What's New in Mechanical Circulatory Support?
2015 Summary

Journals

- ASAIO JOURNAL (53 articles)
- JOURNAL OF THORACIC AND CARDIOVASCULAR SURGERY (20 articles)
- JOURNAL OF CARDIAC FAILURE (15 articles)
- CIRCULATION HEART FAILURE (12 articles)
- JOURNAL OF THE AMERICAN COLLEGE OF CARDIOLOGY (1 article)

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The year 2015 was exciting for the field of mechanical circulatory support (MCS). Close to 101 articles were published in the 5 journals listed above with topics related to MCS. Overall, the survival of patients on MCS continues to improve, our knowledge about the impact of MCS on the human physiology is expanding and programs continue to develop innovative approaches to deal with adverse events. Moreover, the field of cardiac recovery is growing with newer studies testing novel cellular therapies during MCS support. Below is a summary of what was published in 2015 in the 5 journals cited followed by a comprehensive list.

MCS OUTCOMES

Registries and single center analyses demonstrated improvement in the outcomes of patients on MCS, especially on patients with short duration of heart failure (< 1 month).(98) However several characteristics can have a negative impact in survival like the severity of end-organ dysfunction calculated by the sequential organ failure assessment (SOFA) (12) and also high BNP levels after implantation. (29) The neutrophil-to-lymphocyte ratio (NLR), a marker of subclinical inflammation, was found to be an independent predictor of postoperative mortality (OR = 1.12, CI [1.02-1.31], p = 0.021) and of postoperative right ventricular (RV) failure (OR = 1.117, CI [1.04-1.20], p = 0.003). (49) Patients with high Doppler blood pressure (> 90 mmHg) had a higher risk of intracranial hemorrhage and aortic insufficiency. (91) And obesity remains a risk factor for heart failure readmissions after left ventricular assist device (LVAD) implantation.(82)

RV failure remains a common complication after LVAD implantation. In a single center analysis, patients with RV dysfunction requiring RVAD had worst survival compared to patients with RV failure treated with milrinone. (13) Lesser tricuspid annular plane systolic excursion and smaller left atrial diameter are independent predictors of the need for RVAD after LVAD implantation. (73)

Patients undergoing tricuspid valve procedures (repair/replacement) at the time of LVAD implantation had similar survival and readmission rates compared to patients without tricuspid valve procedures, and the tricuspid valve procedures were found to protect against further regurgitation. (2)

Patients with pump thrombosis undergoing pump exchange with a subcostal approach (with motor exchange only) were found to have a better 1 year survival compared to sternotomy (100% vs 63%). (14)

EFFECTS OF MCS ON PHYSIOLOGY

Platelet function

Bleeding is a frequent complication during mechanical support. The causes are multifactorial; however acquired von-Willebrand syndrome affecting platelet function remains an area of interest. A recent analysis demonstrated that MCS affects platelet functionality increasing the intra-platelet reactive oxygen species generation, mitochondrial damage, and platelet apoptosis. The degree of platelet dysfunction varies depending on the type of continuous flow device and could be associated with clinical events including major bleeding, infections, systemic inflammatory response syndrome, and RV failure. (19) Another study found that platelet dysfunction measured by the mitochondrial membrane potential was identified in patients who developed a systemic inflammatory response syndrome after LVAD implantation. (79)

Aorta and aortic valve

The lack of pulsatile flow has been associated with vascular changes in patients with MCS. Recent data demonstrated that patients with LVADs were found to have increased aortic wall thickness, vessel stiffness, collagen and smooth muscle content accompanied by a reduction in elastin and mucinous ground-substance content. (97)

The opening and closing of the aortic valve remains an area of attention. A recent study showed that the opening of the aortic valve during exercise at 3 months after implantation was a protective factor for the development of aortic insufficiency and was associated with lower readmissions rates, suggesting the hypothesis that cardiac rehabilitation could have an impact in outcomes. (42) Uriel et al, demonstrated that the effects of ramp studies in the aortic valve opening depends on the type of continuous LVAD (axial vs centrifugal) and the parameter slopes are different for each type of LVAD. (81)

MANAGEMENT OF SIDE EFFECTS

Several case reports for the treatment of adverse events were published including the utilization of intraventricular thrombolysis and tandem heart for pump thrombosis,(6) particle embolization for epistaxis,(7) left stellate ganglion blockade before surgical ganliolysis for refractory ventricular tachycardia,(8) octreotide for recurrent GI bleeding,(10) and interventional thrombectomy of a basilar artery thrombus (24).

CARDIAC RECOVERY

Stempien-Otero et al. published in the Journal of the American College of Cardiology the results of 6 patients with ischemic cardiomyopathy who underwent epicardial injections of autologous CD34+, CD34-, bone marrow mononuclear cells and a saline control immediately before LVAD implantation. (101) Contrary to preclinical models that showed increased vascularity with stem cell therapy, in this study the histological analysis demonstrated decreased density of endothelial cells in the myocardium injected with stem cells compared to the myocardium injected with saline. Several limitations could have been related to these results including the very limited sample size, the dose and mechanistic model of stem cell delivery and also a very advanced heart failure population with poor chances for recovery. These results should not be interpreted as a lack of cardiac recovery with stem cell therapy during MCS support; moreover these data will complement and be used to improve the experimental models to test the effects of adjuvant therapies for myocardial recovery.

ASAIO JOURNAL

January - February

1. Ryan TD, Jefferies JL, Zafar F, Lorts A, Morales DLS. The Evolving Role of the Total Artificial Heart in the Management of End-Stage Congenital Heart Disease and Adolescents. ASAIO J 2015; 61:8–14
2. ♦♦ Dunlay SM, Deo SV, Park SJ. Impact of Tricuspid Valve Surgery at the Time of Left Ventricular Assist Device Insertion on Postoperative Outcomes. ASAIO J 2015; 61:15–20
3. Wang Y, Koenig SC, Slaughter MS, Giridharan GA. Rotary Blood Pump Control Strategy for Preventing Left Ventricular Suction. ASAIO J 2015; 61:21–30
4. Zhu J, Kato H, Fu YY, Zhao L, Foreman C, Davey L, Weisel RD, Van Arsdell GS, Honjo O. Cavopulmonary Support with a Microaxial Pump for the Failing Fontan Physiology. ASAIO J 2015; 61:49–54
5. Doersch K, Sareyyupoglu. Mini Right Thoracotomy as an Approach to Aortic Valve Closure in an Assist Device Patient. ASAIO Journal 2015; 61:96–97
6. Agarwal R, Raina A, Lasorda DM, Moraca RJ, Bailey SH, Kanwar M, Sokos G, Murali S, Benza RL. Successful Treatment of Acute Left Ventricular Assist Device Thrombosis and Cardiogenic Shock with Intraventricular Thrombolysis and a Tandem Heart. ASAIO J 2015; 61:98–101
7. Letzen BS, Matouk CC, Bonde P. Particle Embolization for the Treatment of Life-Threatening Epistaxis in a Left Ventricular Assist Device Patient. ASAIO J 2015; 61:102–103
8. Smith DI, Jones C, Morrid GK, Kralovic S, Massey HT, Sifain A. Trial Ultrasound-Guided Continuous Left Stellate Ganglion Blockade Before Surgical Gangliolysis in a Patient with a Left Ventricular Assist Device and Intractable Ventricular Tachycardia: A Pain Control Application to a Complex Hemodynamic Condition. ASAIO J 2015; 61:104–106
9. Davis ME, Haglund NA, Tricarico NM, Matafonov A, Gailani D, Maltais S. Immediate Recovery of Acquired von Willebrand Syndrome After Left Ventricular Assist Device Explantation: Implications for Heart Transplantation. ASAIO J 2015;61:e1–e4
10. Loyaga-Rendon RY, Hashim T, Tallaj JA, Acharya D, Holman W, Kirklin J, Pamboukian SV. Octreotide in the Management of Recurrent Gastrointestinal Bleed in Patients Supported by Continuous Flow Left Ventricular Assist Devices. ASAIO J 2015; 61:107–109
11. Levy DT, Minamoto GY, Da Silva R, Puius YA, Peck N, Goldstein D, D'Alessandro D, Muggia VA. Role of Gallium SPECT-CT in the Diagnosis of Left Ventricular Assist Device Infections. ASAIO J 2015; 61:e5–e10

March – April

12. Zachary C. Landis, Behzad Soleimani, Edward R. Stephenson, Aly El-Banayosy, and Walter E. Pae. Severity of End-Organ Damage as a Predictor of Outcomes After Implantation of Left Ventricular Assist Device. ASAIO J. Mar-Apr 2015; 61(2): 127-132
13. Athanasios Tsiouris, Gaetano Paon e, Robert J. Brewer, Hasan W. Nemeh, Jamil Borgi, and Jeffrey A. Morgan. Outcomes of Patients with Right Ventricular Failure on Milrinone After Left Ventricular Assist Device Implantation. ASAIO J. Mar-Apr 2015; 61(2): 133-138
14. Allison P. Levin, Nir Uriel, Hiroo Takayama, Kanika P. Mody, Takeyoshi Ota , Melana Yuzefpolskaya, Paolo C. Colombo, Arthur R. Garan, Marija Dionizovik-Dimanovski, Robert N. Sladen, Yoshifumi Naka, and Ulrich P. Jorde. Device Exchange in HeartMate II Recipients: LongTerm Outcomes and Risk of Thrombosis Recurrence. ASAIO J. Mar-Apr 2015; 61(2): 144-149
15. Federico Pappalardo, Domenico A. Cristaldi, Ignazio L. Fragalà, Salvatrice Millesi, Michele De Bonis, and Antonino Gulino. Spectroscopic and Morphological Characterization of Inflow Cannulas of Left Ventricular Assist Devices. ASAIO J. Mar-Apr 2015; 61(2): 150-155
16. Yaron Hellman, Adnan S. Malik, Hongbo Lin, Changyu Shen, I-wen Wang, Thomas C. Wozniak, Zubair A. Hashmi, Arslan Shau kat , Jeanette Pickrell, Marco A. Caccamo , Irmina Gradus-Pizlo, and Azam Hadi. B-Type Natriuretic Peptide–Guided Therapy and Length of Hospital Stay Post Left Ventricular Assist Device Implantation. ASAIO J. Mar-Apr 2015; 61(2): 156-160
17. Yu Wang, Steven C. Koenig, Mark S. Slaughter, and Guruprasad A. Giridharan. Suction Prevention and Physiologic Control of Continuous Flow Left Ventricular Assist Devices Using Intrinsic Pump Parameters. ASAIO J. Mar-Apr 2015; 61(2): 170-177

May - June

18. Benton CR, Sayer G, Nair AP, Ashley K, Domanski MJ, Henzlova MJ, Anyanwu AC, Pinney SP. Left ventricular assist devices improve functional class without normalizing peak oxygen consumption. ASAIO J. 2015;61:237-243
19. ♦♦ Mondal NK, Sorensen EN, Feller ED, Pham SM, Griffith BP, Wu ZJ. Comparison of intraplatelet reactive oxygen species, mitochondrial damage, and platelet apoptosis after implantation of three continuous flow left ventricular assist devices: Heartmate II, Jarvik 2000, and HeartWare. ASAIO J. 2015;61:244-252
20. ♦♦ Doersch KM, Tong CW, Gongora E, Konda S, Sareyyupoglu B. Temporary left ventricular assist device through an axillary access is a promising approach to

improve outcomes in refractory cardiogenic shock patients. ASAIO J. 2015;61:253258. Accompanying editorial Maltais S, Stulak JM, Zalawadiya SK. Mechanical bridge to long-term device implant: The necessary step for better outcomes. ASAIO J. 2015;61:225-226

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22. Giridharan GA, Koenig SC, Soucy KG, Choi Y, Pirbodaghi T, Bartoli CR, Monreal G, Sobieski MA, Schumer E, Cheng A, Slaughter MS. Hemodynamic changes and retrograde flow in LVAD failure. ASAIO J. 2015;61:282-291
23. Giridharan GA, Koenig SC, Soucy KG, Choi Y, Pirbodaghi T, Bartoli CR, Monreal G, Sobieski MA, Schumer E, Cheng A, Slaughter MS. Left ventricular volume unloading with axial and centrifugal rotary blood pumps. ASAIO J. 2015;61:292-300
24. Zerdzitzki M, Schmid C, Hirt S, Wendl C, Schlachetzki F, Camboni D. Successful interventional thrombectomy of a basilar artery thrombus in a long-term LVAD patient. ASAIO J. 2015;61:e17-18
25. Jung MH, Hassager C, Balling L, Russell SD, Boesgaard S, Gustafsson F. Relation between pressure and volume unloading during ramp testing in patients supported with a continuous-flow left ventricular assist device. ASAIO J. 2015 May-Jun;61(3):307-12
26. Loghmanpour NA1, Kanwar MK, Druzdzel MJ, Benza RL, Murali S, Antaki JF. A new Bayesian network-based risk stratification model for prediction of short-term and long-term LVAD mortality. ASAIO J. 2015 May-Jun;61(3):313-23
27. Sindermann JR, Holthaus AJ, Schepers M, Schluter B, Martens S, Scherer M. False-positive hepatitis c testing in long-term LVAD support. ASAIO J. 2015;61:e19

July - August

28. Moazami N, Anandamurthy B. Acute Circulatory Support with ECMO: Great Achievements but Still a Long Road Ahead ASAIO J 2015;61; 371-372
29. ♦♦ Sato T, Seguchi, O, Iwashima Y et al. Serum Brain Natriuretic Peptide Concentration 60 Days After Surgery as a Predictor of Long-Term Prognosis in Patients Implanted With a Left Ventricular Assist Device. ASAIO J 2015;61; 373-378
30. Lovich MA,Pezone MJ, Wakim MG et al. Inhaled Nitric Oxide Augments Left Ventricular Assist Device Capacity by Ameliorating Secondary Right Ventricular Failure ASAIO J 2015;61;379-385
31. Dionizovik-Dimanovski M1, Levin AP, Fried J, et al. Correlation Between Home INR and Core Laboratory INR in Patients Supported with Continuous-Flow Left Ventricular Assist Devices. ASAIO J. 2015 Jul-Aug;61(4):386-90
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33. Wang D, Jones C, Ballard-Croft Cherr et al. Development of a Double-Lumen Cannula for a Percutaneous RVAD ASAIO J 2015;61; 397-402
34. Truby L, Mundy L, Kalesan B et al. Contemporary Outcomes of Venoarterial Extracorporeal Membrane Oxygenation for Refractory Cardiogenic Shock at a Large Tertiary Care Center ASAIO J 2015;61; 403-409
35. Haglund NA, Davis ME, Tricarico NM et al. Readmissions After Continuous Flow Left Ventricular Assist Device Implantation: Differences Observed Between Two Contemporary Device Types ASAIO J 2015;61; 410-416
36. Nielsen VG, Sobieski MA II, Slaughter, MS et al. Left Ventricular Assist Device– Associated Carbon Monoxide and Iron-Enhanced Hypercoagulation: Impact of Concurrent Disease ASAIO J 2015;61; 417-423
37. Karimov JH, Steffen RJ.; Byram N et al. Human Fitting Studies of Cleveland Clinic Continuous-Flow Total Artificial Heart ASAIO J 2015;61; 424-428
38. Rhodes LA, Sasser WC, Mcmahon WS et al. Transhepatic Cannulation for Venovenous Extracorporeal Membrane Oxygenation ASAIO J 2015;61; e29-e30

September - October

39. Halaweish I, Cole A, Cooley Elaine, Lynch WR, Haft JW. Roller and Centrifugal Pumps: A Retrospective Comparison of Bleeding Complications in Extracorporeal Membrane Oxygenation. ASAIO J 2015;61(5):496-501
40. Sieg Adam, Mardis BA, Mardis CR, Huber MR, New JP, Meadows HB, Cook JL, Toole JM, Uber E. Developing an Anti-Xa-Based Anticoagulation Protocol for Patients with Percutaneous Ventricular Assist Devices. ASAIO J 2015; 61(5):502-508
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42. ♦♦ Imamura T, Kinugawa K, Nitta D, Hatano M, Ono M. Opening of Aortic Valve During Exercise Is Key to Preventing Development of Aortic Insufficiency During Ventricular Assist Device Treatment. ASAIO J 2015;61(5):514-519
43. ♦♦ Tolpen S, Kanmaat K, Reider C et al. Programmed speed reduction enables aortic valve opening and increased pulsatility in the LVAD-assisted heart. ASAIO J 2015; 61:540-547
44. Taghavi S, Jayarajan SN, Mangi AA, Hollenbach K, Dauer E, Sjoholm LO, Pathak A, Santora TA, Goldberg AJ, Rappold JF. Examining Noncardiac Surgical Procedures in Patients on Extracorporeal Membrane Oxygenation. ASAIO J 2015;61(5):520-525
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46. Sparks J1, Epstein D, Baltagi S, Mehegan ME, Simpson KE, Canter CE, Silvestry S, Eghtesady P. Continuous Flow Device Support in Children Using the HeartWare HVAD: 1,000 Days of Lessons Learned From a Single Center Experience. ASAIO J. 2015;61(5):569-73

November - December

47. ♦♦ Boehme, AK, Pamboukian SV, Geroge JF, et al. Predictors of Thromboembolic Events in Patients with Ventricular Assist Device. ASAIO J. 2015;61(6):640-647.
48. Davis J, Sanford D, Schilling J, et al. Systematic Review of Outcomes After Noncardiac Surgery in Patients with

Implanted Left Ventricular Assist Devices. ASAIO J. 2015;21(11):648-651
49. Yost GL, Joseph CR, Tatooles AJ, Bhat G. Neutrophil-to-Lymphocyte Ratio Predicts Outcomes in Patients Implanted with Left Ventricular Assist Devices. ASAIO J. 2015;21(11): 664-669
50. Brunet J, Valette X, Ivascau C, et al. Extracorporeal Life Support for Refractory Cardiac Arrest or Shock: A 10-Year Study. ASAIO J. 2015;21(11):676-681
51. Shein SL, Maul TM, Li H, Kurland G. Surfactant Administration During Pediatric Extracorporeal Membrane Oxygenation. ASAIO J. 2015;21(11):682-687
52. Miller JR, Epstein DJ, Henn MC, et al. Early Biventricular Assist Device Use in Children: A SingleCenter Review of 31 Patients. ASAIO J. 2015;21(11): 688-694
53. Barbara DW1, Olsen DA, Pulido JN, et al. Periprocedural Management of 172 Gastrointestinal Endoscopies in Patients with Left Ventricular Assist Devices. ASAIO J. 2015;61(6):670-5

Journal of Thoracic and Cardiovascular Surgery

January - February

54. Anand J, Singh SK, Hernandez R, Parnis SM, Civitello AB, Cohn WE, Mallidi HR. Continuousflow ventricular assist device exchange is safe and effective in prolonging support time in patients with end-stage heart failure. J Thorac Cardiovasc Surg 2015;149:267-78
55. Bartoli CR, Restle DJ, Zhang DM, Acker MA, Atluri P. Pathologic von Willebrand factor degradation with a left ventricular assist device occurs via two distinct mechanisms: Mechanical demolition and enzymatic cleavage. J Thorac Cardiovasc Surg 2015;149:281-9
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March - April

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May – June

59. Cheng-Long Li, Hong Wang, Ming Jia, et al. The early dynamic behavior of lactate is linked to mortality in postcardiotomy patients with extracorporeal membrane oxygenation support: A retrospective observational study. J Thorac Cardiovasc Surg 2015;149(5):1445–1450
60. Prashant N. Mohite, Diana Garcia-Saez, Aron-Frederik Popov, Andre R. Simon. Use of trifurcate arch graft in left ventricular assist device implantation via the sternal sparing approach. J Thorac Cardiovasc Surg 2015;149(6):e113–e114
61. Evgenij V. Potapov, Tomohiro Saito, Alain Carpentier, et al. Long-term follow-up of a patient with Uhl anomaly after biologic and mechanical circulatory support. J Thorac Cardiovasc Surg 2015;149(6):e115–e116

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64. Mallidi HR, Anand J, Singh SK. Long-term mechanical circulatory support: A new disease state? J Thorac Cardiovasc Surg 2015;150: e13–e14
65. Vincenzo Tarzia, Giacomo Bortolussi, Roberto Bianco et al. Extracorporeal life support in cardiogenic shock: Impact of acute versus chronic etiology on outcome. J Thorac Cardiovasc Surg 2015;150(2):333–340

September – October

66. Jamshid H. Karimov, Nader Moazami, Mariko Kobayashi et al. First report of 90-day support of 2 calves with a continuous-flow total artificial heart. J Thorac Cardiovasc Surg 2015;150(3):687–693.e
67. Andrew Callington, Quan Long, Prashant Mohite et al. Computational fluid dynamic study of hemodynamic effects on aortic root blood flow of systematically varied left ventricular assist device graft anastomosis design. J Thorac Cardiovasc Surg 2015;150(3):696–704
68. Fang Yang, Robert L. Kormos, James F. Antaki. High-speed visualization of disturbed pathlines in axial flow ventricular assist device under pulsatile conditions. J Thorac Cardiovasc Surg 2015;150(4)
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72. Masaki Tsukashita, Hiroo Takayama, Koji Takeda, et al. Effect of pulmonary vascular resistance before left ventricular assist device implantation on short- and long-

term post-transplant survival. J Thorac Cardiovasc Surg. 2015;150(5):1352–1361.e2

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Journal of Cardiac Failure

January – February

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75. Snehal R. Patel, Alan Sileo, Ricardo Bello, et al. Heart Transplantation Versus Continuous-Flow Left Ventricular Assist Device: Comprehensive Cost at 1 Year. Journal of Cardiac Failure 2015;21(2): 160–166

March - April

76. ♦♦ Michael S. Kiernan, Amy L. French, David Denofrio, Yuvrajsinh J. Parmar, Duc Thinh Pham, Navin K. Kapur, Natesa G. Pandian, and Ayan R. Patel. Preoperative Three-Dimensional Echocardiography to Assess Risk of Right Ventricular Failure After Left Ventricular Assist Device Surgery. Journal of Cardiac Failure. 2015;21(3):189-197
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May – June

78. ♦♦ Charanjit S. Rihal, Srihari S. Naidu, Michael M. Givertz et al. 2015 SCAI/ACC/HFSA/STS Clinical Expert Consensus Statement on the Use of Percutaneous Mechanical Circulatory Support Devices in Cardiovascular Care. Journal of Cardiac Failure 2015;21(6):499–518

July – August

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81. Uriel, Nir et al. Left Ventricular Decompression During Speed Optimization Ramps in Patients Supported by Continuous-Flow Left Ventricular Assist Devices: Device-Specific Performance Characteristics and Impact on Diagnostic Algorithms. Journal of Cardiac Failure 2015;21(10):785 - 791
82. Mohamedali, Burhan et al. Obesity as a Risk Factor for Consideration for Left Ventricular Assist Devices. Journal of Cardiac Failure 2015;21(10):800 – 805
83. Bruce, Courtenay R. et al. Reasons Why Eligible Candidates Decline Left Ventricular Assist Device Placement. Journal of Cardiac Failure 2015;21(10):835 - 839
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85. Dunlay, Shannon M. et al. Use of Post-acute Care Services and Readmissions After Left Ventricular Assist Device Implantation in Privately Insured Patients. Journal of Cardiac Failure 2015;21(10)816 – 823
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88. ♦♦ Sintek MA, Gdowski M, Lindman BR, et al. Intra-Aortic Balloon Counterpulsation in Patients with Chronic Heart Failure and Cardiogenic Shock: Clinical Response and Predictors of Stabilization. J Card Fail. 2015;21(11):868-876

Circulation: Heart Failure

January

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March

90. Lindsay M. Ryerson, Gonzalo Garcia Guerra, Ari R. Joffe, Charlene M.T. Robertson, Gwen Y. Alton, Irina A. Dinu, Don Granoski, Ivan M. Rebeyka, David B. Ross, and Laurance Lequier , for the Western Canadian Complex Pediatric Therapies Program Follow-Up Group. Survival and Neurocognitive Outcomes After Cardiac Extracorporeal Life Support in Children Less Than 5 Years of Age: A Ten-Year Cohort. Circ Heart Fail. Mar 2015;8 (3): 312-321, doi:10.1161/CIRCHEARTFAILURE.114.001503

May

91. ♦♦ Saeed O, Jermyn R, Kargoli F, Madan S, Mannem S, Gunda S, Nucci C, Farooqui S, Hassan S, McLarty A, Bloom M, Zolty R, Shin J, D'Alessandro D, Goldstein DJ, Patel SR. Blood pressure and adverse events during continuous flow left ventricular assist device support. Circ Heart Fail. 2015;8:551-556
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sites, and left ventricular assist device implanting centers. Circ Heart Fail. 2015;8:629-635

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94. Kapur NK, Jumean M, Halin N, Kiernan MS, DeNofrio D, Pham DT. Ventricular square-wave response: Case illustrating the role of invasive hemodynamics in the management of continuous-flow left ventricular assist device dysfunction. Circ Heart Fail. 2015;8:652-654

July

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