Roller vs Centrifugal Pump for ECMO

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AWARD FOR EXCELLENCE IN LIFE SUPPORT
ELSO
CENTER OF EXCELLENCE
PLATINUM

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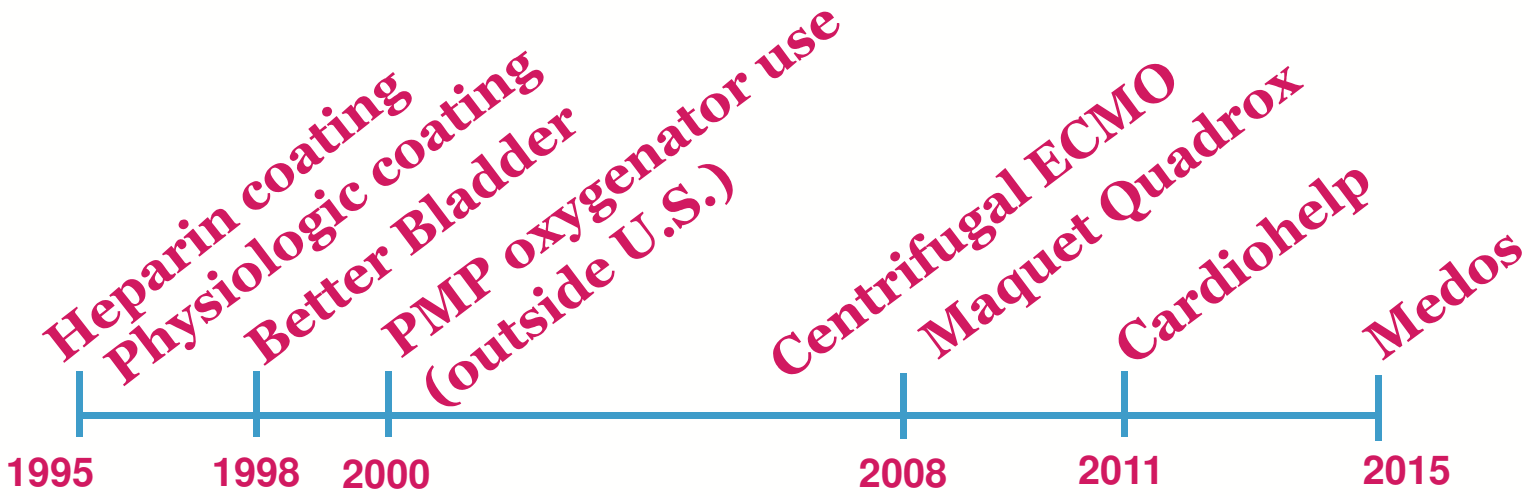
Disclosures

- No financial relationship with any of the products discussed

Evolution of the ECMO Circuit



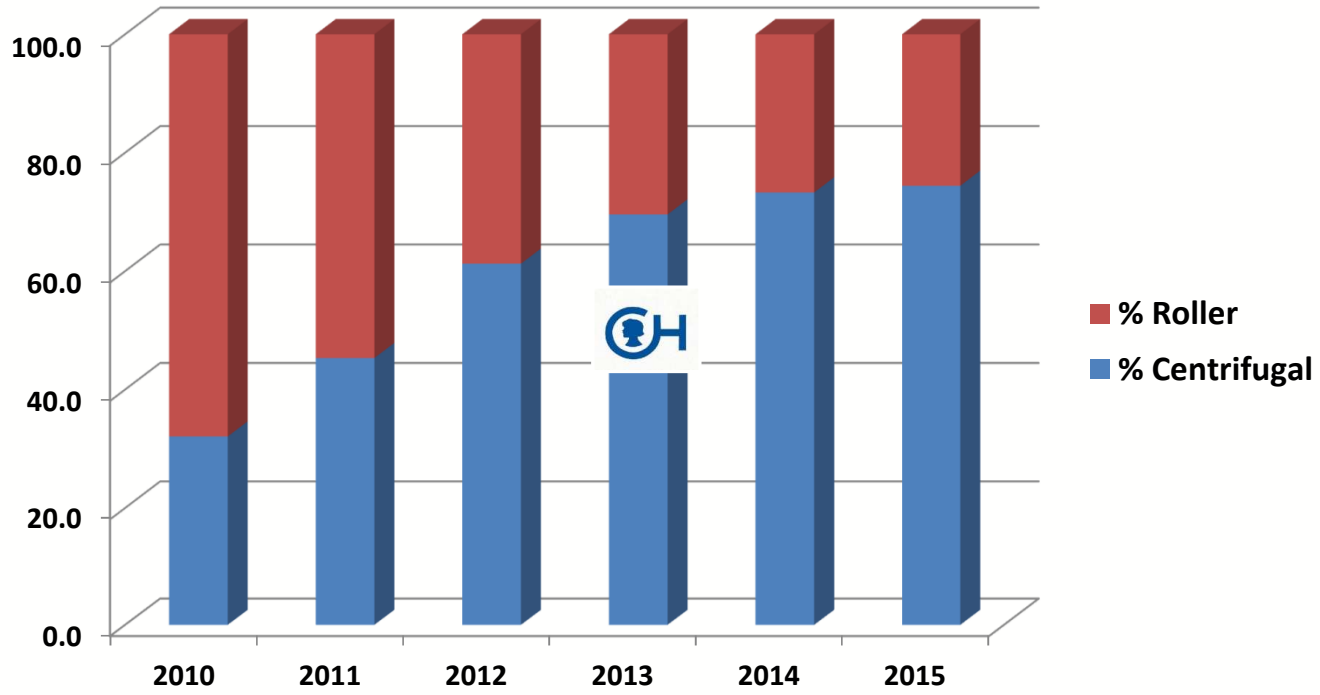
Evolution of the ECMO Circuit

- Physiologic/Heparin coating
- Better Bladder/Compliance chamber
- Oxygenators
- **Roller pump vs centrifugal pump**

Centrifugal Pump Advantages

- Elimination of raceway
- Simplified circuit
- Less inflammatory response/hemodilution
- Ease of transport
- Specific pump for pediatrics
- Improved design/air handling

Roller to Centrifugal



Based on ELSO Registry data for all patients < 18 years old.

Centrifugal Pump Options

Centrifugal Pump	Prime Volume	Maximum Flow	Transport Use Y/N	Approved Long term use Y/N
Revolution	57 ml	8.0 LPM	Yes (SCPC)	6 hrs
Rotaflow	32 ml	10 LPM	Yes	6 hrs
CentriMag	31 ml	10 LPM	Yes	Yes/30 days
PediMag	14 ml	1.5LPM	Yes	Yes/30 days
CardioHelp	600ml Full circuit	7.0 LPM	Yes	6 hrs

Pump Type for Neonatal ECMO-FPP AmSECT

	Revolution	Affinity	Rotaflow	CardioHelp	Centri/Pedimag	Roller
	CHOAtlanta >6kg CHOAlabama USC Phoenix Children's Advocate Holtz (C/PICU) MUSC >10kg	Arnold Palmer U of Minnesota St. Louis (C/PICU) Nicklaus U of Wisconsin Advocate	Arkansas (CICU) CHOColorado Doernbecher U of Oklahoma Texas Children's Primary Children's CHORichmond	Main Medical Boston >5kg Duke Columbia/NYP UCSF Montreal	U of Michigan Mayo Clinic Rochester WVU	Arkansas (NICU) Boston <5kg CHOAtlanta <6kg St. Louis (NICU) Miami Valley CHOP (NICU, Cardiac) Vanderbilt Holtz (NICU) MUSC <10Kg
ELSO since 2010 # of runs <5kg	1169	59	2969	248	155/1904	5298

CHOP Conversion

Roller

Centrifugal

Pediatric ECMO Outcomes: Roller vs Centrifugal Pumps

- ELSO data 2007-2009
- Survival to discharge
- ECMO-related complications

Table 5. ECMO-related Morbidities and Outcomes in Children (< 18 Years) Supported With VA ECMO Using Newer Model Centrifugal Pumps *Versus* Roller Pumps

	Propensity Score-matched Data			
ECMO-related Complications	Centrifugal (n = 57)	Roller (n = 57)	OR [95% CI]	*p*-value
Circuit complications n (%)				
Mechanical complications	13 (23)	14 (25)	0.91 [0.38–2.15]	0.826
Circuit thrombosis	19 (33)	3 (5)	9.00 [2.49–32.58]	< 0.0001
DIC - Bleeding complications	2 (4)	2 (4)	1.00 [0.14–7.35]	1.000
Cannula or surgical site bleeding	23 (40)	22 (39)	1.08 [0.51–2.28]	0.848
Hemolysis	12 (21)	1 (2)	14.93 [1.87–119.22]	0.001
ECMO support complications n (%)				
Inotrope use on ECMO	39 (68)	30 (53)	1.95 [0.91–4.18]	0.085
CPR on ECMO	0	2 (4)	0.96 [0.92–1.01]	0.496
pH < 7.2 on ECMO	0	3 (5)	0.95 [0.89–1.00]	0.243
pH > 7.6 on ECMO	3 (5)	2 (4)	1.53 [0.25–9.51]	1.000
Cardiac complications n (%)				
Myocardial stun	18 (32)	2 (4)	12.69 [2.78–57.89]	< 0.0001
Cardiac arrhythmias	7 (12)	7 (12)	1.00 [0.33–3.06]	1.000
Cardiac tamponade	6 (11)	1(2)	6.59 [0.77–56.60]	0.113
Hypertension	18 (32)	5 (9)	4.80 [1.63–14.05]	0.002
Respiratory complications n (%)				
Pulmonary hemorrhage	1 (2)	4 (7)	0.24 [0.03–2.19]	0.364
Pneumothorax	3 (5)	1 (2)	3.11 [0.31–30.84]	0.618
Gastrointestinal complications n (%)				
GI hemorrhage	0	2 (4)	0.97 [0.92–1.01]	0.496
Hyperbilirubinemia	21 (37)	0	1.58 [1.30–1.93]	< 0.0001
Acute renal failure n (%)	36 (63)	10 (18)	8.06 [3.38–19.22]	< 0.0001
Neurological injury n (%)				
Brain death	10	1 (2)	0.98 [0.95–1.02]	1.000
Hemorrhage	7 (12)	7 (12)	1.00 [0.33–3.06]	1.000
Infarction	8 (14)	0	1.16 [1.05–1.29]	0.006
Clinical seizure	5 (9)	2 (4)	2.64 [0.49–14.2]	0.438
EEG seizure	2 (4)	0	1.04 [0.99–1.09]	0.496
Survival n (%)	37 (65)	32 (56)		0.338
Transplant n (%)	5 (8)	2 (4)		0.438

CI, confidence interval; CPR, cardiopulmonary resuscitation; DIC, disseminated intravascular coagulation; ECMO, extracorporeal membrane oxygenation; EEG, electroencephalogram; GI, gastrointestinal; OR, odds ratio; VA, venoarterial.

Barrett C et al. ASAIO 2(2013)ElSO Registry 2007-2009

Centrifugal Pumps and Hemolysis in Pediatric ECMO: ELSO Registry

- 2010-2015
- Hemolysis
  - 5% Roller
  - 14% Centrifugal
- Limitations
- Association of hemolysis

Table 2
Complications of ECMO.

	Roller	Centrifugal	*p*-Value
Cannula problems	491 (9%)	892 (10%)*	0.001
Acidosis	351 (6%)	971 (11%)*	≤0.001
Circuit thrombosis	1323 (23%)	2327 (26%)*	≤0.001
Circuit bladder thrombosis	404 (7%)	216 (2%)*	≤0.001
Filter thrombosis	270 (5%)	354 (4%)	0.057
Other thrombosis	687 (12%)	1431 (16%)*	≤0.001
Oxygenator thrombosis	640 (11%)	1117 (13%)*	0.003
Bridge thrombosis	137 (2%)	120 (1%)*	≤0.001
Air in circuit	210 (4%)	347 (4%)	0.344
DIC	345 (6%)	474 (5%)	0.132
Hemolysis	291 (5%)	1272 (14%)*	≤0.001
Hyperbilirubinemia	212 (4%)	715 (8%)*	≤0.001
Renal failure	797 (14%)	1755 (20%)	≤0.001

* Indicates a p value <0.05.

O'Brien C et al. jped Surg 52(2017)

CHOP Next Steps

- Stop the use of the centrifugal ECMO circuit for *Cardiac patients*
- Compare patient outcomes
  - Equal amount of centrifugal pump *runs* and roller pump *runs*
- Decision based on data

CHOP Rapid Cycle Improvement
Roller vs Centrifugal

- Retrospectively compared patient outcomes
- Equal number of ECMO runs in each group
- Only Cardiac ECMO patients

CHOP Rapid Cycle Improvement Data Summary

ROLLER

- n = 85 runs
- 81 patients
- 647 days

CENTRIFUGAL

- n = 85 runs
- 82 patients
- 492 days

CHOP Rapid Cycle Improvement Variables (47)

PATIENT DEMOGRAPHICS

Age ▪ Weight ▪ Height
Gender ▪ Diagnosis ▪ Surgery
Genetic Syndrome
Extracardiac Anomalies

ECMO VARIABLES

Duration ▪ CPR? ▪ Pump Type
▪ Cannula Size ▪ Cannula Location
Component Change-outs ▪ Platelets
SCUF or Dialysis?

DAILY VALUES

Platelet Count ▪ Hgb ▪ Plasma Hgb
ACT ▪ pTT ▪ Anti Xa
Heparin Dose
Pump RPMs ▪ Weight-based flow
Pre- and Post-oxygenator pressures

OUTCOMES/COMPLICATIONS

Bleeding ▪ Arrhythmias ▪ Infection
Cardiac ▪ Pulmonary ▪ Neurologic
Renal
Length of Stay

Statistical Analysis

- STATA v10 (Stata Corp., College Station, TX)
- Wilcoxon Rank Sum test or Pearson chi-square
- Statistical significance established at a two-tailed p-value<0.05

Results: Demographics

	ROLLER *(n=85)*		CENTRIFUGAL *(n=85)*		
	Count	Percent	Count	Percent	p
Male	50	60%	48	59%	0.9
Neonate	33	39%	33	40%	0.9
Post-op ECMO	*61*	*72%*	*70*	*82%*	*0.1*
Known Syndrome	28	33%	29	35%	0.78
Chromosomal Anomaly	32	38%	31	38%	0.97
	Median	Range	Median	Range	p
Age at operation (days)	93	(1-6972)	73.5	(0-10905)	0.71
Weight at operation (kg)	4.55	(1.7-110)	4.4	(1.8-100)	0.69

Results: Ecmo Data

	ROLLER *(n=85)*		CENTRIFUGAL *(n=85)*		
	Count	Percent	Count	Percent	p
Survived ECMO	59	69%	48	56%	***0.11***
Initiation during CPR	32	38%	27	32%	0.42
Dialysis or SCUF	9	11%	6	7%	0.59
Platelets Given	74	87%	75	88%	1
	Median	Range	Median	Range	p
ECMO Duration (hrs)	112	(1-694)	94	(3-538)	***0.12***
Amount of Platelets	423	(35-12193)	370	(38-4773)	0.59

Results: Cannulation

	ROLLER *(n=85)*		CENTRIFUGAL *(n=85)*		
	Count	Percent	Count	Percent	p
Arterial					0.35
Chest	19	22%	25	30%	
Neck	63	74%	57	69%	
Femoral	3	3.5%	1	1%	
Venous					0.36
Chest	21	25%	25	29%	
Neck	62	73%	59	69%	
Femoral	2	2%	0	0%	

Results: Change Outs

	ROLLER *(n=85)*		CENTRIFUGAL *(n=85)*		
	Count	Percent	Count	Percent	p
Any Component Change	20	24%	28	33%	0.23
Oxygenator Change	10	12%	18	21%	*0.15*
Circuit Change	10	12%	5	6%	0.28
Bladder Change	6	7%	2	2%	0.28

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Centrifugal pumps and hemolysis in pediatric extracorporeal membrane oxygenation (ECMO) patients: An analysis of Extracorporeal Life Support Organization (ELSO) registry data. O'Brien C, Monteagudo J, Schad C, Cheung E, Middlesworth W. J Pediatr Surg. 2017 Jun;52(6):975-978. Epub 2017 Mar 16.

Results: DAILY VALUES

	ROLLER *(n=646)*		CENTRIFUGAL *(n=497)*		
	Mean	SD	Mean	SD	p
Max Flow (ml/kg/min)	117	40	116	41	0.77
Min Flow (ml/kg/min)	**95**	**42**	**88**	**40**	**0.005**
Max Pre-Oxy Pressure	**194**	**54**	**205**	**60**	**0.0013**
Min Pre-Oxy Pressure	**152**	**48**	**171**	**60**	**<0.0001**
Max Post-Oxy Pressure	**177**	**51**	**191**	**57**	**<0.0001**
Min Post-Oxy Pressure	**137**	**44**	**157**	**56**	**<0.0001**

Results: DAILY VALUES

	ROLLER *(n=494)*		CENTRIFUGAL *(n=649)*		
	Mean	SD	Mean	SD	p
Max Hemoglobin	**12.6**	**2**	**12.9**	**1.8**	**0.035**
Min Hemoglobin	11.5	1.8	11.6	1.9	0.5

Review of a Large Clinical Series

High Hemoglobin Is an Independent Risk Factor for the Development of Hemolysis During Pediatric Extracorporeal Life Support

Journal of Intensive Care Medicine
1-6

DOI: 10.1177/0885066617708992
journals.sagepub.com/home/jic
SAGE

Christopher L. Jenks, MD[1,2], Ayesha Zia, MD[3,4], Ramgopal Venkataraman, PhD[5,*], and Lakshmi Raman, MD[3,4,*]

Conclusions

- No significant differences in outcomes between roller and centrifugal pump runs
- Analysis of patients <10kg also showed no significant differences

Result: Surgeon preference to continue using roller pumps for all cardiac ECMO patients

QI Project Limitations

- Retrospective
- Single center
- Non-routine measures pfh, bilirubin
- Evaluation of further testing- ex. MRI of brain

Hemolysis on ECMO
Is the Pump Type to Blame

- Physical and non-physical factors contribute to RBC damage during ECMO
  - Patient characteristics
  - Temperature
  - Hemodilution
  - Anticoagulation strategy
  - Venous inlet pressure
  - Circuit components

Song Lou et al. Crit Care Med 2014; 42:1213-1220

Change

"If there is no struggle, there is no progress." - Frederick Douglass