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Neonatal carotid repair at ECMO decannulation: patency rates and early neurologic outcomes

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Abstract

Purpose—Neonates placed on veno-arterial extracorporeal membrane oxygenation (VA-ECMO) undergo either carotid repair or ligation at decannulation. Study aims were to evaluate carotid patency rates after repair and to compare early neurologic outcomes between repaired and ligated patients.

Methods—A retrospective study of all neonates without congenital heart disease (CHD) who had VA-ECMO between 1989 and 2012 was completed using our institutional ECMO Registry. Carotid patency after repair, neuroimaging studies, and auditory brainstem response (ABR) testing at time of discharge were examined.

Results—140 neonates were placed on VA-ECMO during the study period. Among survivors, 84% of carotids repaired and imaged remained patent at last study. No significant differences were observed between infants in the repaired and ligated groups regarding diagnosis, ECMO duration, or length of stay. A large proportion (43%) developed a severe brain lesion after VA-ECMO, but few failed their ABR testing. Differences in early neurologic outcomes between the two groups of survivors were not significant.

Conclusions—At this single institution, carotid patency is excellent following repair at ECMO decannulation. No increased incidence of severe brain lesions or greater neurosensory impairment in the repair group was observed. Further studies are needed to investigate the effects of ligation on longer-term neurocognitive outcomes.

Keywords

ECMO; Carotid artery repair; Auditory brainstem response; Neurologic outcomes

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1. Background/Purpose

ECMO (Extra-corporeal membrane oxygenation) has been successfully used as a means of cardio-pulmonary support in the neonatal population since the 1970s [1]. Although veno-venous ECMO (VV-ECMO) is increasingly performed, especially in older children having respiratory failure, veno-arterial ECMO (VA-ECMO) is still commonly used in neonatal patients [2]. VA-ECMO is preferentially used in neonates with cardiac dysfunction due to its ability to augment heart perfusion and function [3]. While the cannulation approach is guided by physiologic parameters, anatomic and size constraints, and established protocols, surgical management at time of decannulation remains controversial. The decision to repair or to ligate the cannulated carotid artery is influenced by theoretical concerns that ligation leaves the patient with a single carotid artery, possibly contributing to lateralized cerebrovascular injury later in life [4,5]. Conversely, carotid repair has the potential risks of stroke, anastomotic blowout, and aneurysm [6,7]. The current lack of knowledge regarding the continued patency of repaired carotid arteries further complicates the risk versus benefit analysis of an additional procedure.

We hypothesized that, for neonates placed on VA-ECMO, carotid artery ligation would increase the risk of medical and neurologic complications before discharge. To test this hypothesis, we compared rates of complications and neurologic imaging between neonatal patients having carotid repair or ligation at time of VA-ECMO decannulation. We also studied carotid patency after repair to aid in surgical decision-making.

2. Methods

To evaluate carotid artery patency rates and early neurologic imaging outcomes among neonates placed on VA-ECMO, we conducted a retrospective cohort study of all patients treated at the Vanderbilt Children's Hospital. Inclusion criteria were patients placed on VA-ECMO in the first 30 days of life. Neonates requiring VA-ECMO but having a congenital heart defect were excluded. Data were obtained from the active and robust ECMO Registry at Vanderbilt University, initially established in 1989, and from the neonatal intensive care unit database using Vanderbilt IRB-approved protocols (IRB #120200).

All VA-ECMO cannulations in this cohort of neonatal patients were performed via the right internal jugular vein and common carotid artery. The decision to repair or ligate the carotid artery was based on physician preference. If physician preference favored repair, the artery was assessed for intimal integrity, antegrade and retrograde flow, and the gap length between the two ends of the carotid artery. If arterial conditions were deemed acceptable based on those factors, the repairs were then performed in a primary fashion — interpositions, grafts or patches were not used. Carotid patency on Doppler ultrasound or magnetic resonance arteriography (MRA) was determined from the pediatric radiologists' imaging reports. Carotid imaging was performed by provider request rather than at pre-determined follow-up times.

To clarify the risks and benefits of carotid repair or ligation at time of decannulation, we further evaluated outcomes in a subset of patients born in or after 2000 due to consistency of

NICU medical practice, ECMO practices, and neuroimaging in this more recent era. Neuroimaging studies had been initially read by pediatric neuroradiologists, and these reports were reviewed for anatomic abnormalities; to assure consistency of interpretation for the current study, images were reevaluated by a single reviewer (NM). Brain lesions were classified as severe according to published literature in neonatal outcomes [8–10]. Severe brain lesions included: intraventricular hemorrhage Grade III–IV (Papile classification) [11], periventricular leukomalacia, ischemia, cerebellar or cortical hemorrhage, infarct, and hydrocephalus requiring shunt placement. Auditory neural function was evaluated using Auditory Brainstem Response (ABR) testing in the 48 hours before discharge [12]. Infants were classified as either pass or referred, unilateral or bilateral. ABRs were chosen as a surrogate for integrity of peripheral to central nervous system pathway function [13,14]. ABRs comprise a portion of an EEG, time-locked to an auditory stimulus and averaged over a large number of trials. Though ABR does not directly correlate with blood flow to the right side of the brain after a carotid artery reconstruction, it does provide us with a measure of functional integrity of peripheral to central nervous system pathways early in the infant's course, which we hypothesized to be decreased in the patients undergoing ligation. Although all children had common risk factors for hearing loss in addition to ECMO (e.g. NICU stay >48 h, gentamycin exposure), none had unique risk factors (i.e. craniofacial abnormalities, documented meningitis or congenital infections contributing to sensorineural hearing loss).

The student's t-test or Wilcoxon rank-sum test was applied to compare continuous variables, and the Chi-squared test or Fisher's exact test was used to compare categorical variables and frequencies between treatment groups.

3. Results

3.1. Carotid patency

At the time of this study, 818 total patients were listed in our active institutional ECMO registry. One hundred forty registered neonates without congenital heart disease (CHD) were placed on VA-ECMO (Fig. 1). Almost half of these patients had a diagnosis of congenital diaphragmatic hernia (CDH). Eighty-four patients (60%) survived until discharge and 51 of these survivors had repair of their cannulated carotid artery. Thirty-seven (73%) of the survivors who underwent repair had follow-up imaging to determine carotid artery patency. Imaging showed that 31 of these 37 (84%) patients had patent carotid arteries at last imaging study obtained at a median of 63 days (range 0–4231 days) after decannulation. Six of the patients with patent carotid arteries initially had Doppler ultrasounds of their carotid arteries more than 4 years after decannulation — all 6 of these carotid arteries remained patent. No aneurysms were reported.

Patients who had patent carotid arteries after repair had a shorter ECMO duration than those whose carotid arteries were not patent (median 6 vs. 5 days, $p = 0.04$). These two groups did not differ significantly in EGA, PMA or birthweight.

3.2. Neuroimaging and ABR

To evaluate most accurately the outcomes of neonates placed on VA-ECMO, a sub-group analysis was restricted to a cohort of patients ($n = 84$) who were placed on VA-ECMO between 1/1/2000 and 12/31/2012 (Fig. 2). This time period corresponds to consistency in ECMO protocols, neuroimaging, auditory brainstem testing protocols and established criteria for classifying brain lesions in neonates. All neonates from this cohort had neuroimaging (cranial ultrasound) on the day of ECMO cannulation and during ECMO. All survivors ($n = 42$) in this sub-group also had neuroimaging before discharge from the hospital with cranial ultrasound or MRI. Surviving infants had auditory brainstem function testing before discharge (40/42).

Neonates who died ($n = 42$) before discharge had a significantly longer duration of ECMO (9.7 vs. 6.2 days; $p < 0.001$) and were more likely to have a diagnosis of CDH (70% vs. 48%, $p = 0.03$) than survivors.

Survivors then were compared according to the repair status of their carotid artery upon decannulation (Table 1). No significant difference was observed between the groups with respect to gender, birth weight, EGA, or PMA. Median cannulation time was 6.5 days both for patients having carotid artery repair and for those who underwent ligation.

Of all neonates managed with VA-ECMO during this time period, 50% had a new finding of brain lesion during the ECMO run; 43% had findings consistent with a new severe brain lesion. On analysis of survivors, infants in the repaired group did not have worse outcomes compared to the ligated group (Table 2).

As a surrogate for functional brain damage, Auditory Brainstem Response (ABR) was evaluated in this sub-group. Thirty-eight infants passed the ABR bilaterally, indicating normal neurosensory auditory function at discharge. Only two infants in the ligated group referred bilaterally on ABR testing in the intensive care unit, indicating a neurosensory impairment. This observation was later confirmed on review of the medical record in early childhood, with repeated testing confirming the need for hearing augmentation devices.

4. Discussion

Although ECMO has now been used since the mid-1970s to support neonates having profound respiratory failure, questions regarding the optimal access route (VA or VV) and effects on neurologic outcome still exist, and practices vary between and even within institutions. A persistent controversy revolves around the treatment of the carotid artery when VA-ECMO is used in the neonatal population. In this single-institution study, we attempted to address outcomes after either carotid artery repair (including patency rates) or ligation at time of decannulation.

In a large group of neonates who were placed on VA-ECMO, we found that patency after carotid artery repair was excellent, both in the immediate time period after repair, as well as several years later. Almost half of all patients placed on VA-ECMO developed new brain lesions found either during or after ECMO, and the majority of these lesions were severe. In

patients who lived until discharge, the frequency of these lesions did not differ between patients undergoing either carotid artery repair or ligation.

When VA-ECMO was first introduced for neonates, carotid ligation was the norm [4,5,15–17]. However, concerns were subsequently raised about the neurologic after-effects of ligation, both on development of the childhood brain and later in life as an increased risk factor for stroke should the sole remaining carotid become stenotic. Several centers attempted to address these concerns by evaluating neuroimaging or neurologic clinical findings after carotid ligation in babies surviving VA-ECMO. Campbell et al. did not observe any increase in right-sided brain lesions on imaging studies of these infants who all underwent ligation, but did see a significant incidence of left-sided seizures, which were speculated to indicate right-sided damage [4]. When examining their own neonatal ECMO population who all underwent ligation, Schumacher et al. found an increased incidence of right-sided brain lesions on imaging as well as abnormal neuromotor findings on the left [5]. Other studies have noted questionable lateralizing signs and variable imaging studies after ligation as well [15,16,18]. In our study and experience, we observed a high frequency of severe brain lesions in all neonates placed on VA-ECMO, regardless of the status of the carotid artery after decannulation. Whether these lesions are related to the underlying severe illness of the infants or to ECMO itself has yet to be elucidated. The rate of sensorineural hearing loss in both groups was significantly lower than in previous studies, perhaps related to improvements in ECMO and medical management in this more recent cohort [19].

Due to the concerns of carotid ligation on neurologic development and late risk for stroke, many surgeons began repairing carotid arteries after decannulation. Repair has been documented without any evidence of increased right-sided brain emboli on imaging [7,17,20–22]. Doppler studies in these arteries before discharge have shown normal flow in the majority of repairs [7,17,23]. In addition, an earlier study showed increased symmetric blood flow to both sides of the brain after carotid repair compared to those patients who underwent ligation [21]. However, studies examining the patency of the artery over time have had mixed results. Desai et al. looked at patients after repair and found little or no change in the patency of the carotid artery from their status at discharge for the majority of patients [18]. Other studies have shown patency, but evidence of increased stenosis in the repaired carotid arteries several months to years after repair [24–26]. This stenosis may improve over time [27,28]. However, a recent study which evaluated patency in repaired carotid arteries 2 years after decannulation found that 56% of right common carotid arteries were occluded, calling to question those earlier results of good patency [29]. In our study, we observed excellent patency after repair, consistent with earlier findings. In a small cohort of our patients who had patent carotid arteries on initial imaging, carotid imaging was performed more than 4 years after decannulation. All of these patients had patent carotid arteries at that time. These observations conflict with the high late-occlusion rate found in Buesing et al.'s study and suggest that if carotid patency is found early, it is unlikely to change in ensuing years. The demonstration of improved patency with shorter ECMO times likely reflects the likelihood that the carotid artery has better structural integrity after a shorter ECMO run and is thus more appropriate for repair.

Many studies of neurologic findings in ECMO patients were completed decades ago in the relative infancy of ECMO. Since then, the etiological profile of patients undergoing ECMO has evolved and advances have been made in their management. An advantage of our study is that our patient outcomes in our sub-group reflect recent NICU ECMO practices as well as the effect of carotid repair or ligation on ABR as a surrogate for brain function or damage. In neonates treated with VA-ECMO since 2000, we found that carotid repair was not associated with an increased frequency of brain lesions after decannulation or with poor auditory neural function when compared to ligation.

We acknowledge several limitations with this study. Our carotid imaging studies were not obtained in a standardized fashion at a set time period for all patients. We attribute this to the fact that the majority of patients receiving repair earlier in the history of our ECMO program had patent carotid arteries at imaging studies performed many years after repair. Therefore, regular imaging did not appear to be needed anecdotally and would not have changed care. Although we have a large number of neonatal patients who have been placed on ECMO over the past 25 years, we still do not have a large enough sample size to appropriately detect small differences in outcomes. Another limitation is the retrospective collection of data for this study. Although data are missing and thus are subject to bias in retrospective data collection, our neuroimaging studies were reviewed for this study period and are complete for the last decade of patients.

In summary, we were able to demonstrate excellent patency of the carotid artery after repair in the immediate time period and also in a smaller cohort years after repair. We were also able to show that there appear to be no significant differences in the incidence of brain lesions in patients who undergo carotid repair at time of decannulation from VA-ECMO compared to those undergoing ligation. Questions remain about the relative incidence of right-sided brain lesions after decannulation in this population, as we did not observe any significant differences between groups. Due to the uncertain long-term effects of carotid artery ligation in these patients' future, further studies are needed to investigate the consequences this ligation has on longer-term neurocognitive outcomes.

References

1. Bartlett RH. Extracorporeal life support: history and new directions. *Semin Perinatol.* 2005; 29:2–7. [PubMed: 15921146]
2. Extracorporeal Life Support Organization. ECLS registry report. 2014.
3. Rais-Bahrami K, Van Meurs KP. Venoarterial versus venovenous ECMO for neonatal respiratory failure. *Semin Perinatol.* 2014; 38:71–7. [PubMed: 24580762]
4. Campbell LR, Bunyapen C, Holmes GL, et al. Right common carotid artery ligation in extracorporeal membrane oxygenation. *J Pediatr.* 1988; 113:110–3. [PubMed: 3385518]
5. Schumacher RE, Barks JD, Johnston MV, et al. Right-sided brain lesions in infants following extracorporeal membrane oxygenation. *Pediatrics.* 1988; 82:155–61. [PubMed: 3399288]
6. Arensman, RM., Short, BL. Extracorporeal membrane oxygenation. In: Goldsmith, JP., Karotkin, E., editors. *Assisted ventilation of the neonate.* 5. St. Louis, MO: Elsevier Health Sciences; 2010. p. 277-91.
7. Crombleholme TM, Adzick NS, deLorimier AA, et al. Carotid artery reconstruction following extracorporeal membrane oxygenation. *Am J Dis Child.* 1990; 144:872–4. [PubMed: 2198805]

8. Hintz SR, O'Shea M. Neuroimaging and neurodevelopmental outcomes in preterm infants. *Semin Perinatol.* 2008; 32:11–9. [PubMed: 18249235]
9. O'Shea TM, Allred EN, Dammann O, et al. The ELGAN study of the brain and related disorders in extremely low gestational age newborns. *Early Hum Dev.* 2009; 85:719–25. [PubMed: 19765918]
10. Maitre NL, Marshall DD, Price WA, et al. Neurodevelopmental outcome of infants with unilateral or bilateral periventricular hemorrhagic infarction. *Pediatrics.* 2009; 124:e1153–60. [PubMed: 19948617]
11. Papile LA, Munsick-Bruno G, Schaefer A. Relationship of cerebral intraventricular hemorrhage and early childhood neurologic handicaps. *J Pediatr.* 1983; 103:273–7. [PubMed: 6875724]
12. Kramer SJ, Vertes DR, Condon M. Auditory brainstem responses and clinical follow-up of high-risk infants. *Pediatrics.* 1989; 83:385–92. [PubMed: 2919142]
13. deRegnier R-A. Neurophysiologic evaluation of brain function in extremely premature newborn infants. *Semin Perinatol.* 2008; 32:2–10. [PubMed: 18249234]
14. Wilkinson AR, Jiang ZD. Brainstem auditory evoked response in neonatal neurology. *Semin Fetal Neonatal Med.* 2006; 11:444–51. [PubMed: 17015048]
15. Towne BH, Lott IT, Hicks DA, et al. Long-term follow-up of infants and children treated with extracorporeal membrane oxygenation (ECMO): a preliminary report. *J Pediatr Surg.* 1985; 20:410–4. [PubMed: 4045667]
16. Krummel TM, Greenfield LJ, Kirkpatrick BV, et al. The early evaluation of survivors after extracorporeal membrane oxygenation for neonatal pulmonary failure. *J Pediatr Surg.* 1984; 19:585–90. [PubMed: 6502432]
17. Adolph V, Bonis S, Falterman K, et al. Carotid artery repair after pediatric extracorporeal membrane oxygenation. *J Pediatr Surg.* 1990; 25:867–9. discussion869–70. [PubMed: 2205714]
18. Desai SA, Stanley C, Gringlas M, et al. Five-year follow-up of neonates with reconstructed right common carotid arteries after extracorporeal membrane oxygenation. *J Pediatr.* 1999; 134:428–33. [PubMed: 10190916]
19. Fligor BJ, Neault MW, Mullen CH, et al. Factors associated with sensorineural hearing loss among survivors of extracorporeal membrane oxygenation therapy. *Pediatrics.* 2005; 115:1519–28. [PubMed: 15930212]
20. Spector ML, Wiznitzer M, Walsh-Sukys MC, et al. Carotid reconstruction in the neonate following ECMO. *J Pediatr Surg.* 1991; 26:357–9. discussion359–61. [PubMed: 2056394]
21. Baumgart S, Streletz LJ, Needleman L, et al. Right common carotid artery reconstruction after extracorporeal membrane oxygenation: vascular imaging, cerebral circulation, electroencephalographic, and neurodevelopmental correlates to recovery. *J Pediatr.* 1994; 125:295–304. [PubMed: 8040781]
22. Graziani LJ, Gringlas M, Baumgart S. Cerebrovascular complications and neurodevelopmental sequelae of neonatal ECMO. *Clin Perinatol.* 1997; 24:655–75. [PubMed: 9394865]
23. Karl TR, Iyer KS, Sano S, et al. Infant ECMO cannulation technique allowing preservation of carotid and jugular vessels. *Ann Thorac Surg.* 1990; 50:488–9. [PubMed: 2400278]
24. Moulton SL, Lynch FP, Cornish JD, et al. Carotid artery reconstruction following neonatal extracorporeal membrane oxygenation. *J Pediatr Surg.* 1991; 26:794–9. [PubMed: 1895187]
25. Cheung PY, Vickar DB, Hallgren RA, et al. Carotid artery reconstruction in neonates receiving extracorporeal membrane oxygenation: a 4-year follow-up study. Western Canadian ECMO Follow-Up Group. *J Pediatr Surg.* 1997; 32:560–4. [PubMed: 9126754]
26. Jaillard S, Pierrat V, Truffert P, et al. Two years' follow-up of newborn infants after extracorporeal membrane oxygenation (ECMO). *Eur J Cardiothorac Surg.* 2000; 18:328–33. [PubMed: 10973543]
27. Taylor BJ, Seibert JJ, Glasier CM, et al. Evaluation of the reconstructed carotid artery following extracorporeal membrane oxygenation. *Pediatrics.* 1992; 90:568–72. [PubMed: 1408511]
28. Levy MS, Share JC, Fauza DO, et al. Fate of the reconstructed carotid artery after extracorporeal membrane oxygenation. *J Pediatr Surg.* 1995; 30:1046–9. [PubMed: 7472930]
29. Buesing KA, Kilian AK, Schaible T, et al. Extracorporeal membrane oxygenation in infants with congenital diaphragmatic hernia: follow-up MRI evaluating carotid artery reocclusion and neurologic outcome. *AJR Am J Roentgenol.* 2007; 188:1636–42. [PubMed: 17515387]

Appendix A. Discussions

Presented by Eileen Duggan, Nashville, TN

Unidentified speaker That was a very nice presentation, thank you. In 1990, simultaneous Vince Adolph, Scott Adzick and I each reported the first successful repairs of carotid artery after ECMO and we've gotten away from it primarily because most ECMO runs that we deal with are diaphragmatic hernia. It's a long duration of cannulation. You had a relatively short duration of cannulation. I think it really comes down to what are the criteria operatively about the carotid artery that makes it worth the risk of reconstruction. Could you tell us a little bit more about what you were using to distinguish those arteries that you would back away from repairing versus those you thought were safe to go on to repair?

Eileen Duggan Thank you for that question. In regards to the longer runs of the carotid artery, we did see that in terms of patency that the carotid arteries that remained patent did tend to have slightly shorter decreased times of ECMO runs than those who did not remain patent.

In regards to the criteria of the carotid artery, we tend to look at the ends of the carotid artery and how "ratty" they appear, I guess is a good word for it. If we feel like we are able to achieve good cleaning of the end and that the gap is not too short, then we do attempt to repair the carotid artery. We also make sure that it has antegrade and retrograde flow. If either one of those is missing, then we would not attempt to repair it.

Richard Ranne (Lubbock, TX) Thank you for the data. It's very helpful for this type of issue. Increasingly there is a trend towards percutaneous cannulation. Now does your institution not do this? Did you exclude these patients? Do you have any data on patency long term of those patients?

Eileen Duggan I believe that percutaneous cannulation in our institution has only recently been started and most people do not use that at this time, at least in this population. It is used more so in the adult population than in the neonatal population, and so I do not have any data on the patency of the carotid artery after this technique.

Unidentified speaker A couple questions. How long do you heparinize the patients after the repair? It's a small population and you did show some differences, some pretty significant differences, in the stroke rate and additional lesion rate for the repaired lesions. Is that due to the heparin? Finally, since you do not show any difference in outcomes between the two groups but you do show 10% occlusion rate and a higher incidence of significant neurologic issues, although not statistically different in this small population, is it worth it?

Eileen Duggan As to the duration of heparin after decannulation, I am sorry, I don't know the answer to that question right now.

As to the difference in neuroimaging outcomes after decannulation, we saw a slightly higher infarct rate in the ligation group and maybe a slightly higher hemorrhage rate in the repair group. We do not know how much of that is due to the heparinization itself.

Finally, in regards to the difference in neuroimaging outcomes, this group is fairly small and, as you saw, the difference was not statistically significant. We don't believe that those results are significant enough for us to not attempt repair. In addition to this, we are continuing to look at later developmental testing between these patients and our early results from that later developmental testing suggests that there may be an improvement in patients who underwent repair compared to ligation, so even though there may be a slight increase in the neuroimaging results in the patients who underwent ligation, since the neurodevelopmental testing results, which we do not have the data for right here, seemed to indicate a slightly better outcome in patients who underwent repair. We don't think yet that we should avoid repair in these patients.

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Fig. 1.
Characteristics of neonates undergoing VA ECMO between 1998 and 2012.

Fig. 2.
Characteristics of neonates undergoing VA ECMO between 2000 and 2012.

Table 1

Characteristics of ECMO survivors.

	Repaired (N = 16)	Ligated (N = 26)	P-value
Male	11 (69%)	18 (69%)	0.97
Birth weight (g)	3350 (2924–3883)	3077 (2710–3670)	0.15
EGA (wk)	38.5 (37.5–41)	38 (37–39)	0.52
PMA at cannulation (wk)	38.8 (37.7–41.1)	38.6 (38–39.6)	0.57
Cannulation time (days)	6.5 (5–9)	6.5 (5–9)	0.71

Expressed as n (%) or median (IQR).

Table 2

Outcomes of ECMO survivors.

	Repaired (N = 16)	Ligated (N = 26)	P-value
Neuroimaging at discharge			
New finding	9 (56%)	12 (46%)	0.53
Severe injury	7 (44%)	11 (42%)	0.93
Right-sided finding	2 (13%)	4 (15%)	0.80
Failed ABR	0 (0%)	2 (8%)	0.52
Length of hospitalization (days)	42.5 (25.5–71.5)	58.5 (48–81)	0.86

Expressed as n (%) or median (IQR).