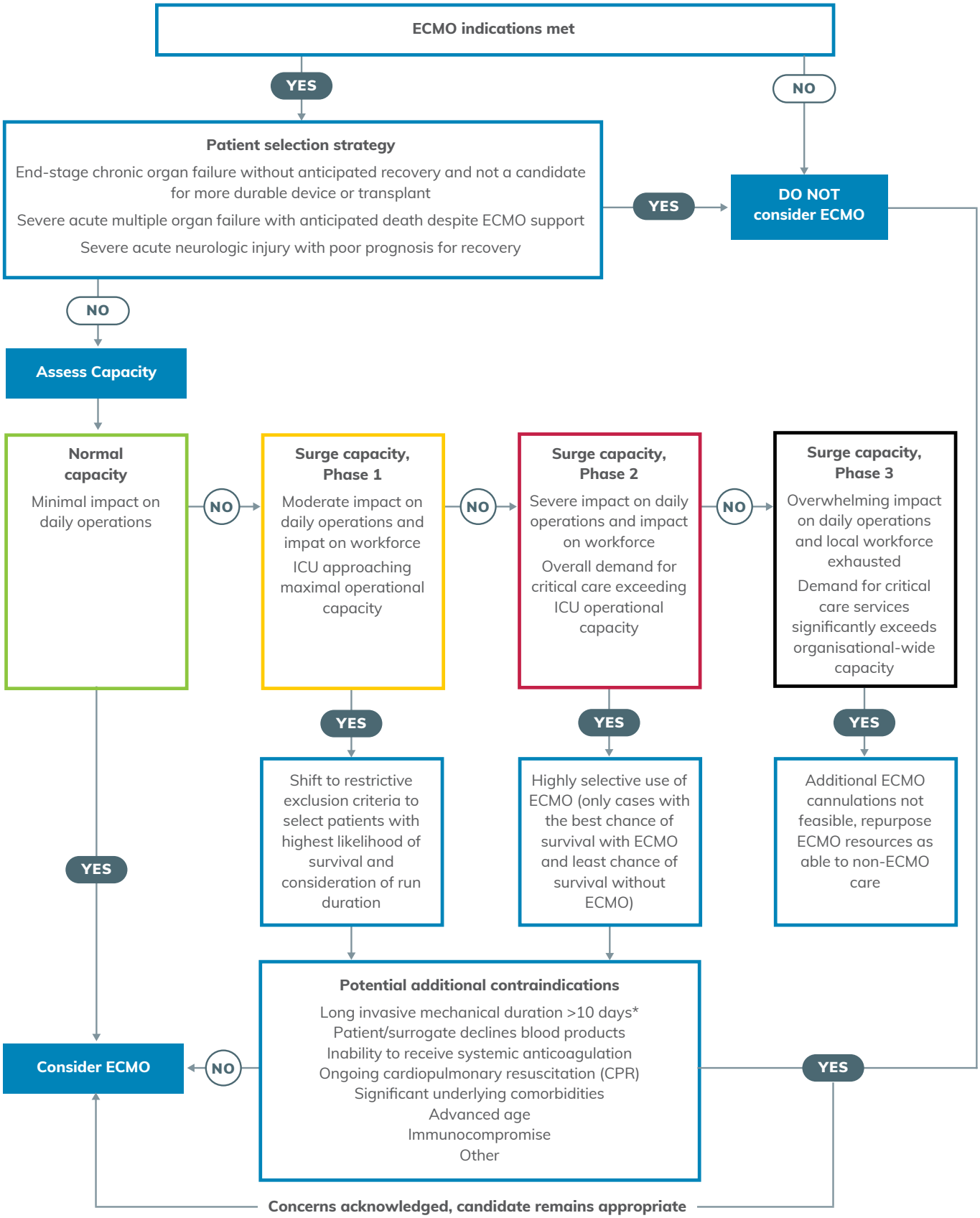
As ECMO is a highly specialised service requiring higher ratios of skilled staff in initiation, maintenance and post treatment phases, its use during a pandemic should be carefully considered:

- Adult patients requiring ECMO may need to be distributed across multiple centres to meet increased demand, so that one or two hospitals are not overwhelmed when skilled staff may be limited.
- Lower volume ECMO-capable hospitals with established resources could manage adult patients on V-V ECMO with support from higher volume centres.
- Any infant, child or adolescent with potential to require V-V or V-A ECMO should be discussed on a case-by-case basis with KERS, via NETS.

Principle: ECMO service when health service is at surge capacity

1. The level of surge contingency within the health system is determined by the NSW Ministry of Health according to phases 1, 2, and 3 of the pandemic short term escalation plan (STEP). [9]
2. The decision to initiate ECMO is based on the ELSO recommendation to provide ECMO during a pandemic, with levels of escalation considered in the context of NSW Pandemic STEP phases.
3. The decision **process** on when to initiate ECMO is based on the preferred model of provision of ECMO care (refer to the *Extracorporeal Membrane Oxygenation for COVID-19: Updated 2021 Guidelines from the Extracorporeal Life Support Organization*).[4]
4. The decision for or against ECMO is based on the likely benefit of the treatment and considers exclusion criteria based on the contingency level (modified Alfred model) for the following cohorts:
    - ARDS secondary to COVID
    - Respiratory failure secondary to other conditions
    - Cardiac indications without ongoing cardiac arrest
    - ECMO during cardiac arrest (ECPR).[10]

Figure 1 (adapted from Badulak et al[4]): Contraindications algorithm for V-A and V-V ECMO use (COVID-19 and non-COVID-19) during a pandemic based on system capacity



* The impact of duration on high-flow nasal cannula and/or noninvasive mechanical ventilation in addition to invasive mechanical ventilation is unknown.

ECMO delivery of care during surge capacity

1. **Adult ECMO centre definitions:**
   - TIER 1 - ECMO referral centre: centre with established ECMO referral and retrieval capacity. Currently Royal Prince Alfred and St Vincent's Hospitals.
   - TIER 2 - ECMO capable centre: experienced in initiating, cannulating and caring for ECMO patients during normal capacity. May require advice or retrieval from ECMO referral centre at times. Currently John Hunter, Liverpool, Prince of Wales, Royal North Shore and Westmead Hospitals.
   - TIER 3 – Severe respiratory failure (SRF) care capable centres: able to deliver SRF care including prone ventilation but not ECMO.
   - TIER 4 - Basic respiratory care hospitals: able to ventilate and provide care during mechanical ventilation but no capacity for proning and other advanced care. All other centres not mentioned above.
2. **Referral models**

Figure 2: Current model for adult ECMO delivery of care in NSW

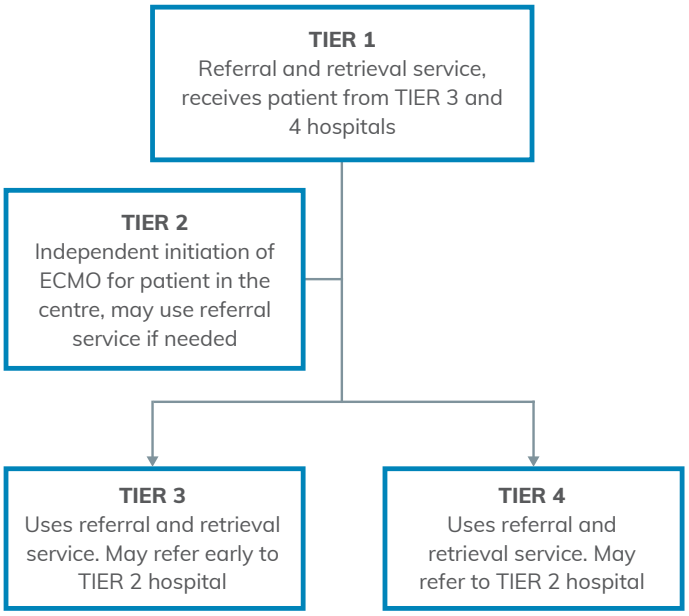
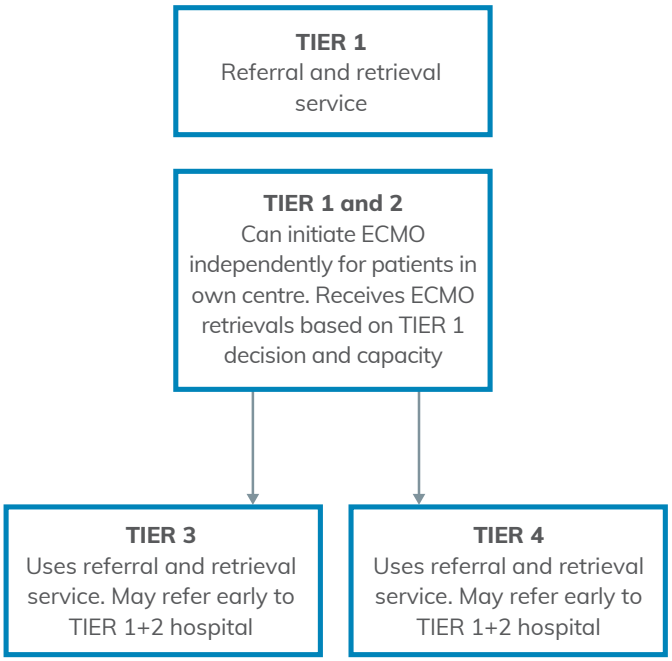


Figure 3: Proposed model for adult ECMO delivery of care in NSW during surge capacity



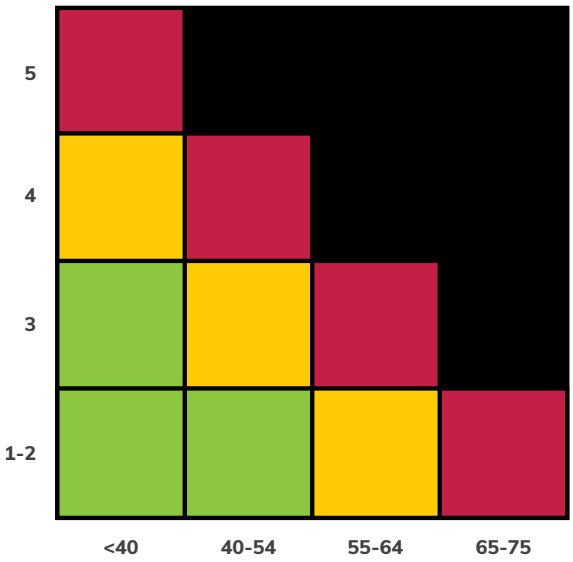
Note, If a TIER 2 centre does not have the resources or capacity to provide ongoing care for the ECMO patient such that a transfer to a TIER 1 centre is anticipated, early discussion with the TIER 1 centre, ideally prior to initiation of ECMO, should occur.

Triggers for consideration of V-V ECMO in adults: when SARS-CoV-2 positive

1. **Hypoxemia** - P:F ratio <100mmHg despite neuromuscular blockade, PEEP optimisation, prone position
2. **Hypercapnia** - $PaCO_2$ >65mmHg and pH <7.25
3. **Failure to maintain lung protective ventilation targets** - VT >8ml/kg or Pplat >30 or severe barotrauma
4. **Significant clinical concern by senior intensive care specialist**

Adult eligibility and expected outcome for V-V ECMO when SARS-CoV-2 positive:

Figure 4: Eligibility chart for V-V ECMO (adapted from Alfred Criteria)[10]



The chart indicates eligibility and expected outcome for V-V ECMO according to patient age and risk score (1-5) which is the diagnostic group 1, 2 or 3 plus presence of acute (+1) and/or chronic modifiers (+1).

GREEN	Good expected outcome
YELLOW	Uncertain expected outcome
RED	Poor expected outcome
BLACK	Negligible benefit

Steps to using chart

Determine diagnostic group (score 1, 2 or 3)

Favourable diagnostic category (Score=1):

Higher likelihood of survival and long-term benefit: should receive ECMO if patients fulfil severity criteria and adequate resources are available. Refer early and prepare for ECMO initiation.

1. Acute severe pneumonitis syndrome features:
    - Severe hypoxaemia refractory to prone ventilation and a trial of high PEEP (>15cm$H_2$0)
    - Rapidly (early after presentation) progressive lung infiltrates (bilateral and symmetrical) typical of ARDS, non-invasive or invasive positive pressure ventilation for <7days
    - Poor pulmonary compliance (dynamic compliance TV/(PIP-PEEP) <20ml/cmH_2O).
2. Acute severe pneumonitis syndrome with early severe acute right heart failure.

High risk diagnostic category (Score=2)

Uncertain outcome benefit following the application of ECMO: application of ECMO in this group should only occur following detailed patient assessment and discussion with a senior panel of ECMO consultants. Application of ECMO will depend on specific patient and disease factors and ECMO capacity.

1. Any of the following ventilatory challenges after more than 14 days in hospital with persistent infiltrates and concern about ventilator or patient induced lung injury:
    - Static compliance <20ml/cmH_2O (need to paralyse and test plateau pressure, dynamic compliance may overestimate)
    - Requiring neuromuscular blockade (infusion or recurrent boluses, e.g. for pCO_2 control)
    - Patient ventilator dyssynchrony
    - Barotrauma as a result of mechanical ventilation (MV).
2. Acute circulatory and respiratory failure with features of distributive or cardiogenic shock prior to established multiorgan failure and high lactate.
3. Secondary bacterial superinfection following pneumonitis/ARDS with asymmetrical lung disease.

Unfavourable diagnostic category (Score=3)

Low likelihood of patient benefit with the application of ECMO: application of ECMO where these processes are present should be avoided. Application of ECMO on compassionate grounds MUST involve a senior panel consensus.

1. More than 14 days of ventilation.
2. Severe acute circulatory and respiratory failure with established organ failures.
3. Prolonged MV cases with severe comorbidities or immunosuppression.
4. ECPR cases.

1. Add Clinical modifier

Increase score by one for the presence of chronic or acute modifiers.

If both acute and chronic modifiers are present increase score by two.

Chronic (comorbidities) – one or more present add one to score (Score+1)

- Peripheral vascular disease (symptomatic, revascularised or amputation)
- Previously known ischaemic heart disease or prior revascularisation
- Moderate or worse COPD (GOLD Stage II, FEV1 50-80%)
- Chronic renal failure stage 3 or 4 CKD (eGFR 60-15)
- Chronic liver disease (Child-Pugh B or C)
- Long term immunosuppression.

Acute clinical condition – one or more present add one to score (Score+1)

- Lactate ≥5
- Noradrenaline ≥0.3mcg/kg/min
- Ischaemic hepatitis defined by AST or ALT >1000
- Anuria >4 hours.

2. Absolute contraindication

Lung disease

- Severe chronic lung disease (with exception of bridge to transplant in specific disease conditions)
- Acute or subacute pulmonary fibrosis is the likely cause of respiratory failure
- Previous known and/or treated systemic lupus erythematous, extra-articular rheumatoid arthritis, scleroderma, dermatomyositis, sarcoidosis
- Clinical course or pathological investigations suggestive of irreversible process (e.g. bleomycin lung injury)
- Obliterative bronchiolitis is the likely cause of respiratory failure*
- Graft versus host lung disease.

*Severe acute restrictive lung disease with relatively clear CXR (early) is suggestive of cryptogenic organising pneumonia (bronchiolitis obliterans with organising pneumonia) and biopsy should be performed prior to instituting ECMO to distinguish from obliterative bronchiolitis.

Patient profile

- Age >75
- Previous bone marrow transplant
- Terminal illness or non-treatable malignancy
- Liver cirrhosis Child-Pugh B or C or jaundice/ascites/encephalopathy
- Severe brain injury
- Severe cardiac disease, cardiomyopathy (on ventricular assist device (VAD) or inotropes)
- Chronic renal failure – chronic kidney disease (CKD) 5 or on dialysis
- ECMO initiation would not be in keeping with known patient wishes or that of the patient's medical treatment decision maker (MTDM)
- Frailty score 5 or above.

Acute condition

- Pulmonary oedema due to left ventricular failure (LVF) – consider V-A ECMO
- Septic shock with hypoxia predominant presentation rather than pulmonary infiltrates
- Advanced microcirculatory failure with severe mottling or established purpura.

Recommendation

- The decision to initiate ECMO is on a case-by-case basis. In the setting of the current COVID-19 pandemic, the criteria listed above should be used by a multidisciplinary team which should include two ECMO specialists and possibly others from relevant specialities.
- In the case of newborns and children state referrals should be made to KERS via NETS.
- ECMO is a resource intensive therapy and preparation for geographical regional surges of patients with COVID-19 should be considered. The ECMO Advisory Group should meet frequently to review ECMO activity during the pandemic.

Glossary

ARDS	Associated acute respiratory distress syndrome
CKD	Chronic kidney disease
ECMO	Extracorporeal membrane oxygenation
ECPR	ECMO during cardiac arrest
ELSO	Extracorporeal Life Support Organisation
KERS	Kids ECMO Referral Service
LVF	Left ventricular failure
MV	Mechanical ventilation
MTDM	Medical treatment decision maker
NETS	Newborn and paediatric emergency transport service
PEEP	Positive end expiratory pressure
SRF	State referral facility
STEP	Short Term Escalation Plan
V-A	Veno-arterial
VAD	Ventricular assist device
V-V	Veno-venous

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