## WORKSHEET for Evidence-Based Review of Science for Emergency Cardiac Care

**Worksheet author(s)**
Kate L Brown

**Date Submitted for review:** 1st Feb 2010

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### Clinical question.

In pediatric patients in cardiac arrest (prehospital [OHCA] or in-hospital [IHCA]) (P) does the use of rapid deployment ECMO or emergency cardiopulmonary bypass (I), compared with standard treatment (C), improve outcome (ROSC, survival to hospital discharge, survival with favorable neurologic outcomes) (O)?

### Is this question addressing an intervention/therapy, prognosis or diagnosis?

Intervention/therapy

### State if this is a proposed new topic or revision of existing worksheet

New

### Conflict of interest specific to this question

Do any of the authors listed above have conflict of interest disclosures relevant to this worksheet?

I am a clinician working in the field of pediatric cardiac intensive care. I have on occasion provided rapid deployment ECMO for children in cardiac arrest. I have participated in several publications about ECMO support for children that have alluded to rapid deployment ECMO but none solely dedicated to this topic (list available on request). I was interviewed for the journal Circulation on March 6 2007 about the topic of ECMO for children in cardiac arrest.

### Search strategy (including electronic databases searched).

**Terms:**

- 'Heart arrest' OR 'Cardiopulmonary resuscitation' as MESH headings
- ‘Extracorporeal circulation’ as MESH heading OR 'Extracorporeal membrane oxygenation’ OR 'Extracorporeal life support' OR 'Cardiopulmonary bypass' as textwords.

Limit search to age group less than 18 years.

In Databases:

Pubmed, Embase.

**Terms (all text words):**

- 'Heart arrest' OR 'Cardiopulmonary resuscitation'
- ‘Infant’ OR ‘Child’ OR ‘Adolescent’

In Databases:

Cochrane, Google Scholar and AHA End Note Master Library.

### State inclusion and exclusion criteria

**Inclusion criteria:**

- Peer reviewed journals
- Subjects were exclusively or included identifiable children under the age of 18 years.
- Subjects had ECPR for either IHCA or OHCA. OHCA with hypothermia treated with emergency bypass in pediatric patients was included.

**Exclusion criteria:**

- Papers for which there was no English version available.
- Review articles.
- Case reports of 1, 2 or 3 cases of ECPR in which there was no new message or additional information such as complications.
- Duplications of the same case (s) where these were clearly identified – some doubt remained on certain studies and this has been noted down.
- Studies in which subjects were exclusively adults over the age of 18 years. There are a large number of adult studies: many have been collated in Nichol, G., R. Karmy-Jones, et al. (2006). "Systematic review of percutaneous cardiopulmonary bypass for cardiac arrest or cardiogenic shock states." Resuscitation 70(3): 381-94. Studies with a combination of children and adults were included if the pediatric group could be delineated separately. In respect of these studies, only data on the children is presented in the evidence evaluation.
- Studies relating to low cardiac output state rather than cardiac arrest or studies where no ECPR group could be seperately identified or delineated: this applies to certain post operative cardiac ECMO series.
- Studies relating to cardiac arrest in the intensive care unit where no ECPR was used.
- Since three recent papers relating to the ELSO Registry were included, therefore raw data from the ELSO Registry was not considered necessary.

### Number of articles/sources meeting criteria for further review:

44 studies were identified as meeting inclusion criteria and are included in the evidence evaluation / citation list.

Of these, 3 were LOE 2 (retrospective with non randomized concurrent controls), 39 were LOE 4 (no controls) and 2 were LOE 5 (animals).
# Summary of evidence

## Evidence Supporting Clinical Question

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### Level of Evidence

- A = Return of spontaneous circulation
- C = Survival to hospital discharge
- E = Long term functional outcome
- B = Survival of event
- D = Intact neurological survival
- Italics = Animal studies

*Contains data on non cardiac patients*

#Contains data on non cardiac patients that opposes the clinical question or is equivocal to the clinical question
## Evidence Neutral to Clinical question

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## Evidence Opposing Clinical Question

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Discussion:

There is weak evidence favoring the use of emergency bypass or ECMO in cases of OHCA with hypothermia in children. There are only very small numbers of paediatric patients appearing in the literature: all evidence was LOE 4, with 3 studies favoring (pediatric patients N=21) (Scaife 2007, Walpeth 1997, Wollenek 2002) 1 study equivocal (Paeds N=12) (Eich 2007) and 1 study unfavorable (Paeds N=3) (Schaller 1990). Therefore the evidence is weakly positive at this time for the use of emergency bypass or ECMO for OHCA with hypothermia. However, one must be mindful of publication bias.

Studies based outside of these specialized and specified conditions or diagnostic groups are very few in number: One small LOE 4 study from the emergency room was equivocal (Posner 2000) and 1 small LOE 4 study from the emergency room was unfavorable (Younger 1999) (total patients in all studies combined = 5). A case report of ECPR in the general medical operating room (Al-Toukri 2004) reported major neurological damage. Therefore at present the evidence does not support the use of ECPR outside the specialized environment of the ICU or similarly supervised area, apart from the specific example of OHCA with hypothermia.

The studies that included information on children with other medical conditions apart from heart disease, whilst supporting the question in cardiac patients did not contain similar positive evidence for non-cardiac patients and indeed either suggested an unfavorable or equivocal outcome in these children: Morris 2004 early survival was 2/21 for ECPR in children with other underlying conditions, Alsoufi 2007 1/9 for ECPR in children with non cardiac diagnosis and Thiagarajan 2007 reviewing the ELSO Registry: pediatric respiratory (n=43, 21% survival), sepsis (n=54, 22% survival) and others (n=52, 23% survival). The exceptions to this were: Thiagarajan 2007 17/34 (50%) neonatal respiratory failure ECPR cases survived but given the Registry’s 20,993 non ECPR neonatal respiratory failure cases, this very small number must be interpreted with caution and Prodhan 2009 5/6 general PICU or NICU ECPR cases survived to discharge. Therefore the evidence does not favor ECPR for non cardiac IHCA at this time. These poor early outcomes must also be considered in the context of the late neurology outcome data available, which suggests that further problems are likely to emerge in survivors over time.

The data on duration of CPR is inconclusive, with conflicting reports for the threshold beyond which the outcome deteriorates. Huang 2008 (N=27) suggested that longer CPR times had a negative effect on outcome in a good quality LOE 4 study. Prodhan 2009 showed borderline evidence that CPR > 60 minutes was a risk factor for death. Several authors emphasized that rapid deployment is the goal (Del Nido 1992, Yamasaki 2006). There are a small number of survivors in case series with CPR times of around 90 minutes (Morris 2004, Alsoufi 2007) and a few even longer (Kelly 2004). The ELSO Registry does not collect data on CPR duration for the ECPR category and this is one of its most striking disadvantages. There is some evidence for tolerance of longer CPR times in children who had ECPR as compared to those who had conventional CPR (Morris 2004, De Mos 2006). This may occur partly because reperfusion with ECMO is advantageous after CA and partly because of patients receiving good quality CPR. This is an important reason for the concentration of favorable reports being from intensive care, the catheter lab or the operating room, where patients are highly monitored by experienced and skilled persons. This also links to the topic of generalisability of published results. All the published reports are likely to be strongly influenced by local practice patterns and resource availability. In a high-risk treatment such as ECMO and even more so ECPR, the local protocols, skills and governance structures are absolutely vital. These cannot be maintained to a good standard without investment of considerable resources in terms of equipment, staff and expertise.

A major caveat and important issue with the majority of favorable studies is that these report neurological outcome based on a clinical examination at discharge (CD in the evidence summary) and a small number of studies did not include any data on neurology at all (C in the evidence summary). The ELSO Registry based studies (Thiagarajan 2007, Barrett 2009 and Chan 2008) only report certain defined neurological abnormalities and do not include any clinical data. Such early outcome measures are not necessarily well correlated with the ultimate neurological outcome long term in particular if detailed testing is performed on
survivors. Therefore End point E (long term neurological outcome) was added to the evidence summary to denote the small number of studies that contain this data. Long-term assessment appears to identify a certain amount of late morbidity: Huang 2008 N = 27 with 41% early survival and 63% survivors intact, Ibrahim 2000 N=21 with 48% early survival and 38% long term survivors intact, Lequier 2008 N=12 with 46% early survival and 38% survivors intact, Prodhan N=34 with 74% early survival and 75% of survivors with no change in neurological status. This issue is an important caution when interpreting favorable early results. Neurological issues in survivors with heart disease, which represents the majority of ECPR patients, may also be linked with the underlying heart condition and subsequent surgeries. Complex heart disease is recognized to carry significant risk of such problems and this further confounds attempts to establish and delineate the links between ECPR and outcome. The neurological burden in survivors may well be greater than first appears in the bulk of the published papers. This issue requires further evaluation.

There is considerable overlap between studies of ECPR in the context of pediatric heart disease and this was indeed so great that it could not be quantified. There are 3 studies based on the ELSO Registry (N= 682) all of which therefore contain the same patients (Thiagarajan 2007, Barrett 2009 and Chan 2008). There are several centers that submit cases to the ELSO Registry, which have also published their center’s experience. The individual experience data may shed more light on the topic but the patients are none-the-less overlapping. An exact list cannot be provided as ELSO centers are not publicized; however there are 110 in North America and a high proportion of included reports are from North America. There are several centers that have published different aspects of their experience and therefore their patients may appear more than once, examples include (Dalton 1993, Del Nido 1992, Del Nido 1993) (De Mos 2006, Hoskote 2006, Alsoufi 2007). It is therefore not possible to provide an objective statistical analysis of evidence based on overall patient numbers. Furthermore this is a caveat suggesting that the true number of patients is less than the total number of studies imply.

**Acknowledgements:**
The worksheet has been amended after the webinar presentation on 27th August 2009, advice from the task force chairs and Dr M Morris. This worksheet was revised in Jan 2010 following advice from Dr P Moreley.
generalised hypoxic ischemic damage, 3 had cerebral +/or basal ganglia infarcts and 1 had a late intracranial hemorrhage. Operating room - but this seems unlikely. 9/19 had neurological injury - in 2 patients support was withdrawn for this reason, 5 had unfavorable outcome. The patient had hyperkalemia, metabolic derangements and pyrexia. Once stabilized on ECMO it transpired that the child had devastating hypoxic ischemic brain damage and support was withdrawn. This case demonstrates that circumstances unfavorable for cerebral protection, such as hyperpyrexia and major metabolic disturbance should potentially be viewed as cautions against the use of ECMPR. LOE 4. Quality poor (one case). Equivocal (one case).

Therefore this study opposes the study question in non cardiac patients. Outcome including basic neurology in 32%. Confounding cannot be accounted for in such a small sample of non cardiac patients (9), but in these the outcome was very poor: 11% favorable outcome. There was only one survivor with meconium aspiration syndrome.

Case series of children on ECMO after cardiac surgery, including 10 who had E-CPR: 8 (80%) survived to discharge. States poor survival outcome after 45 minutes CPR time, but this position is not clarified further. Only 2 deaths and so this conclusion does not rest on a large amount of data. Cardiac case mix, surgeries and ECMO technique are described but ECPR patient selection and processes are not. Complications are reported for whole cohort (ECPR + non ECPR): renal, sepsis but no neurological complications are noted and there may be ascertainment bias for neuro injury. Neurological assessment was a physical examination at discharge and follow up is not alluded to. Small sample. Retrospective and therefore there is possible selection bias. Supports the intervention in this context - post cardiac surgery, in the ICU. CPR time < 45 minutes.

Case report of an 11 year old child with IHCA secondary to malignant hyperthermia, location was OR, CPR time was 80 minutes with unfavorable outcome. The patient had hyperkalemia, metabolic derangements and pyrexia. Once stabilized on ECMO it transpired that the child had devastating hypoxic ischemic brain damage and support was withdrawn. This case demonstrates that circumstances unfavorable for cerebral protection, such as hyperpyrexia and major metabolic disturbance should potentially be viewed as cautions against the use of ECMPR. LOE 4. Quality poor (one case). Equivocal (one case).

Case series of 19 patients with ECPR in the catheter lab1996-2004 (USA), which may overlap with series by Duncan (1996-1997) from same institution of 11 patients. May also overlap with Ibrahim 2000. LOE is 4. Quality is fair. Study was supportive for survival and basic neurology in this context. 15/19 (79%) survived to discharge: 8/19 (42%) had favorable neurology at hospital discharge and 7/19 (37%) survived with neurological abnormalities. Retrospective therefore cause selection criteria may be biased. Median CPR time 29 minutes, most had peripheral cannulation. Details of all interventions and complications are listed in tabular form - very thorough (sepsis, bleeding, rhythm etc). Outcome assessed by review of case notes including a basic neurological examination at hospital discharge in all cases. ECPR process is described. Authors note that most patients had a relatively brief adverse event in the catheter lab leading to ECPR and suggest that the good results in terms of survival compared to post operative ECPR may reflect this. A high proportion of the series had CNS imaging and therefore this series is likely to have minimised ascertainment bias for neuro injury, since this was actively sought. Other possibility is the catheter lab is a more adverse environment for neuro injury than the ICU / operating room - but this seems unlikely. 9/19 had neurological injury - in 2 patients support was withdrawn for this reason, 5 had generalised hypoxic ischemic damage, 3 had cerebral +/or basal ganglia infarcts and 1 had a late intra cranial hemorrhage.

Case series of 80 children treated with ECPR from 2000 - 2005 (Canada). Overlaps with included study by de Mos (1997 - 2002) and Hoskote from same institution (1997 - 2003), topics were different in the later studies). LOE is 4. Quality is good. Supportive in children with heart disease: survival and basic neurology). Unfavorable for children with non cardiac disease. Sample size for cardiac patients was good for this context (80). Retrospective case series therefore possible selection bias for cases receiving ECPR.

Patient types: Majority are children with cardiac disease (71) with a small sample of other diagnoses such as respiratory disease (9). Survival overall: 34% to discharge with favorable neurology in 30%. Evidence supports the question in cardiac patients: favorable outcome including basic neurology in 32%. Confounding cannot be accounted for in such a small sample of non cardiac patients (9), but in these the outcome was very poor: 11% favorable outcome. There was only one survivor with meconium aspiration syndrome. Therefore this study opposes the study question in non cardiac patients. Outcome: Outcome evaluation was survival to 1 and 3 years with basic data (POPC / PCPC scores) on neurological status. The authors have reviewed the patient's charts to assess clinical information about neurology and attempted to track them outside the hospital to provide longer term survival outcomes to 1 and 3 years. The commonest cause of death was brain injury in 17 (21%). Details of the PCPC and POPC scores are not presented therefore data completeness cannot be ascertained. There were some small infants in the series in which early neurological assessment may be difficult. Therefore the potential for ascertainment bias for neurological abnormalities is present. ECMO leading to transplantation was associated with better outcome (p<0.001) but this may also reflect patients selected for transplant are likely to have been in better condition free of ECMO related complications. Other
factors analyzed were unrelated to outcome (diagnosis, cannulation site, time of day).

**Generalisability:** Location for IHCA was the intensive care unit in the majority of patients, remainder were operating room or catheter lab. Processes are described. Median CPR time was 41 (19-110 minutes). There was no statistical relationship between CPR duration and outcome. However the authors present a graph, which suggests that longer CPR times may be less favorable. At least half the cardiac patients had open chest and therefore would have had open massage.

Quality of evidence reasonable given caveats regarding the very tightly defined patient inclusion criteria - IHCA in ICU with staff trained and prepared, patient diagnosis cardiac disease.


This is a review of ELSO Registry data on early neurological abnormalities in children < 18 years after ECPR. LOE is 4, quality poor, favorable. Study overlaps with Chan 2008 and Thiagarajan 2007.

Registry issues -- as for Thiagarajan 2007.

The authors state that neurological injury is frequent after ECPR: 147/682 (22%). Brain death occurred in 74 (11%), cerebral infarction in 45 (7%), and intra cranial hemorrhage in 45 (7%). Neurological injury was linked to risk of death: 89% died. There are issues that indicate the rate likely to be considerably higher - The study acknowledges that functional outcome is not ascertained in the Registry, long term status is unknown, and clinical data on the included patients that may impact on neurology are not collected by ELSO.

Further – protocols for detection of neurological abnormalities may differ between centers and all series that include longer term data report much higher rates of neurological abnormalities than this study (Hamrick 2003, Huang 2008, Ibrahim 2000, Lequier 2008), though these are more likely to include smaller studies.

The study found that cardiac patients, patients with lesser acidosis and uncomplicated ECMO runs were at lower risk.


Report of 26 children treated with post cardiotomy ECMO (Saudi Arabia), with 4 ECPR. LOE 4. Study is supportive for survival outcome in this context. Poor quality. 4 children with IHCA due to cardiac disease had ECPR out of whom 2 (50%) survived to discharge. CPR time mean 45 minutes range 30 to 55 minutes. Five of 26 in the whole series died from cerebral injury and when this was suspected an assessment was performed. No information is presented on neurological status specifically relating to the 4 ECPR patients. Retrospective series may have selection bias.


Large case series of cardiac ECPR (N= 492, 42% survival) reported to the ELSO Registry between 1992 and 2005. There is overlap with Thiagarajan, 2007 and Barrett 2009. Furthermore, this study may contain the same patients reported in other included studies from ELSO registered centers (for example, Morris 2004, Alsoufi 2007). Non cardiac ECPR cases are excluded (N=168), as the study aimed to evaluate the impact of case mix on outcome in the context of ECPR for children with heart disease. Non cardiac cases are reported in Thiagarajan, 2007.

LOE is 4. Quality of evidence is fair. Study is favorable for survival and basic neurology.


Therefore ELSO Registry capture of events (110 reporting centers) in North America may be fairly good but for Europe and Asia (only 14 reporting centers) capture is likely incomplete. Center identity is confidential and therefore not included in the study.

Furthermore, interpretation of Registry data is limited by the parameters included and the data quality. One concern is the robustness of the ECPR case definition and the tendency of some authors to report intermittent cardiac arrests or CPR for very low output as ECPR - this possibility cannot be excluded in ELSO Registry data. Furthermore, no CPR times are documented and therefore this important aspect could not be explored. Also, the survival status may reflect the status at discharge from one institution to another rather than to home, since transfer from a tertiary center is a common scenario and ELSO Registry data submission occurs at that stage.

There were 196 single ventricles (35% survival), 186 biventricular patients (48% survival) and 110 heart muscle disease patients (45% survival). Patients with single ventricle had worse outcome (p=0.03) after adjustment for other factors. This is consistent with other ELSO Registry data on single ventricle ECMO outcomes.

Patients with worse pre ECMO acidaemia (p=0.01) and more complex surgery based on the RACHS score (p=0.02) also had worse outcome. ECMO complications including neurological injury were also associated with worse outcome as was longer duration of ECMO. Seizures were present in 58 (12%) and abnormal brain radiology in 52 (11%). There may be under detection of neurological abnormalities in the dataset, as: 1) radiology may not reflect function 2) protocols for neurology evaluation at the various centers submitting data are unknown 3) case series that include longitudinal data are notable for abnormal neurological findings detected later on during follow up (Hamrick 2003, Huang 2008).

Carotid artery cannulation was associated with a lower risk of death (p=0.03) which was a surprise to the authors since these patients are more likely to have had closed chest CPR. The reasons for this are uncertain but may include more stability prior to the arrest leading to the chest being closed or center related issues.
Case series of 16 children treated with ECMO after cardiac surgery (French), includes 4 ECPR. LOE is 4. Quality is poor. Study is favorable for survival and basic neurology. 4 undergoing ECPR all survived with grossly intact basic neurology. For the whole group there was 53% 'long term' survival. The authors state that 'no survivor presented obvious neurological damage'. There may be ascertainment bias, as the approach to neurology assessment is not stated. Details of ECPR cases and process are brief. CPR time range was 2 to 45 minutes therefore it is not clear that all 4 were true ECPR, as 2 minutes is relatively brief for ECPR. Retrospective series may have selection bias.

There are two concerns when considering this study as evidence for the study question:

1) The study only includes 5 ECPR patients and the other 23 ECMO cases had ROSC before ECMO actually started. Therefore case mix for the ECMO group is likely to differ from a pure ECPR group: this is a bias.
2) There is a lack of clarity around the indications used to determine whether or not the intervention (ECMO for IHCA) was deployed. We do not know how a decision was made whether to offer ECMO or not, as the full ECPR service was not yet operational (this is discussed below). There are only 5 ECPR cases included in the study (2 survivors), but ECMO was used immediately and up to 24 hours post IHCA in 28 out of the total 91 children. The diagnoses in ECMO patients are not given and there may be additional patient factors (case type, severity of illness), which might have influenced the selection of children to receive ECMO (versus not to receive it) that might have influenced their prognosis. This is therefore a source of confounding.

The authors analyzed the cohort for factors related to more favorable outcome (both case mix and intervention related factors) and indicate that the use of ECMO during or post resuscitation significantly increased the odds of favorable outcome (p=0.03). The children who received ECMO after cardiac arrest had longer CPR times than those children who did not have ECMO, but the proportion of survivors was greater. These factors support the proposition that use of ECMO is favorable.

This is a retrospective cohort study of 91 pediatric IHCA witnessed in the ICU (1997 - 2002) from Canada. The data overlaps with Alsoufi's case series of 80 ECPR (2000 to 2005) and Hoskote's HLHS on ECMO from same institution (1997 - 2003). LOE is 2. Quality is poor in respect to this specific question though it is supportive for survival and basic neurology. The study includes ICU patients with IHCA who were treated with ECMO and those who were not treated with ECMO. There are two concerns when considering this study as evidence for the study question:

1) The study only includes 5 ECPR patients and the other 23 ECMO cases had ROSC before ECMO actually started. Therefore case mix for the ECMO group is likely to differ from a pure ECPR group: this is a bias.
2) There is a lack of clarity around the indications used to determine whether or not the intervention (ECMO for IHCA) was deployed. We do not know how a decision was made whether to offer ECMO or not, as the full ECPR service was not yet operational (this is subsequently reported in Alsoufi's paper in 2007). There are only 5 ECPR cases included in the study (2 survivors), but ECMO was used immediately and up to 24 hours post IHCA in 28 out of the total 91 children. The diagnoses in ECMO patients are not given and there may be additional patient factors (case type, severity of illness), which might have influenced the selection of children to receive ECMO (versus not to receive it) that might have influenced their prognosis. This is therefore a source of confounding. The outcome is survival to discharge and post procedural performance category (PCPC) score, which is a basic neurological assessment tool reflecting clinical functional outcome. 25% of patients in the whole cohort survived to hospital discharge, but 36% of those that had ECMO survived.

Neurology (PCPC) data was collected consistently for 91% of survivors. The authors analyzed the cohort for factors related to more favorable outcome (both case mix and intervention related factors) and indicate that the use of ECMO during or post resuscitation significantly increased the odds of favorable outcome (p=0.03). The children who received ECMO after cardiac arrest had longer CPR times than those children who did not have ECMO, but the proportion of survivors was greater. These factors support the proposition that use of ECMO is favorable.

This is a case series of post heart surgery ECMO in 68 children including 11 who had E-CPR with 6 survivors. Gross neurological function was reasonable. This study (1981-1994) overlaps with Del Nido 1992 (1981-1990) - also 11 patients and Dalton 1993 (1981-1990) - also 11 patients - from the same institution. Greatest detail about the ECPR cases is given in Del Nido 1992. LOE is 4. Quality is poor and favors the intervention in children with cardiac disease for survival and basic neurology. All the IHCAs were witnessed in an ICU and the average CPR time was 63 minutes. In most cases the CPR was done via open chest. The authors cannot draw absolute conclusions about
the link between CPR times and outcome, which went up to 90 minutes in survivors. Retrospective series may have selection bias.


This is a case series of 11 ECPR cases post heart surgery with 6 (54%) long term survivors. First case series of ECPR in children with heart disease to be published. Gross neurological function was reasonable. This study (1987-1991) overlaps with Del Nido 1996 (1981-1996) - also 11 ECPR patients and Dalton 1993 (1981-1990) - also 11 ECPR patients - from the same institution with some slight differences between the reports. This report gives the greatest information pertinent to the study question. The LOE is 4. Quality fair. Favorable for survival and basic neurology in children with cardiac disease. Retrospective series and therefore susceptible to case selection bias. The process is described including readiness of the ECMO circuit.

All the IHCAs were witnessed in an ICU and the average CPR time was 63 minutes. In most cases the CPR was done via open chest. The authors cannot draw absolute conclusions about CPR times, which went up to 90 minutes in survivors. Three children had ECMO withdrawn because of severe neurological damage. No details of the neurological assessment of survivors are provided but basic summary information such as neurology normal is stated in results.


First case series from this institution (USA) of 11 cases of ECPR 1996 - 1997. May overlap with Allan specifically relating to cath lab 2006, may overlap with Ibrahim 2000. LOE is 4, quality is fair. Supportive for survival and basic neurology.

7/11 (64%) cardiac ECPR cases survived to discharge, 2 with neurological impairment. 1 patient arrested in the cath lab and 10 in the ICU. Median CPR time was 55 mins (range 20-103 mins). The circuit and ECPR processes are clearly described. The ECPR response times are compared with historic controls that had ECPR with a different and less rapidly prepared circuit. Of the historic controls 2/7 survived. ECPR times are not significantly linked to outcome likely because of the small numbers, although times were reduced by the policy change from median of 90 minutes to 55 minutes. Retrospective series may have selection bias. Neurology outcome was assessed by making a telephone call to the child's primary care doctor or parent following discharge. There is the possibility of ascertainment bias for neurological status.


Case series of 12 hypothermic drowned children with OHCA treated with emergency CPB (German). LOE is 4, quality fair, equivocal / neutral to the question in the case of hypothermic OHCA.

Five/12 (42%) survived, two (17%) with good neurological outcome but 3 (25%) were in a vegetative state (PCPC 5). The authors have been systematic in terms of data collection methodology: all drowned children with OHCA treated with emergency bypass between 1987 and 2005 were reviewed retrospectively. Similar treatment protocols followed the same variation in re-warming speed.

The authors have tried to identify predictors of outcome but this is difficult in the small series. They note that the two children with good outcome had initial idioventricular bradycardia, had somewhat lower K levels and were re-warmed slowly.


This is a case report of ECPR for IHCA due to shunt occlusion in a baby with heart disease. The child suffered the complication of a splenic infarct, which led to catastrophic intra abdominal bleeding on ECMO. The child had a successful splenectomy on ECMO and later had a shunt revision. The outcome was favorable. Bleeding complications are an important factor to consider in cases of ECPR. LOE 4, quality poor, equivocal (one case).


RCT of pigs receiving either percutaneous ECLS or open chest massage after induction of cardiac arrest. LOE 5 - animal study. Quality of evidence poor. Supportive for ROSC.

Animals were prepared by chest opening or cannulation before CA was induced. VF arrest was induced and pigs were cardioverted. The pigs on ECMO had ROSC within 6-7 mins but the pigs with open chest massage either took longer or died.

Outcome was ROSC therefore can not comment on further elements of outcome - survival to discharge and cerebral injury, which are important considerations for ECPR.

The arrests were all VF and time to establishing the study intervention was reduced compared to clinical ECPR scenarios, because animals had already been prepared with ECMO cannula insertion / open chest for massage. Mean time to ROSC was 7 min for ECMO and 15 min for open chest massage. Therefore this aspect may not be applicable to the scenario in a child with IHCA.

There is evidence from the study that the ECLS group had reduced myocardial acidemia and better coronary perfusion. Myocardium appeared to recover more promptly with ECLS than open chest massage because it was perfused by the ECLS flow. This data is applicable to post open heart surgery arrest and performance of the myocardium, which may be particularly vulnerable at that time.
ECLS was more effective than open chest massage in achieving ROSC.


LOE 5 - animal study. Quality of evidence - outcome is ROSC therefore cannot comment on further elements of outcome. Study protocol differs from clinical scenario for example wait of 10 minutes before starting CPR. Only focus is on myocardial function. Therefore quality can only be poor but is supportive for ROSC with ECMO / bypass compared with conventional CPR.


Case series of 14 children managed with ECPR (France) 2003 - 2006 of who 8 (57%) survived. There is overlap with Ghez report of cardiac ECMO (2005) from the same institution and era therefore only this paper is included as it pertains to the study question. LOE is 4, quality poor, supportive for survival and basic neurology.

One survivor is stated to have cerebral infarction but no information is presented about the approach to neurological evaluation of survivors, so one cannot say if this was objective. Retrospective with small numbers: there may be selection bias. It is not clear whether ECPR was offered to all patients or if there was a selection process. This is relevant because a particular emphasis of the report is the available resources and the variability of access to ECPR over 24 hours of the day. Process for cannulation is described: prepared ECMO circuit but team not resident. Despite non resident team, ECPR times given - mean 44 and highest 112 minutes are comparable to other centers with a resident team. The authors do not link CPR times with outcome. Most patients had open chest. All IHCA were witnessed in the ICU or cath lab. We do not know, for example, if patients with IHCA at night were less likely to be included - it is not stated whether or not patients died without access to ECPR at night.


This is a long term neurological follow up study of children that had ECMO post cardiac surgery between 1990 and 2001 (USA). LOE is 4, quality is fair and the study is unfavorable. The method of patient evaluation was systematic and thorough - there were complete neurological, physical and developmental examinations at 1, 1.5, 2.5 and 4.5 chronological years of age. This follow up approach is unique in the ECPR / cardiac ECMO literature and the authors are to be congratulated. Of 53 cases, the indication for ECMO was IHCA in 12. Only 1/12 (6%) ECPR cases survived. 16/53 (32%) of the cohort survived to discharge and 14/53 (26%) survived long term. Only 7/53 (13%) of the cohort were neurological intact, with the other 7/14 (50%) of long term survivors having significant neurological problems. Adverse neurology came to light during longer term follow up. The authors do not give information about the ECPR process, CPR times etc as this is not the focus of the study and therefore these 12 ECPR cases cannot be compared easily with other reported series. The outcome for ECPR in this cohort is very poor. This is an early series and it is possible that ECPR processes have improved since these patients were treated, with better outcomes in the current era. The neurological outcome in the group as a whole, with a proportion of abnormalities coming to light with detailed longer term evaluation is an important reminder that the non systematic assessment at the time of hospital discharge following ECPR (which is presented in the majority of reports) is inadequate to detect problems.


Case series of post operative ECMO in single ventricle patients including 14/25 ECPR cases (Canadian). CPR times and ECPR processes are well described. Survival for the ECPR patients was 45% to discharge but fell to 32% over follow up with some late deaths (median follow up 27 months). Neurological assessment is not included. LOE is 4, quality fair, favorable for survival to discharge only.


This is a case series of 27 ECPR patients from Taiwan. This is a very thorough study. May overlap with Wu 2009. LOE is 4, quality good, supportive for survival and somewhat supportive for intact neurological survival. The process for delivery of ECPR is documented, including staffing, education, equipment, response times for the ECPR team and CPR times for all patients. The patients are a heterogeneous group with heart disease: post operative, secondary pneumonia, rejection, myocarditis etc. Patient survival to hospital discharge was 11/27 (41%) with one patient neurologically abnormal at that time. Outcome evaluation was based on PCPC scores at discharge but further clinical evaluation of patients was performed at follow up for a median of 3.2 years. A further 4 children were demonstrated to have neurological problems at this later stage. This finding confirms that the initial basic bedside assessment of ECPR survivors at discharge from hospital is inadequate to detect problems, with a final total of 6/27 (22%) intact neurological survival. The non survivors had longer CPR times (mean of 60 versus 45 minutes) and this was statistically significant (p presented as <0.05).
Of note the activation time for the ECPR team was also significantly longer for the non survivors (p presented as < 0.01). The provision of details on activation times, cannulation times and ECPR times are useful to the reader. Regarding patient selection, the paper states that the staff was educated to call for ECPR in all cardiac surgery patients early. This systematic approach is likely to have reduced selection bias in terms of offering ECPR.


LOE is 4, quality fair, supportive for survival to discharge, equivocal or borderline for intact neurological outcome. The patients included in this study may also be reported in Duncan (1996-1997). This is a follow up study of children with cardiac disease that underwent post operative ECMO (includes both ECPR and non ECPR patients) between 1987 and 1996 at one US institution. There were 26/96 (27%) long term survivors for the groups combined, when assessed at a median of 43 months post ECMO. There were 21 ECPR patients who had a survival to discharge rate of 48%. 8/21 (38%) surviving ECPR cases were included in the long term assessment. It is unclear if the missing patients were alive or dead at assessment. ECPR times were reported as 53 +/- 28 minutes.

The ECPR and non ECPR groups are not separated out, but ECPR is not presented as an adverse risk factor for outcome. Assessment consisted of telephone interviews with the parent, not face to face contact; therefore there may be some observation type bias in measurement of the outcomes. Of the whole group 62% were either moderately or severely disabled and 38% were either normal or had mild abnormalities. Therefore approximately 14% of ECPR patients were eventually neurologically intact. There were also a number of medical issues for the survivors such as re-operations (around 20%) and a range of cardiac problems.


Post cardiotomy ECMO series including 6 cases of ECPR of whom 3 survived (USA). Basic neurology at discharge was reported. LOE 4. Quality poor. Supports the question for survival and basic neurology only.


These are 2 case reports of children with cardiac disease who survived after prolonged ECPR of 176 and 97 minutes. One of the survivors had moderate developmental / neurological problems and the other is described as neurologically normal. The details of the neurological assessment in the normal case are not provided. The cases indicate that survival and reasonable neurological outcome is possible in children with cardiac disease after prolonged ECPR. However they do not provide sufficient detail to determine whether the neurology was truly intact.

LOE 4, quality poor, favorable for survival and basic neurological assessment.


LOE 4, quality fair (good method but small number of ECPR). Favorable for survival. Borderline or neutral for intact neurological survival.

Review of 39 post operative cardiac ECMO patients under 5 years old, of whom 12 had ECPR (Canadian). Patients were followed up for 2 years after ECLS with detailed medical mental and motor evaluation at least 6 months after discharge from hospital. There was a high rate of disability in survivors. Survival at discharge 46% and 2 years 41%. The ECPR group is not delineated in detail but it is stated that these patients did not differ statistically in terms of outcomes from the non ECPR group. Most survivors had a reduced mental score. The mean for all survivors DQ / IQ was 73 (reduced compared to normal population). There was mental disability in 50%, motor or sensory disability in 12.5% and many (88%) had behavioral disorders. There were also a high number with general medical health needs - (growth, feeding, pulmonary and cardiac medical issues). The high rates of these problems were attributed to the combination of heart disease plus severe low output / cardiac arrest, plus ECMO.


LOE is 4, quality fair, supportive for survival and favorable neurological outcome. Detailed neurological outcome not assessed. This is a cost utility study of salvage ECMO for 32 children after cardiac surgery and includes 18 ECPR cases (USA). There is limited information about ECPR selection and processes because this is not the focus of the study. Survival to discharge was 50% and the quality of life in survivors was QALY: 0.75 +/- 0.19, where 0 is equivalent to very poor life quality that is no better than death and 1 is equivalent to perfect health and development. Therefore on average the survivors had a quality of life that was 0.75% as good as a totally healthy normal person. Quality of life was assessed by parental completion of the Human Utilities Index 2. This is a 10 to 12 items questionnaire and therefore it is not a very searching evaluation and may miss things. However it is a validated generic measure used in many children.


This is a retrospective cohort study including a group of 64 children that had ECPR between 1995 and 2002, and a control group of 73 children with IHCA but not ECPR between 2000 and 2002 (USA). May overlap with Ravishankar 2006. LOE is 2, quality fair. Evidence is supportive for ECPR in children with isolated cardiac disease and opposing for ECPR in children with other medical conditions.

Outcome measures were survival to hospital discharge and early basic neurological assessment (change in PCPC and POPC scores). PCPC and POPC were collected in 10 of 13 survivors who were > 2 months at discharge, therefore no neurology outcome is available for 11 ECPR survivors: 8 children < 2 months survived and could not be assessed as too young. Detailed long term neurology is not presented therefore the study is equivocal for intact neurological survival.

One bias is probable differences in the selection process of cases that had ECPR versus the control group. The ECPR group had a higher proportion of children with isolated cardiac disease: 84% versus 30% in the control group (p<0.01). Possibility reflecting a view that isolated cardiac disease was more likely to benefit from ECPR, or a practice preference of the clinicians caring for the cardiac patients favoring ECPR. A least 5 of the other medical conditions patients offered ECPR had cardiac disease as one of their issues alongside other medical problems, therefore these could be viewed as 'poor cardiac candidates' but have been classified as 'non cardiac'.

ECPR group - Survival to discharge was 19/43 (44%) in children with isolated heart disease, but significantly worse (p<0.01) for children with other medical conditions 2/21 (9%). Therefore this study suggests unfavorable or equivalent results for ECPR compared to conventional treatment in the non cardiac patients.

Controls - 26/73 (36 %) survived to hospital discharge and this proportion did not differ from the ECPR group overall (cardiac + non cardiac combined). The survival proportion for cardiac controls was 33% and for other medical conditions was (36%) - all the survival proportions were statistically similar between controls and ECPR. However the CPR times were much longer in the ECPR patients than controls. In controls median CPR was 8 minutes versus 50 minutes in the ECPR group. This aspect favors ECPR, as 44% of the isolated cardiac disease patients survived, despite these relatively long periods of CPR. The authors did not find a link between CPR duration and outcome, with a 2 survivors having ECPR > 76 minutes.

Generalisability - The authors present the process for ECPR and protocols followed. A proportion of children had open chest massage but we are not given the detailed information on this / whether it was linked to outcome.


This is a case series of 32 children with cardiac disease that had CA in the cardiac ICU 1995 to 1997 (USA). Of 32 patients 4 were rescued by ECPR and all these 4 survived. Survival for the case series was 42%. LOE is 4, quality poor, favors the question. Patients were either post cardiac surgery (26) or cardiac cases without surgery (12).

Outcome is survival to discharge and mention is made of neurological abnormality in 4 (23%) long term survivors - not stated if these were ECPR children or not. The type of neurological evaluation is not stated and it is not clear whether all patients were seen at the study institution or what approach was taken for assessment.

The median duration of CPR was 20 minutes for the whole cohort and median of 16 minutes (range 12 to 20 minutes) for the ECPR patients. CPR duration overall was not related to patient outcome. The duration of CPR for the 4 ECPR patients is shorter than the times reported in other studies (medians elsewhere range between 40 and 50 minutes approximately), and this issue may have had implications for patient survival (favourable). It is not clear whether the authors used any different procedures or definitions in order to achieve these relatively rapid ECPR times. Retrospective series may have selection bias.


2 case reports of children with OHCA secondary to cardiac disease treated with ECPR in the ED (USA). The first case (survivor) had intermittent non-perfusing rhythm and had a period of ROSC in the ED before ECMO was initiated. The second child who had OHCA during flight to the hospital, died.

LOE is 4, quality poor (one of the two cases may not be 'true ECPR'), equivocal for the question. Included as ED based data in children is scarce.


Case series of mainly cardiac ECPR patients. 5/6 non cardiac cases survived. Results very positive – better than other reports to date.


This is a case series of 36 children with hypoplastic left heart syndrome that had ECMO at stage one surgery 1998 to 2005 (USA). Of 36, 22 had ECPR. May overlap with Morris 2004. LOE is 4, quality for this purpose is poor, supportive for hospital survival outcome only.

In the report, the ECPR cases are not well delineated from the non ECPR cases. The survival to hospital discharge is 39%, but in the discussion it is stated that 50% of patients placed on ECMO after a cardiac arrest survived to discharge. Further factors such as more
prolonged surgery and earlier requirement for ECMO (< 24 hours) post operatively were linked to poor outcome (ECPR parameters are not mentioned). There are only 7/36 (19%) late survivors from the group as a whole after a median follow up time of 20 months, suggesting considerable late attrition and deaths after the initial ECMO event. Neurology outcome is not included. Retrospective series may have selection bias.


This is a case series of ECPR for OHCA with hypothermia in 4 children from 2004 to 2006 (USA). LOE is 4, quality fair, supportive for the intervention. Survival and basic neurology. Systematic inclusion therefore bias minimized.

The authors are reporting the results of a clear and detailed protocol for use of ECMO in the scenario of hypothermia with non perfusing rhythm. 2/4 children who met inclusion criteria for their protocol survived and both are reported to have some degree of long term neurological impairment though mild to moderate. Both children had neuro rehabilitation and MRI scans details of which are included in the report.


This is a case series of hypothermic OHCA due to avalanches and exposure with intoxication. Patients were treated with emergency CPB during rewarming. There were 3 children in the avalanche group, all of whom died. LOE 4, quality for children was poor, unfavorable.

The group with exposure hypothermia due to intoxication did better, but none were children and this is an unlikely scenario for a child. One confounding factor is all the avalanche patients were in OHCA where as only 2/15 of the intoxication series were in OHCA. Children appear more often in series of drowning.


This is a case series of ECMO for children following cardiac surgery 2001-2004, of whom 28/94 had cardiac arrest / ECPR (USA). LOE is 4, quality poor, supportive.

The outcome in ECPR patients was 9/28 (32%) survivors to hospital discharge. No neurology data is presented. All ECPR was performed in the ICU and the majority had open chest CPR / cannulation. ECMO processes are described. CPR times are not given. No further details on the ECPR patients are presented. Retrospective series may have selection bias.


This is an evaluation of 682 ECPR cases < 18 years reported to the ELSO Registry 1992-2005. Overlap with Chan, 2008 and Barrett 2009. Also contains data on from other ELSO participant centers who have published on ECPR (Morris 2004, AlSoufi 2007) LOE is 4. Quality fair. Supportive for children with cardiac disease.

Registry issues:
1) The Registry contains ECMO data from 110 centres, of which 14 are outside the USA. A recent survey (VandenBerg SD, Hutchison JS, Parshuram CS. A cross-sectional survey of levels of care and response mechanisms for evolving critical illness in hospitalized children. Pediatrics. 2007;119(4):e940-6.) stated that 51 centres in US and Canada practice ECPR. Therefore ELSO Registry capture of events (110 reporting centers) in North America may be fairly good but for Europe and Asia (only 14 reporting centers) capture may be less complete.

2) Interpretation of the data is limited by the parameters included and the data quality. One concern is the robustness of the ECPR case definition and the tendency of some authors to report intermittent cardiac arrests or CPR for very low output as ECPR - this possibility cannot be excluded in the Registry data.

3) No CPR times are documented and therefore this important aspect could not be explored.

4) The survival status may reflect the status at discharge from one institution to another rather than to home, since transfer from a tertiary center is a common scenario and ELSO data submission would occur at that stage.

5) A combination support mode was reported in 56 patients (this may mean VV followed by VA) and VV support was reported in 6 patients. It is difficult to reconcile the use of VV ECMO with true ECPR, but these cases are only a minority of the whole sample.

The use of ECPR appears to be increasing over time (p<0.001) but the proportion discharged alive remained constant at 30-40% per year (p=0.96). The Registry does not contain clinical neurology data, but data related to specific complications. Seizures were reported in 83, abnormal radiology in 81 and brain death in 74 patients. A separate Registry study has shown that cardiac arrest (all types) is an adverse risk factor for neurological events in the ECMO population (Cengiz P, Seidel K, Rycus PT, Brogan TV, Roberts JS. Central nervous system complications during pediatric extracorporeal life support: incidence and risk factors. Crit Care Med. 2005;33(12):2817-24).

The majority of patients were cardiac (n=499, 42% survival), with the remainder: neonatal respiratory (n=34, 50% survival), pediatric
respiratory (n=43, 21% survival), sepsis (n=54, 22% survival) and others (n=52, 23% survival). Cardiac and neonatal respiratory failure diagnoses were linked to greater chance of survival (p<0.001). Non white race (p=0.01) and severity of acidemia before ECLS (p<0.001) were also linked to worse outcome. It is difficult to draw conclusion from the data presented on 34 neonates with respiratory failure that had ECPR, since the ELSO Registry for 2007 also reported data on 20,993 neonatal respiratory failure cases (survival 76%) that did not have ECPR indicating that the sample size for ECPR in this subset is a very small proportion of the whole. Since the data presented on these 34 neonates is limited in other respects the data must be interpreted with caution. The approach to cannulation (open chest versus peripheral) was not linked to survival. This was surprising to the authors as they expected open chest to allow for open chest CPR, which might be considered more effective. CNS damage (p=0.001), renal injury (p=0.009) and pulmonary hemorrhage (p=0.02) on ECMO were all linked with worse outcome.


This is a cardiac ECMO case series with 15 of 27 cases undergoing ECPR (USA) 2002-2004. LOE is 4, quality poor, supportive for survival only. ECPR process and inclusion is described. The mean CPR time was 63 min (range 4-127 min). 11 (73%) survived to discharge and 9 (60%) survived to longer term at median follow up time of 17 months. Neurology is not recorded.


This is a review of IHCA at a children’s hospital in Australia in which all CA events were recorded using Utstein template (1999-2002). LOE is 4, quality poor for this study question, favorable for survival. There were 111 arrests of which 89 occurred in the ICU and 22 in the ward. 12/89 (13%) patients with IHCA in the ICU were treated with ECPR of these 4/12 (33%) survived. CPR times were mean 91 +/- 49 minutes. No attempt was made to further analyze the ECPR data, as this was not the focus of the study. For all IHCA (ICU + ward) survival was 36% to discharge and 34% at 1 year. Neurology was not included.


This is a late follow up study of 15 survivors (out of 32 patients, 47% survival) from emergency bypass as treatment for OHCA with hypothermia (Switzerland). The early data relating to some of these patients may be included in Walpoth 1990. LOE is 4, quality good, supportive. Of the 15 long term survivors 4 were children aged 9 to 17 years. The study included MRI, EEG and detailed neurophysiology testing, with very encouraging results. All patients were leading a full life and none had more than minor abnormalities found at testing.


This is a case series of emergency bypass for children who had OHCA with hypothermia. The author presents 3 cases that he cared for and then reviews 9 further cases from 6 case reports / case series (Bolte 1988, Fox 1988, Norberg 1992, Letsou 1992, Antrefter 1994, Mair 1994). These case reports have not been included individually in the citation list. LOE is 4, quality poor, supportive for OHCA with hypothermia. All 12 children suffered hypothermia secondary to submersion or exposure and were treated with either fem-fem (7) or open chest (5) bypass. 10 survived and 9 were definite long term survivors. Of the survivors, 1 is described as normal, 5 to have clear neurological deficits although the nature of these abnormalities is not stated and 3 to have possible neurological deficits. The main problem with this data is the lack of clarity regarding the long term neurological outcomes. The survival rate is clearly favorable, but the further detail on the neurology would add to the quality of the evidence.


This is a retrospective cohort study of 316 patients with IHCA between 2000- 2006 (Taiwan). May overlap with Huang 2008. LOE is 2, quality poor, equivocal for the study question. This study consists of: ‘controls’ 212 patients that had conventional CPR, with survival at 1 year 17.9% and good neurological outcome (PCPC 1,2,3) 15.5%, and ‘ECPR or ECMO’ 64 patients that had either ECPR or post ROSC ECMO, with survival 21.9% at 1 year and good neurological outcome 17.8%. The difficulties with methodology with implications for interpretation:

1) There is no protocol or guideline to clarify in what circumstances patients were selected for ECMO versus conventional resuscitation.
2) ECPR and post ROSC ECMO are combined together and apart from survival rates no further information is given on this group. Post ROSC ECMO patients may differ from true ECPR patients.
3) The median CPR duration for the cohort (both groups) was 20.5 min range 5-124 minutes. The CPR times are not divided by whether or not ECMO / ECPR was used. None of the 49 patients with CPR longer than 60 minutes survived. This differs to some of
the other reports of ECPR and may mean that the procedure followed at this institution also differed or that these consisted of quite a few conventional CPR cases with very long resuscitation times.

4) The case mix overall is somewhat unusual in that it contains 43 hem oncology patients with 2.3% good neurological outcome - in other words nearly all of them died. The authors state that this is for cultural reasons and that DNAR orders are less often applied in their hospital for that reason. No break down of the ECPR and conventional resuscitation groups is given and therefore we do not know if these patients are distributed to both groups.


This is a case series of two children with myocarditis who had ED based ECPR and survived (Hawai). Both children are stated to have been spontaneously moving during ECPR, which suggests that some spontaneous cardiac output may have been present at least intermittently. Furthermore, both came to the ED breathing with natural airway and were semi electively intubated for suspected myocarditis, therefore both events were IHCA in the presence of senior personnel. On the face of it, the case report may read as a success for ECPR in an ED setting (and is a report of two heroic saves), but in fact the details indicate that these were special cases, with many similarities to other reports of successful cardiac ICU based ECPR. Basic neurology outcome data is reported as favorable in both children. LOE is 4, quality poor, equivocal


This is a case series of 35 children post cardiac surgery 1997-2004 (Japan) with emergency ECMO support for either cardiac arrest (ECPR) or severe low output state (not true ECPR) in the ICU, cath lab or operating room. The LOE is 4, quality poor and it is neutral to the question.

The authors changed from a conventional centrifugal pump based ECMO circuit (blood primed) to a smaller low prime circuit, also centrifugal, that was more rapid to prepare. 22 children were supported with the original (called conventional) circuit, of whom 1/22 (5%) survived to discharge and 12 were supported with the smaller rapid prime circuit of which either 3/12 (25%) or 5/12 (42%) survived to discharge. Both numbers are presented in the paper as being the proportion of survivors to discharge - the table of cases states that only 3 survived to discharge whereas the text paragraph states 5 survived.

Problems with interpretation of the data:
1) The authors do not state how many children were actually in cardiac arrest during cannulation and how many were in severe low output, but merge these conditions together.
2) It is stated that patients required emergency or salvage type ECMO support. Some of the patients were put on ECMO in the operating room. It is not entirely clear whether this was true emergency support and if it was, why this was the case given that presumably the bypass machine would have been weaned in a controlled manner.
3) The outcome with the rapid prime circuit was better, and this is attributed to time to support (shorter). No data on times are presented so it is difficult to be conclusive about this or to compare the times with other published series.
4) No neurology outcome data is presented.
5) As stated above there are discrepancies in the data for the rapid prime circuit outcomes.


This is a case series of Emergency department and inpatient based ECPR 1991-1997 that includes 3 of 25 children (remainder adults, USA). Data is clearly presented with a description of the process for ECPR. ECPR was not offered to every case of OHCA / IHCA but was mobilized based at the attending clinicians discretion, also based on the patients condition (not for severe acidemia) and duration of CA (ECPR was not activated if the arrest had been in progress for 30 minutes or longer). Outcome measure was survival to discharge. All 3 children (2 drowning and 1 tamponade on the ward) died. LOE is 4 and quality poor because of small number of children and lack of systematic approach to ECPR deployment. Study is unsupportive / unfavorable for OHCA / ward based IHCA use of ECPR for children.