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ECMO

It is important to remember that most studies of ECMO patients are based on registry data that span a significant period, potential changes in practice patterns and interventions and include multiple centers in the data set.

Survival
Overall survival rates after ECMO (60–70%) have remained stable over the years. The estimated survival rate for neonatal ECMO is 75 % and is higher compared to conventional management.
Late mortality, defined as death more than 90 days after neonatal ECMO, has been reported in 5.5% of a neonatal ECMO cohort in the UK, with the highest risk in CDH patients
Most of these studies are based on cases of venoarterial ECMO. This method might affect cerebral blood flow and increase the risk of intracranial hemorrhage and infarction, possibly resulting in neurodevelopmental problems.
5% - 10% of survivors will have severe neurologic complications; this may be as high as 20% in neonatal patients. The remaining 90% of survivors are at risk for subtler long-term neurodevelopmental problems
Several studies have reported neurologic outcomes after placement on ECMO following cardiac surgery and have found 50% incidence of moderate to severe cognitive delay, and 12–25% incidence of neuromotor delay among long-term survivors.

Outcome Predictors
Outcome of ECMO-treated neonates is determined by many different factors.

- Pre-treatment-related factors such as congenital anomalies, birth asphyxia, loss of cerebral autoregulation due to hypoxia, cardiopulmonary resuscitation and severe respiratory failure may play a role.
- Neonate are also exposed to treatment-related factors such as anticoagulation therapy with its associated risks for intracerebral hemorrhage.
- Post-treatment- related factors such as chronic lung disease, SNHL, and frequent or prolonged hospitalization may contribute to adverse outcome.

A few medical variables have a significant association with outcome (see Table).

- There was correlation noted with poor neurodevelopmental outcome and the younger the age of the patient at the time of placement on ECMO
- An abnormal MRI was highly predictive of a poor neurodevelopmental outcome. This suggests that routine neuroimaging post-ECMO can be helpful both to give prognostication to families and make sure that these children are followed on a regular basis to identify and address developmental delays.

Hearing
Risk factors for SNHL after neonatal intensive care have been identified: presence of CDH, prolonged ventilatory support, prolonged ECMO, sepsis or bacterial meningitis, prolonged administration of aminoglycosides, severe birth asphyxia, cerebral bleeding or cerebral infarction, and clinical seizures prior to ECMO treatment.
A 1996 study demonstrated 7.5% of ECMO survivors suffered from SNHL. Ongoing hearing screening should be conducted in all neonates subjected to ECMO as several groups have reported delayed onset of SNHL.

Sequelae / Residual effects
Neurologic sequelae associated with ECMO ranges from subtle neurocognitive deficits to seizures, infarction, devastating intracranial hemorrhage, and brain death. The mean IQ of children treated with ECMO is similar to normative population data not does not seen to be

significantly affected by the reason for ECMO, though some studies feel that children treated with ECMO for congenital diaphragmatic hernia score lower but still in the “normal range”. IQ also seems to be stable over time – studies at 2 year, 5 year and 8 years of age.
Long-term neurodevelopmental problems are under-recognized and underreported in the ECMO population.
Several studies have shown these children to be at risk for gross motor function problems and problems with academic achievement despite normal intelligence. Social, selective attention (particularly in the CDH population), working memory, information retrieval and visuo-spatial problems may occur too, often combined with other cognitive and behavioral problems. They also appear to have more difficulty with working speed and accuracy.
Clinical behavioral problems after neonatal ECMO treatment have been reported in a range of 10–35% in different studies without a typical pattern. Problems of hyperactivity and attention have been reported both at preschool and at school age and somatic complaints

School Issues

IQ testing can provide valuable insights into the overall cognitive functioning of an ECMO survivor but is not suited to detect subtle neuropsychological impairments and in isolation did not identify those at risk for academic problems. Children without apparent delays remain at risk for (subtle) cognitive deficits.
While 91% of children treated with ECMO were in a regular education setting at 8 years old, a higher percentage of them required additional support in a regular class or in special education compared to the general population

- 37% of ECMO survivors need extra help at school compared with 20% of children in the general population.
- 7% of ECMO survivors require special education compared with 4.4% in the general population.

Table 2 – Overview of long-term outcomes reported following neonatal ECMO treatment.

	Infancy (<2 yr)	Preschool age (2–5 yr)	School age (6–12 yr)	Adolescence (>12 yr)
Medical outcome				
Lung function	Airflow obstruction,[7,8] normal lung volume,[7,8] and hyperinflation in CDH[9]	–	Airflow obstruction,[10,11,13] air trapping[10,13]; problems mainly in CDH patients[13]	Airflow obstruction and air trapping[10]
Exercise capacity	–	Decreased[14]	Decreased[11,14] to normal[10]	Normal[10]
Growth	Normal[5,7] to slightly decreased weight[8] especially in CDH[9]	Normal[14]	Normal,[12,14] decreased height and weight in CDH[12]	–
SNHL	Prevalence ranging from 3% to 26%, in different studies over time[17–22,33]			
Chronic kidney disease	Abnormal urine protein/creatinine ratio or estimated glomerular filtration rate in 11%[31]			
(Neuro)developmental outcome				
Motor function	Normal in 84%[32]	Normal in 64–73%[16,36]	Normal in 43%[39] and normal in 71% of CDH patients[35]	–
Cognition	Normal in 92%[32]	Normal average scores[15,33,38,45]	Normal in 68%[39] and normal average scores[43]	–
Neuropsychological tests	–	Decreased scores at verbal, reasoning and spatial abilities,[22] and neuropsychological deficit at ≥1 domain in 11%[38]	Spatial ability scores below 10th percentile in 26%,[39] visual-motor integration below average in 20%,[43] memory problems in 26–48%,[39] decreased working speed in 70%,[43] and decreased accuracy in 39%[43]	Memory problems in 46–57%[36]
School performance	–	–	Special education 9–20%[39,43]; extra support 20–39%[39,43]	–
Behavior	–	Normal in 48.5–65%,[45,47] more problems compared with controls in social, attention, and hyperactivity domains[38]	Clinical total problems 18%, social problems 5%, and attention problems 6%[43]	Self-reported externalizing problems 6%[36]

CDH = congenital diaphragmatic hernia; SNHL = sensorineural hearing loss.