



**FRESENIUS
MEDICAL CARE**



Critical Care – ECMO

Respiratory indications

Cardiac indications

Neonatal and Pediatric Extracorporeal Life Support

Heart and Lung Therapies

The use of **extracorporeal life support (ECLS)** has grown **tremendously** in recent years, especially since the range of possible applications has increased and the safety improved.^{1, 2}

By the year **2022**, the **Extracorporeal Life Support Organization (ELSO)** has registered more than **196,000 runs** of extracorporeal membrane oxygenation (**ECMO**).³

Approximately **40 percent** of these were performed in **neonates** (up to 28 days of age) and **pediatric patients** (between 29 days and 18 years of age).³

Contents

page

Respiratory indications for ECMO in children 4

- Pneumonia
- Acute respiratory distress syndrome (ARDS)
- Congenital diaphragmatic hernia (CDH)
- Meconium aspiration syndrome (MAS)
- Persistent pulmonary hypertension of the newborn (PPHN) / Persistent fetal circulation (PFC)

Cardiac indications for ECMO in children 10

- Congenital heart defects
- Cardiogenic shock
- Cardiac arrest and cardiopulmonary resuscitation (CPR)

Improved outcome and survival rates 14



Respiratory indications for ECMO in children

Pulmonary support accounts for the majority of ECMO runs in children: more than half of the cases listed in the ELSO Registry 2022 International Summary are based on respiratory indications (Fig. 1a).³

Pulmonary	56.58%
Pediatric ECMO runs	15.15%
Neonatal ECMO runs	41.43%
Cardiac	32.34%
Pediatric ECMO runs	19.53%
Neonatal ECMO runs	12.81%
ECPR	11.08%
Pediatric ECMO runs	7.98%
Neonatal ECMO runs	3.10%

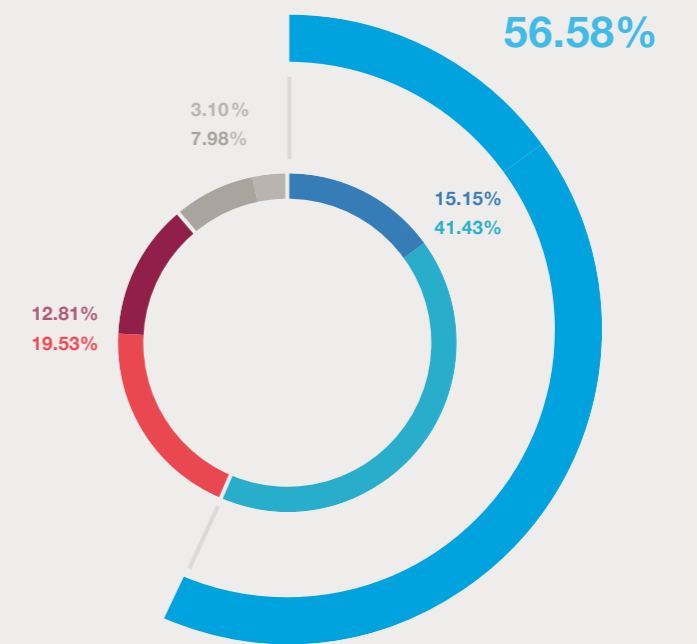


Fig. 1a: Proportions of ECMO runs for pulmonary and cardiac indications and cardiopulmonary resuscitation (CPR) in neonatal and pediatric patients, 1990 to 2022.³

Respiratory indications for ECMO in children

In pediatric patients, the main indications are viral and bacterial pneumonia, as well as acute respiratory distress syndrome (ARDS), and acute respiratory failure not related to ARDS.³

In neonates, respiratory indications primarily include congenital diaphragmatic hernia (CDH), meconium aspiration syndrome (MAS), and persistent pulmonary hypertension of the newborn (PPHN).³

Pneumonia

Pneumonia is the leading infectious cause of death in children worldwide: in 2019, 14 percent of deaths in children under five were due to this disease.⁴

Viral pneumonia is mostly caused by respiratory syncytial virus (RSV), while bacterial pneumonia is mostly caused by *Streptococcus pneumoniae*,⁴ for which the Robert Koch Institute reports increasing infection rates in Germany since the end of 2022.⁵

Acute respiratory distress syndrome (ARDS)

Acute respiratory distress syndrome is a non-cardiogenic pulmonary edema associated with dyspnea, tachypnea, and hypoxemia. It may be non- or post-traumatic and can rapidly progress to respiratory failure.⁶

Estimates regarding the incidence in children range from 2 to 12.8 cases per 100,000 person-years.⁶ Pneumonia and sepsis are the major risk factors for ARDS.⁷

For the years 2018 to 2022, ELSO captured a total of 147 pediatric ECMO runs due to viral pneumonia, 152 due to bacterial pneumonia, and 38 due to aspiration pneumonia (Fig. 2).³

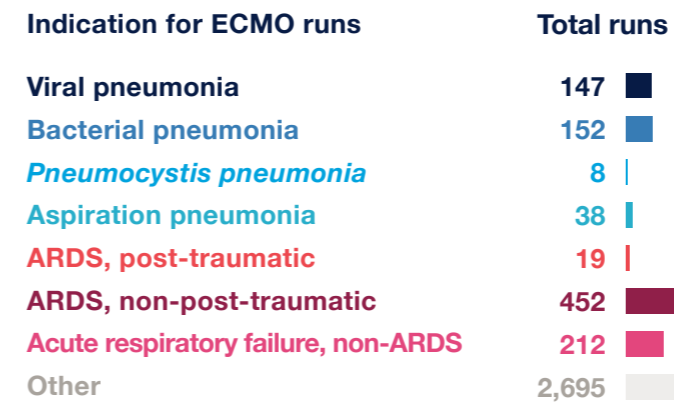


Fig. 2: ECMO runs based on respiratory indications in pediatric patients, 2018 to 2022.³



From 2018 to 2022, ELSO reports 452 pediatric ECMO runs in the context of non-post-traumatic ARDS and 19 pediatric ECMO runs in the context of post-traumatic ARDS (Fig. 2).³

Reminder:

Pulmonary support accounts for the majority of ECMO runs in children: more than half of the cases listed in the ELSO Registry 2022 International Summary are based on respiratory indications.³

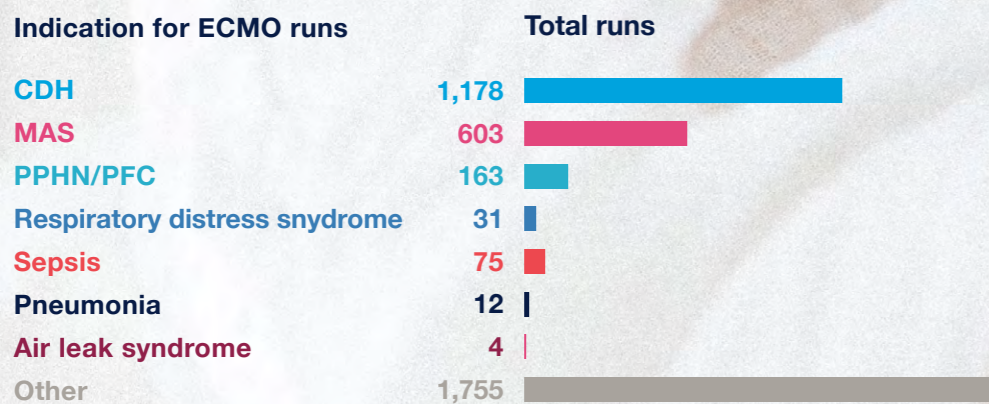


Fig. 3: ECMO runs based on respiratory indications in neonatal patients, 2018 to 2022.³

Congenital diaphragmatic hernia (CDH)

In congenital diaphragmatic hernia, patients exhibit an abnormal development of the diaphragm, resulting in herniation of abdominal contents into the thoracic cavity. Major complications include pulmonary hypoplasia and pulmonary hypertension. Neonates may present with cyanosis and respiratory distress, leading to hypoxemia, hypercapnia, and respiratory acidosis.^{8,9}

CDH occurs approximately once in 2,200 live births, with male newborns being 1.5 times more frequently affected compared to female newborns.^{8,10} The ELSO Registry International Summary indicates 1,178 neonatal ECMO runs for 2018 to 2022 (Fig. 3).³ Overall, CDH is the most common indication for ECMO in neonates.¹¹

CDH is the most common indication for ECMO in neonates.¹¹

Meconium aspiration syndrome (MAS)

Meconium aspiration syndrome occurs in infants born through amniotic fluid stained with meconium – the first intestinal discharge consisting of components such as water, skin and intestinal desquamation cells, gastrointestinal secretions, and bile.¹² For MAS patients aspirate meconium-stained amniotic fluid either prenatally by gasping or during the first breaths after

birth. The pathophysiology can involve mechanical airway obstruction, inactivation of the pulmonary surfactant and persistent pulmonary hypertension (PPHN).¹² MAS accounts for about 10 percent of neonatal respiratory failure.¹² For the years 2018 to 2022, 603 neonatal ECMO runs related to MAS are reported by ELSO (Fig. 3).³

MAS accounts for about 10 percent of neonatal respiratory failure.¹²

Persistent pulmonary hypertension of the newborn (PPHN) / Persistent fetal circulation (PFC)

Persistent pulmonary hypertension of the newborn, also known as persistent fetal circulation, reflects an impaired circulatory adaptation in neonates. Relaxation of the pulmonary vasculature is impaired or delayed at birth. Pulmonary vascular resistance is permanently increased, and persistent hypoxemia occurs.¹³

PPHN can result secondary from a variety of conditions, including sepsis, pneumonia, MAS, CDH, or congenital heart disease, and affects approximately two out of every 1000 live births.¹³ As reported by ELSO, 163 neonatal ECMO runs were performed due to PPHN between 2018 and 2022 (Fig. 3).³

PPHN affects approximately two out of every 1000 live births.¹³



Cardiac indications for ECMO in children

According to the ELSO Registry 2022 International Summary, cardiac indications account for approximately one-third of ECMO runs in children, the majority of which are pediatric patients (Fig. 1b).³

Pulmonary	56.58%
Pediatric ECMO runs	15.15%
Neonatal ECMO runs	41.43%
Cardiac	32.34%
Pediatric ECMO runs	19.53%
Neonatal ECMO runs	12.81%
ECPR	11.08%
Pediatric ECMO runs	7.98%
Neonatal ECMO runs	3.10%

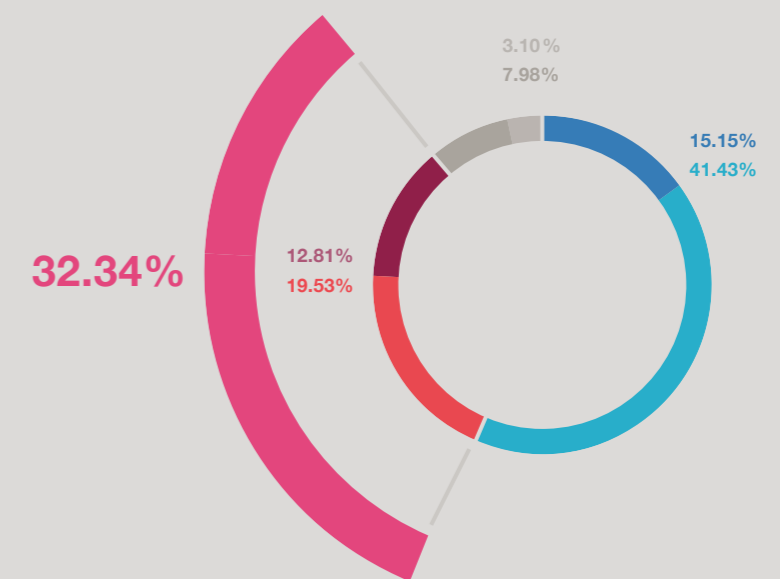


Fig. 1b: Proportions of ECMO runs for pulmonary and cardiac indications and cardiopulmonary resuscitation (CPR) in neonatal and pediatric patients, 1990 to 2022.³

Cardiac indications for ECMO in children

Most cardiac ECMO runs in children are due to congenital defects, followed by cardiogenic shock and, especially in pediatric patients, also cardiac arrest.³

Congenital heart defects

In patients born with a cardiac defect, ECMO serves primarily as a method to post-operatively manage low cardiac output syndrome or failure of weaning from cardiopulmonary bypass, but also to pre-operatively improve end-organ perfusion and provide physiological stability.¹⁴

Congenital heart defects in which ECMO support is employed include hypoplastic left heart, and cyanotic congenital heart disease with decreased pulmonary blood flow, as well as left-to-right shunt, particularly in pediatric patients.³

In the context of congenital heart diseases, ELSO has registered 1,570 ECMO runs for pediatric and 1,324 ECMO runs for neonatal patients from 2018 to 2022 (Fig. 4).³

1,570 ECMO runs for pediatric patients and 1,324 ECMO runs for neonates from 2018-2022.

Cardiogenic shock

As an acute impairment of myocardial contractility, cardiogenic shock is the most advanced and severe stage of heart failure, rapidly leading to multiple organ failure and death if untreated.¹⁵ In children, cardiogenic shock can have numerous causes, such as congenital heart defects, cardiomyopathies, myocarditis, arrhythmias, cardiac surgery, sepsis, pulmonary embolism, or pneumothorax. 5 to 13 percent of diagnosed

cases of shock in pediatric emergencies correspond to cardiogenic shock.¹⁵ According to the ELSO Registry International Summary, from 2018 to 2022, 784 pediatric ECMO runs and 205 neonatal ECMO runs were conducted in the setting of cardiogenic shock (Fig. 4).³

784 ECMO runs for pediatric patients and 205 ECMO runs for neonates from 2018-2022.



Cardiac arrest and cardiopulmonary resuscitation (CPR)

Cardiac arrest is rare in children – only about 1.5 to 2.2 percent of all cases occur in pediatric patients. Although methods of conventional cardiopulmonary resuscitation have evolved in the last decades, mortality rates remain high.¹⁶ ECMO can be initiated during CPR (ECPR) to provide rapid reperfusion with oxygenation and cardiovascular support.¹⁷ Previous concerns that cerebral hypoxia from cardiac arrest would lead to worse neurologic outcomes have not been confirmed.¹

In patients with cardiac arrest, ECMO can serve as a bridge to therapy, intervention, transport, transplantation, or recovery, for example.¹⁷ For 2018 through 2022, ELSO indicates 131 ECMO runs in pediatric patients and 19 ECMO runs in neonates due to cardiac arrest, as well as 2,707 pediatric and 864 neonatal ECPR runs (Fig. 4).³

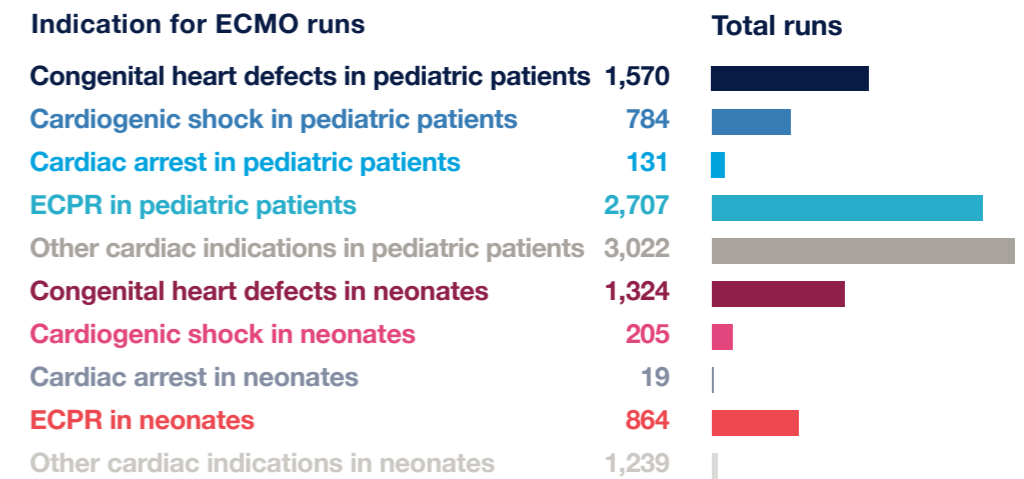


Fig. 4: ECMO runs based on cardiac indications and ECPR in pediatric patients and neonates, 2018 to 2022.³





Improved outcome and survival rates

With decades of advances in technology and equipment and increasing experience in extracorporeal life support, even more complex diagnoses may benefit from ECMO.^{1, 18}

For example, timely initiation of ECMO reduces the risk of cardiac arrest in the event of cardiogenic shock.¹⁵ Relatively high ECMO survival rates are, furthermore, observed for some respiratory indications, e.g., about 90 percent for MAS and 71 percent for PPHN.³ For high-risk CDH patients treated in experienced centers, ECMO has been shown to reduce mortality by approximately 20 percent.¹⁹

Table 1 summarizes the survival rates for children documented by ELSO from 1990 to 2022. The rates are particularly high for pulmonary ECMO in pediatric patients and neonates, at 61 percent and 72 percent, respectively, at hospital discharge.³

		Total runs	Survived to discharge or transfer
Pediatric patients	Pulmonary	12,784	61%
	Cardiac	16,471	55%
	ECPR	6,729	41%
Neonates	Pulmonary	34,952	72%
	Cardiac	10,802	44%
	ECPR	2,619	43%

The rates are particularly high for **pulmonary ECMO**.

Tab. 1: Pulmonary and cardiac ECMO runs and ECPR including survival rates documented by ELSO in pediatric patients and neonates from 1990 to 2022.³

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