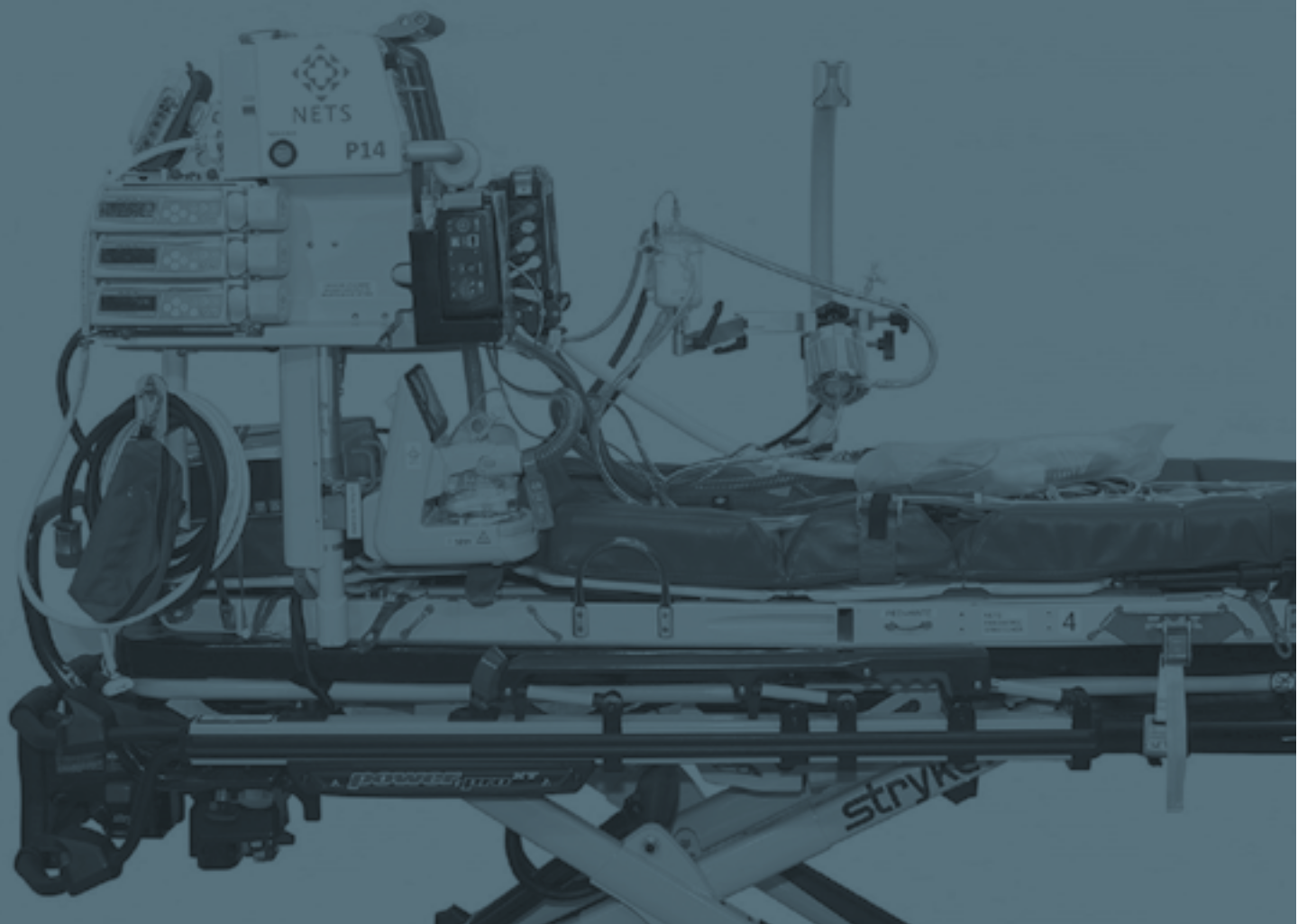


ECMO (extracorporeal membrane oxygenation) retrieval services in NSW

Neonatal and paediatric patients

NOVEMBER 2020



NSW ECMO model of care, at a glance



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There are three types of transfers

1. Transfer for ECMO
2. Cannulating at referring site and transferring on ECMO (primary transport)
3. On ECMO and transferring to another ECMO site (secondary transport)

Summary

Extracorporeal membrane oxygenation (ECMO) is an advanced form of life support – focused on the heart and lungs. Usually delivered in an intensive care setting, there are two main types of ECMO – venovenous and venoarterial. Both provide respiratory support, but only venoarterial ECMO provides haemodynamic support.

In neonatal and paediatric care, ECMO is a low-volume, specialist service, generally consolidated into a specialist high-volume centre. This means that retrieval, or transport to the specialist service is an important component of care. Retrieval is a multi-stage process that comprises care at the referring hospital to guide the decisions to initiate ECMO and preparation and management of the patient awaiting transfer, the organisation and dispatch of appropriate personnel and equipment to the referring hospital, and transport back to the specialist centre.

Currently in NSW, there is no dedicated neonatal and paediatric ECMO retrieval program. ECMO retrievals rely on Newborn and Paediatric Emergency Transport Services NSW (NETS), specialist staff and equipment, organised on a case-by-case basis.

The organisational model of care has been informed by a rapid review of the peer reviewed and grey literature; and consultation with the clinical community in NSW.

The model incorporates three main elements.

1. An ECMO capable site – in NSW, this is a tertiary referral network on two sites with a paediatric intensive care unit (PICU), evidence informed policies and procedures, multidisciplinary teams, robust supervision and training regimens, and quality assurance processes.
2. A retrieval service – in NSW, the Newborn and Paediatric Emergency Transport Service (NETS) coordinates transfers to the specialist centre from non-ECMO referral sites and has the ability to cater for patients of varying age, size and complexity.
3. Referring sites from around the state initiate consultations, optimise pre-retrieval patient care, prepare documentation and investigations for handover.

As current numbers of patients requiring ECMO are small, the establishment of a paediatric ECMO retrieval service would require consideration of staging of any proposed models. Standardising equipment across hospitals and services is essential. The establishment of an on-call roster for specialised advice from a paediatric ECMO consultant and the ready availability of a medical officer able to cannulate would also be essential components of an early model.

The organisational model of care for neonatal and paediatric ECMO retrievals focuses on eight key components.

- **Operationalising retrievals**
The organisational structure to provide access to appropriate paediatric ECMO services for the entire state.
- **Communication and decision making**
Clear consistent processes guiding decisions for eligibility and appropriateness of ECMO for neonates and paediatric patients.
- **Checklists and protocols**
To guide- retrieval logistics and patient preparation, necessary equipment, consumables, safety checks and handovers.
- **Team composition**
Key decision-makers and roles and responsibilities in ECMO-capable sites, retrieval teams and referral sites.
- **Data and information**
Measures of patient outcomes, patient and family experience, service effectiveness and efficiency used to guide ongoing improvement efforts.
- **Education and training**
Regular, specialised training and continuing education ensure high quality life support is delivered by local and specialist clinicians.
- **Governance**
Framework of ECMO program scope, accountabilities, interdependencies and delivery.
- **Patient, family and carer support**
Clear, proportionate and compassionate information and care provided throughout the ECMO process.

ECMO retrieval for neonatal and paediatric patients

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Introduction

Extracorporeal membrane oxygenation (ECMO) provides temporary life-support for:

- critically ill patients who have reversible acute respiratory or cardiac failure that is not responding to conventional treatments, or
- patients who require a 'bridge' to transplantation.

ECMO is a high-risk, low-volume, specialist service. This means that retrieval or transport of eligible patients to a specialist centre is an important component of care.

Retrieval is a multi-stage process which comprises care at the referring hospital to guide the decisions to initiate ECMO and preparation and management of the patient awaiting transfer, the organisation and dispatch of appropriate personnel and equipment to the referring hospital, and transport back to the specialist centre.

In NSW, ECMO for neonatal or paediatric patients has been provided at two hospitals with an ad hoc retrieval service. It is available for post cardiac surgery for neonates (greater than 2kg and 34–36 weeks gestation) and paediatric patients (children aged up to 16 years).

In 2018–19, 27 paediatric patients underwent ECMO in NSW. In terms of retrievals, there were 11 paediatric or neonatal patients transferred on ECMO over the five year period 2015–2019, noting that there has been an increase in ECMO cases in the 2019–2020 period since our original review. The number of children who were transferred early and received optimised, conventional treatment and were considered for ECMO, cannot be determined.

Currently in NSW, there is no dedicated neonate and paediatric ECMO retrieval program. ECMO retrievals rely on Newborn and Paediatric Emergency Transport Services NSW (NETS), specialist staff and equipment, organised on a case-by-case basis.

Internationally, centres that perform at least 20–30 annual ECMO neonate or paediatric patient runs do significantly better than the low-volume centres (five or fewer runs per year). Most systems use a hub and spoke model where the 'hub' is a high-volume centre and the spokes are low-volume centres, which have the capability to commence ECMO and support an eligible patient for hours or days, until they can be transferred to the high-volume centre by a mobile ECMO team.¹

The model of care outlined in this document has been developed to support the delivery of high-quality ECMO retrieval services. It focuses on eight key components.

- Operationalising retrievals
- Communication and decision making re eligibility
- Checklists and protocols
- Team composition
- Data and information
- Education and training
- Governance
- Patient, family and carer support.

This model of care has been informed by a rapid review of the peer reviewed and grey literature; and consultation with the clinical community in NSW.

Operationalising retrievals

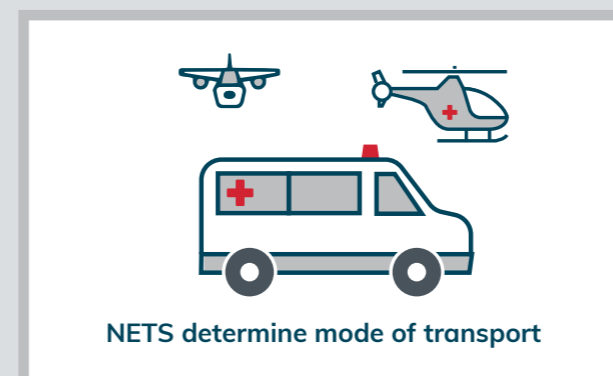
The model of care is centred on one tertiary referral centre (or network) with a paediatric intensive care unit (PICU), where appropriate policy and procedures,

supervision, training, and quality assurance processes are all in place.²



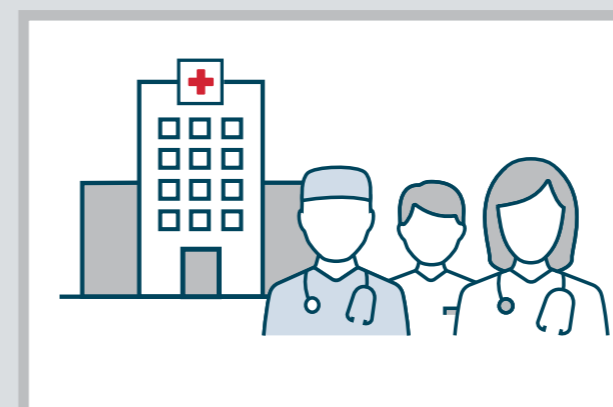
REFERRAL SITES

- Communication, coordination, initial consultation with NETS and ECMO specialist for advice and decision making
- Pre-ECMO management
- Arrange investigations and blood products
- Handover.



RETRIEVAL

- Equipment in appropriate size
- Consumables and medications – sufficient for retrieval
- Conversation between sites
- Provide referral site with list of requirements
- Education and training.



NSW ECMO CAPABLE CENTRE

- Multidisciplinary teams
- Maintenance of equipment
- Data and information
- Education and training
- Governance.

Communication and decision making

International guidance recommends that any decision to initiate ECMO is made on a case-by-case basis by an ECMO (intensive care) specialist in conjunction with clinicians from the referring hospitals, as well as retrieval services. A conference call is the crucial first step.

NETS coordinates the call, confirms that the patient meets the referral criteria, and links the call to an ECMO specialist consultant. The specialist consultant, in collaboration with the staff on a conference call, provides the final decision about whether to deploy the ECMO team or transfer to an ECMO capable centre on conventional therapy.

There are three key decisions:

- Is ECMO appropriate?
- When should ECMO be commenced?
- Where should ECMO be commenced?

Best practice is to seek early referral advice from NETS regarding the utility of ECMO for deteriorating patients. For adult-sized children, NETS to liaise and collaborate with adult ECMO transport services.

The types of indications for neonatal and paediatric ECMO internationally are summarised in Table 1.³

Table 1: International indications for neonatal and paediatric ECMO

Indications	Neonate	Paediatric
Cardiac	Congenital defect <ul style="list-style-type: none"> • Total anomalous pulmonary venous return (TAPVR) • Hypoplastic left heart syndrome • Left ventricular outflow obstruction • Right ventricular outflow obstruction • Septal defects • Cardiomyopathy (bridge to recovery, transplant or long term mechanical circulatory support) • Myocarditis 	Congenital defect <ul style="list-style-type: none"> • Left ventricular outflow obstruction • Right ventricular outflow obstruction • Septal defects • Cardiomyopathy (bridge to recovery, transplant or long term mechanical circulatory support) • Myocarditis
Respiratory	<ul style="list-style-type: none"> • Meconium aspiration syndrome (MAS) • Persistent pulmonary hypertension of newborn/persistent fetal circulation • Respiratory distress syndrome • Congenital diaphragmatic hernia • Pneumonia (viral/bacterial/aspiration) • Sepsis 	<ul style="list-style-type: none"> • Pneumonia (viral/bacterial/aspiration) • Acquired respiratory distress syndrome
Other indications at any age		
<ul style="list-style-type: none"> • Sepsis • Anaphylaxis • Cardiac arrest from any cause 	Elective periprocedural support <ul style="list-style-type: none"> • During lung transplantation or tracheal surgery • Air leak syndrome • Failure to wean from cardiopulmonary bypass 	
Transplantation		
<ul style="list-style-type: none"> • Pre-transplantation as bridge to transplant • Primary graft dysfunction after heart or lung transplant 		

Contraindications

Contraindications to ECMO are pre-existing conditions which are incompatible with recovery (such as severe neurologic injury and end-stage malignancy).^{4,5}

Referral pathways

There are three types of transfers:

- transfer for optimising conventional care and consideration of ECMO

- cannulating at referring site and transferring for ECMO (known as primary transport)
- on ECMO and transferring to another ECMO site (known as secondary transport).

Transfers occur along one of three referral pathways:

- intra-campus pathway where PICUs and NICUs are co-located
- tertiary referral pathway (via NSW retrieval service)
- intrastate, interstate and international referral pathway.

The patient selection criteria for ECMO retrieval is summarised in Table 2.⁶

Table 2: Patient selection criteria for ECMO retrieval

1. Refractory hypoxemia and hypercapnia (failure of mechanical ventilator support)
I. Unacceptable risk of deterioration during conventional transport in the best clinical judgment of managing physicians.
II. Inability to maintain acceptable oxygenation and ventilation without high frequency oscillatory ventilation. Although high frequency modes of ventilation during transport are possible in select patient populations, transport on high frequency oscillation ventilation is not currently feasible.
III. Dependence upon inhaled nitric oxide (iNO) in the treatment of hypoxemic respiratory failure is not an absolute contraindication to conventional transport, as iNO can be safely administered during transport.
IV. Presence of air leak syndrome(s) likely to worsen with continued high levels of positive airway pressure and altitude.
2. Refractory septic and/or cardiogenic shock despite aggressive inotropic and pressor support
I. ECMO support for refractory septic shock may be considered as an indication for ECMO transport, primarily in neonatal and paediatric patients.
II. Degree of pre-transport hypoperfusion, hypotension and acidosis coupled with risk of further deterioration during transport. The expected duration of transport must be considered.
3. Specific clinical scenarios which may necessitate ECMO transport
I. Refractory respiratory failure at a centre not capable of providing ECMO.
II. ECMO support initiated at referring centre for primary cardiac failure and patient needs transport to a transplant centre for evaluation for possible heart transplantation or other cardiac intervention.
III. Patient who is a possible candidate for lung transplantation requires ECMO for safe transfer to a transplant centre.
IV. Patient placed emergently and unexpectedly on ECMO support at a centre without resources to maintain the patient on long-term ECMO support.

Source: ELSO patient transfer guidelines.⁶

Table 3: Specific neonate and paediatric ECMO criteria⁴

Neonate	Paediatric
<p>Any neonate greater than 2kg, 34 – 36 weeks and up to 28 days or older, managed in a neonatal intensive care unit or in the Sydney Children's Hospital Network.</p> <ul style="list-style-type: none"> Oxygenation index >40 for >4 hours. Severe hypoxic respiratory failure with acute decompensation (PaO₂ <40mmHg) unresponsive to intervention. Prolonged acidosis <ul style="list-style-type: none"> Ph <7.25 for 2 hours. Pressor resistant hypotension. 	<p>Any patient under 16 years of age who is not in a neonatal intensive care unit.</p> <ul style="list-style-type: none"> Marginal or inadequate gas exchange at risk of ventilator-induced lung injury and those that fail invasive therapy within the first 7 days of mechanical ventilation with high levels of support. Severe respiratory failure as evidenced by sustained PaO₂/FiO₂ ratios <60-80 or OI>40 for 2 hours where changes are happening rapidly and maximum therapy has been reached at your hospital. Elevated ventilator pressures (eg mean airway pressure >20-25 on conventional ventilation or >30 on HFOV or evidence of iatrogenic barotrauma). Hypercapnia respiratory failure – severe, sustained respiratory acidosis (pH <7.1) despite appropriate ventilator and patient management. Hypotension or shock refractory to maximal therapy at your institution including inotropic and vasoactive support. Low cardiac output with: <ul style="list-style-type: none"> evidence of inadequate end organ perfusion despite medical support: persistent oliguria, diminished peripheral pulses mixed venous or superior vena cava central venous (for single ventricle patients) oxygen saturation <50% despite maximal medical management persistent lactate >4.0 and persistent upward trend despite optimisation of volume status and maximal medical management.

Policies and procedures

The model ensures patients receive appropriate care from clinicians who are supported by standardised protocols and procedures. This section outlines four key checklists for pre-retrieval care; retrieval equipment; retrieval consumables and safety checks; and handover protocols.

Pre-retrieval: logistic and clinical preparation

	Referring site	Receiving ECMO site	Retrieval team/ NETS
LOGISTIC PREPARATION			
Conference call establishes management and coordination plans	●	●	●
Key support and authorisation bodies are engaged and alerted, as required <ul style="list-style-type: none"> Blood bank, theatre, ICU, bed managers NETS regarding mode of transport and paediatric support in remote locations Families and carers. 	●		●
Emergency contingency plans are established and reviewed: <ul style="list-style-type: none"> sufficient supplies for the retrieval protocols for emergencies (e.g. mass air entrainment, pump head failure, accidental decannulation, bleeding). 			●
'Time out' to review plans is conducted prior to departure			●
Checklists of equipment and drugs are completed and filed		●	●
CLINICAL PREPARATION			
Management of patients awaiting ECMO guided by an ECMO specialist consultant from a ECMO capable site.	●	●	
If the referring site has capability to cannulate, ECMO can be initiated prior to arrival of retrieval team (if protocol is in place).	●		
In the event of ECMO emergency, clinical responsibilities are clearly delineated in terms of: <ul style="list-style-type: none"> resuscitation, ensuring ventilation is intact commencing adrenaline infusion and bolus fluid as necessary perfusionist troubleshooting of the circuit in cardiac arrest, advanced life support is delivered. 	●	●	●

Retrieval equipment

	Referring site	Receiving ECMO site	Retrieval team/ NETS
MINIMUM COMPONENTS FOR MOBILE ECMO			
Suitable blood pump and centrifugal pump (in appropriate size for patient)			●
Membrane oxygenator, appropriate for the patient size			●
Device(s) for heating and regulating circuit blood temperature			●
Medical gas tanks, regulators, hoses, connectors, flow meters, and blenders for provision and adjustment of blended sweep gas to the oxygenator			●
Venous and arterial pressure monitoring device(s), according to centre-specific practices			●
Point-of-care anticoagulation monitoring equipment (e.g. Activated Clotting Time)			●
Uninterruptable power source(s) capable of meeting the power needs of equipment during transfer between vehicles and in the event of vehicle power source failure			●
An emergency pump or manual control mechanism in the event of primary pump failure or power failure			●
Portable ultrasound machine*	●		●
When retrieval team cannulates, consider additional transport.			●

Adapted from ELSO Patient Transfer Guidelines⁶

Equipment is stored and replenished at the ECMO capable centres that provide support to the retrieval team. A checklist is used to ensure that the emergency equipment rescue kit, console and drive-unit, and blood products are available and appropriate.

The checklist should be completed by two team members before departure and the total weight is known to assist aviation planning. Medical equipment used in ECMO retrieval is the same as

that used in hospital ECMO treatment and should be standardised across the ECMO capable centres.⁷ If not, standardised consideration of the differences need to be planned for to mitigate the risk. Equipment should be integrated into ambulance and air-ambulance configurations, be field and flight-tested in order to ensure compliance with WH&S and Civil Aviation Safety Authority (CASA) regulations.*

* Where portable ultrasound is not available, coordination with the medical imaging department may be required.

Handovers

	Referring site	Receiving ECMO site	Retrieval team/ NETS
HANDOVER FROM REFERRING HOSPITAL TO RETRIEVAL TEAM			
Handover at the referring hospital includes the senior medical and nursing staff that have been caring for the infant/child, to follow the principles of ISBAR – identify, situation, background, assessment and recommendations. Handover should include key clinical information, both verbal and documented, to ensure safe continuity of care.	●		●
HANDOVER FROM RETRIEVAL TEAM TO ECMO CAPABLE CENTRE			
The patient arrives at the ECMO capable paediatric intensive care unit (PICU) and handover commences while maintaining ECMO connection.		●	●
Clear corridors and egress for easy movement of the team.		●	
Connection to haemodynamic monitoring and ECMO gas and power.		●	
Retrieval intensivist handover to medical and nursing intensive care team covers <ul style="list-style-type: none"> team introductions equipment plan patient's diagnosis, condition and management. 		●	●

Note: no protocol is included here for maintenance or weaning as this is a retrieval model of care.

Team composition, roles and responsibilities

ECMO relies on a multidisciplinary team in referral sites and ECMO capable centres. The roles and responsibilities of team members require clear definition in a coordinated service.

In developing a retrieval service, when the anticipated number of patients are small, circumstances should be assessed to determine the staffing requirements on a case-by-case basis. The referral process should occur as early as possible so the transfer of patients on ECMO or those who require establishment of ECMO prior to transfer is kept to a minimum. Standardisation of equipment should be a priority to ensure that when a patient requires transfer from one facility to another, the equipment used is the same.

The retrieval team composition outlined in this document details the potential roles and responsibilities of a full team. As a statewide service is being developed, an emphasis is being placed on early ECMO referral and assessment, such that if a patient transfer is required, it will occur early. Integral to timely assessment and advice provision to clinicians looking after critically ill children include the establishment of an on-call paediatric ECMO consultant roster to support advice through NETS, and a medical officer readily available to cannulate patients requiring ECMO support.

REFERRING SITE TEAM

Referral sites consult the retrieval service (NETS) for all neonatal and paediatric patients. For patients who are eligible for ECMO, NETS will consult with the ECMO specialist, who makes decisions for ECMO. NETS will coordinate a conference call between the referring site and receiving site. Referrals that are intra-campus or co-located should follow site policies and NETS may not be required.

Referring site team will undertake the following

- Ensures the child's safety is considered at all times with regard to transfer decisions
- Assesses and determine the need for transfer of a child to a higher level of care, in consultation with the local or network paediatric intensivist at the receiving hospital
- Ensure a full explanation is given to parent/carer and patient (age appropriate)
- The physical and emotional wellbeing of the child is paramount at all times and staff should never feel obliged to keep paediatric patients because of pressure from carers or others when the child's clinical needs or if safe conditions cannot be met⁸
- Informs the parent or carer and obtains consent as the child is critically ill and unable to provide consent
- Consults with NETS and relevant senior clinicians at the destination hospital and make arrangements for the appropriate timing of transfer
- Agrees time-frames, departure goals, and plans for any change in patient's condition
- Documents agreed treatment plan while awaiting transfer, and communicates this to nursing staff
- Ensures that the destination hospital has full details of the child's medical condition and requirements
- At the time of transfer, documents any treatment not commenced or incomplete with respect to the agreed treatment plan⁸
- Ensure full patient record accompanies the child during transfer, including relevant x-rays scans and pathology
- Inform nursing staff at destination hospital of departure time and estimated arrival time
- Provide a documented discharge/transfer summary to the destination nursing staff
- If the ECMO team decides that cannulation is required at the referring site prior to retrieval, then the referring site must ensure a large and safe location is obtained. The retrieval team will bring the cannulas if the site is not an ECMO capable hospital
- The retrieval of any critically ill neonatal or paediatric patient can be a stressful event, staff involved should attend a hot and/or cold debrief of the event and be provided with wellbeing support if required.

RETRIEVAL TEAM

Requires advanced skills in patient assessment, cannulation, priming the ECMO circuit, initiating ECMO, and managing patients on ECMO. The retrieval team provides the referring hospital with a list of requirements once ECMO retrieval has been agreed.⁴ If the referring hospital has the resource capability, skilled personnel that have been trained to cannulate and initiate ECMO, this should be performed prior to the arrival of the retrieval team.⁶

While awaiting transfer, the child's condition should be continually monitored and reevaluated. NETS should receive up-to-date assessments, providing ongoing coordination and communication while the retrieval team are enroute.

ECMO specialist consultant

- An intensivist with ECMO experience provides medical management advice, including threshold for ECMO
- In collaboration with the staff in the conference call, makes decision to deploy mobile ECMO team or attempt transfer to an ECMO capable centre on conventional therapy
- Assesses patient, reviews laboratory data, radiographs and other clinical data
- Informs patient/family/carer and obtains informed consent for ECMO support and for transport
- Assumes medical management of the patient during cannulation, including provision of further deep sedation during cannula placement and administration of a heparin bolus
- Manages ventilator
- Checks cannula positions with ultrasound and/or radiograph.

Nurse retrieval specialist

- Assumes nursing management of the patient
- Manages equipment, medication delivery and monitoring
- Provides direction with specific governmental regulations regarding the operation of devices in an aircraft.

Perfusionist

- Management of the patient
- Primes the circuit
- Maintains ECMO circuit, monitoring and troubleshooting.

Cannulating medical officer

- Cannulation and checks cannula positions with ultrasound and/or radiograph.

Availability

- Retrieval is a 24/7 service.
- Experienced retrieval teams are required to attend ECMO calls as part of their roles and responsibility.

Stress and fatigue

- Long distance transports represent a unique level of complexity, coordination and personnel demand.
- The potential for physiological stress and fatigue should not be underestimated.
- Retrieval staff should be supported to be well-rested before and after a long distance transport.

RECEIVING ECMO SITE**Admitting intensive care**

- Ensure the child's safety at all times with regard to transfer decisions.
- Undertakes patient assessment via phone or telemedicine and document the findings, using standardised assessment tool.
- Provide advice and assistance to the referring medical officer and relevant clinicians to ensure that the interhospital transfer is appropriate.
- Provide ongoing support to the referring hospital until the transfer occurs.
- Provide feedback about the retrieval/transfer to the referring facility and a discharge summary to the referring doctor, the child's general practitioner and allied health and community health staff where relevant.
- Receiving hospitals should provide feedback and patient outcome information on request to the transporting retrieval service.⁸

Data and monitoring

Measurement will occur across the dimensions of:

- outcomes (clinical and patient, parent and carer reported)
- experience (patient, carer and clinician)
- effectiveness and efficiency. This includes considerations of appropriateness, impact, sustainability, access and reach, and quality and safety
- measure adverse events and system problems using multiple modalities
- follow up of the ECMO patient
- routine debrief and review.

Measurements will include the following:

- high quality data are routinely collected and used to ensure patient safety and quality improvement (all referrals even if patient does not go onto ECMO)
- establish network M&M (mortality and morbidity) review process
- definition of minimum data set required
- data collected by ELSO, ANZICS and ANZPIC
- collect data for the neonatal intensive care unit (NICUS data)
- establish a virtual registry.

Education and training

High quality cardiac and respiratory life support is delivered by a team of local and specialist clinicians trained in specialist retrieval and ECMO services.

The minimum training and experience required to become part of an ECMO team varies between centres and countries. Similar to adult services, paediatric ECMO staff should receive regular training and education on theoretical and practical aspects of ECMO, including simulation training. More simulation

training is recommended for staff who handle a lower volume of ECMO cases. Staff participation in these education programs should be recorded and their proficiency evaluated, with retraining of team members as needed, on the basis of criteria set out by the ECMO program.⁹

	Referring site	Receiving ECMO site	Retrieval team/NETS
Education on eligibility criteria, expectations of pre-retrieval care and resources required prior to transfer	●		
Training courses lead to accreditation of ECMO specialist site(s)		●	●
Multidisciplinary ECMO simulations Retrieval simulation training every six months Sites with lower-volume of cases require more simulation opportunities		●	●
Credentialing and competence-frequency based on volume and individual performance		●	
Essential skills – all practitioners			
<ul style="list-style-type: none"> Advanced life support Introductory 8 hour multidisciplinary workshop (didactic and practical high fidelity simulation) Focus on each aspect of initiation, cannulation and management Supernumerary days at the bedside post workshop Complete a learning package Competency assessment Attendance at weekly 0.5-1 hour multidisciplinary simulations and half hour debrief. In lower-volume centres more simulation will be required. 			
Continuing education			
<ul style="list-style-type: none"> Case reviews Updates on ECMO therapy Quality assurance review of ECMO Interactions with NETS Updates on policy and procedures Administrative information. 			
Additional skills for medical officers			
<ul style="list-style-type: none"> Eight hour workshop on management and trouble shooting Need to be proficient with transoesophageal echocardiography during ECMO cannulation. 		●	●
Additional skills for cannulating staff			
<ul style="list-style-type: none"> Two day cannulation animal course Complete supervised cannulations until proficient and maintain skills competence. 			

Governance

Patients receive high-quality care, underpinned by sound governance structures and clinical leadership.

	Referring site	Receiving ECMO site	Retrieval team/NETS
Formal governance arrangements are documented and signed off by PICU and NICU Directors.	●	●	●
The ECMO retrieval model for neonates and paediatric patients has local executive sponsorship and oversight and local implementation support.	●	●	●
An ECMO coordinator has responsibility for the supervision and training, quality assurance, policy and procedures.		●	
Clinical roles and responsibilities are clearly defined and documented, including scopes of practice and interdependencies between referral sites, ECMO capable centres and the retrieval teams.	●	●	●
Clear processes and reliable systems for telemedicine.	●	●	●
Local, documented and implemented processes including: patient eligibility criteria, clinical pathways and workflows including feedback mechanisms, standardised decision making processes for patients who require retrieval for escalation of care, and formal and documented arrangements between the NETS and the ECMO capable site in NSW and interstate.	●	●	●
Timely and complete record keeping.	●	●	●
Care delivery is regularly reviewed against clinical pathways/protocols.	●	●	●
Program evaluation.	●	●	●

Patient, family and carer support

Patients and their families and carers are informed and supported throughout the ECMO process.

	Referring site	Receiving ECMO site	Retrieval team/NETS
Referring hospital medical officer to discuss the need for transfer with parents, carers and patient (age-appropriate), covering: <ul style="list-style-type: none"> the reason for and timing of transfer mode of transport, approximate travel time and estimated time of arrival treatment that may be required during transport. Telehealth may facilitate connection with ECMO specialists to ensure consistent and appropriate information is provided for treatment consent.	●	●	●
Families and carers are provided with information regarding the destination hospital in writing, including directions and contact details for key staff at destination hospital.	●		●
Whenever possible, families and carers are offered the option to travel with their child to the destination hospital. They should be informed at the outset that there may be circumstances that prevent them being able to accompany their child (e.g. weight restrictions on aircraft). ⁸	●		●

Where possible, a social worker should be engaged to support the family and carers throughout the time at the referring hospital, ensuring they are updated appropriately and that their transfer and accommodation needs are met.

Relocating patients away from where they live can cause stress, particularly for families identifying as Aboriginal or Torres Strait Islander. Where possible, a senior elder should be included in discussions and an Aboriginal liaison officer engaged at both the referring and receiving hospital.

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Appendix 1 – Suggestions for pre-retrieval management

Treatment prior to transfer

- Higher nursing dependency and close monitoring of the neonatal or paediatric patient's condition.
- Full cardio respiratory monitoring (heart rate and rhythm, respirations, blood pressure, oxygen saturations).
- Continuation or initiation of treatment as required such as:
 - temperature
 - neurological observations
 - level of consciousness, (including Paediatric Modified Glasgow Coma scale or AVPU if clinically relevant)
 - neurovascular (if clinically relevant)
 - blood loss (if clinically relevant)
 - pain assessment and management
 - blood glucose levels for infants and unwell children
 - hydration - intravenous access, intraosseous access and fluid administration
 - administration of prescribed medication
 - urinary output from IDC for accurately assess UO
 - oxygen therapy administration.
- Documentation of care.⁸

Oxygenation

- Aim for saturations of >95% and PaO₂ of 80–100mmHg to lower pulmonary vasoconstriction.
- After oxygen, inhaled Nitric Oxide (iNO) is the vasodilator of choice in term babies with PPHN and a normal systemic blood pressure.

Consider inhaled nitric oxide when:

- A neonate with severe hypoxic respiratory failure is unable to maintain a PaO₂ above 80mmHg despite maximal respiratory support.
- There is an additional nitric oxide accredited team member available.

Ventilation

- If intubation and ventilation is indicated, use an adequate sized endotracheal tube, sedate well and intubate with experienced personnel.
- Use of a cuffed endotracheal tube maybe recommended for transfer.
- Oxygenate and ventilate well to achieve optimal lung inflation.
- A higher PEEP may be required in the presence of lung disease. Avoid over-distension as this will exacerbate VQ mismatch by reducing pulmonary blood flow.
- PEEP of 5cm may be sufficient where there is no evidence of intraparenchymal lung pathology on CXR.
- Maintain PaCO₂ at 35–45mmHg – this may require significant ventilation pressures.
- Avoid hypercarbia. The only caveat to this is in congenital diaphragmatic hernia, where we would allow permissive hypercapnia (50–60mmHg) in an effort to prevent barotrauma to already hypoplastic lungs.

Acidosis

- In consultation with multidisciplinary team determine the cause of prolonged acidosis.
- Aim for a normal pH. Sodium bicarbonate is no longer recommended, however in the presence of a normal CO₂, it is thought to potentially improve cardiac function.

Circulation

- Insertion of a peripheral arterial line or umbilical venous and arterial catheterisation is recommended.
- Inotropic support – normalise the blood pressure by targeting the 50th percentile values for gestation or for age and weight in children and avoid 'suprasystemic' pressures.

Electrolytes

- Maintain normal Ca, Mg, PO₄ and haematocrit levels.
- Maintain normal blood sugar level.

Fluid management

- Aim for euvolemia. Avoid fluid overload and maintain an adequate blood pressure.

Haemodynamics, access and monitoring

- Maintain normothermia. This may require warming with or without fluid warming.
- IV cannulas secured and flushing.
- If possible, a central venous access catheter should be inserted where ECMO is being considered.
- Fluids/blood on pump sets.
- Arterial line secured.
- Vasopressor infusions – consider central venous catheter.
- Urinary catheter – secured and monitored hourly.

Sedation/muscular relaxation

- Maintain adequate sedation during transport.
- Muscular relaxation with vecuronium or rocuronium infusions may be required.

Temperature

- Avoid hypothermia and hyperthermia as both may worsen oxygenation status.

Supportive care/investigations

- There is insufficient evidence that steroids reduce mortality or morbidity in MAS.

Glossary

ARDS	Acute respiratory distress syndrome
CA	Cardiac arrest
CPR	Cardiopulmonary resuscitation
ECCO2R	Extracorporeal membrane carbon dioxide removal
ECMO	Extracorporeal membrane oxygenation
ECLS	Extracorporeal life support
ELSO	Extracorporeal Life Support Organization
EXCEL	An ECMO national registry on the treatment and outcomes of patients requiring ECMO supported by the Australian and New Zealand Intensive Care Research Centre, Monash University
IHCA	In-hospital cardiac arrest
ICU	Intensive care unit
Low-flow time	Duration between commencement of CPR until ECMO has reached full flow support
MAS	Meconium Aspiration Syndrome
mCPR	Mechanical cardio-pulmonary resuscitation
MOF	Multi-organ failure
NICE	National Institute Clinical Excellence
No-flow time	The time between the moment a person collapses until CPR commences
OOHCA	Out of hospital cardiac arrest
PaO ₂	Partial pressure of oxygen
PaCO ₂	Partial pressure of carbon dioxide
ROSC	Return of spontaneous circulation
TAH	Total artificial heart
VAD	Ventricular Assists Devices
V-A ECMO	Venoarterial Extracorporeal membrane oxygenation
V-V ECMO	Venovenous Extracorporeal membrane oxygenation

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