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Technique Article

Novel Multi-Functional Life Support System

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Abstract: Concepts of cardiopulmonary support (CPS), extracorporeal membrane oxygenation (ECMO), and ventricular support (VS) have been thoroughly studied and refined. These perfusion adjuncts often require multiple devices, skill sets, and significant financial burden to purchase, maintain, deploy, and use. We describe a novel system that is rapidly deployable, user-friendly, portable, safe, and economical. Over a 1-year period we have used a multi-functional life support system (MLS) in the cardiac catheterization laboratory, cardiovascular intensive care unit, and cardiac surgical suites. Further, we have conducted multiple transports within the hospital and one to an alternate facility. Applications have included ECMO, cardiopulmonary resuscitation-supported cardiogenic shock, high risk percutaneous coronary intervention (PCI), valvuloplasty, right ventricular assist device transition to ECMO post cardiotomy, left ventricular assist device transition to ECMO, ventricular septal defect closure, and ECMO transition to conventional cardiopulmonary bypass (CPB). Duration of support has ranged from approximately 39 minutes to several days. **Keywords:** extracorporeal membrane oxygenation (ECMO), percutaneous ventricular assist device, cardiopulmonary support, portable cardiopulmonary life support, ventricular assist. *JECT. 2010;42:232–234*

CPS, ECMO, and VS are all common therapies indicated for various pathologies and circumstances (1–6). While there are many devices to perform these support modalities there are significant costs associated with purchasing and maintaining the related hardware. Additionally, the corresponding disposable supplies may remain on the shelf for a significant period of time until a suitable situation arises. As many of these devices may not be used routinely, ongoing training is essential to maintain operator proficiency. This may result in significant financial burden for the perfusion department and/or medical facility.

This prompted the pursuit of a system that could be used for multiple modalities in various settings with a range of circumstances. We established a single disposable tubing pack maintained on the device that can be prepared in a few minutes with a 1 L bag of crystalloid. The system also encompasses an insertion package containing a standard percutaneous cannula set (Edwards Lifesciences, Irvine, CA) and access kit. The basic premise was to have a safe, efficacious system with a small foot print that could be managed and transported by a single individual.

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MATERIALS AND METHODS

The MLS hardware utilizes the Jostra Rotaflow centrifugal pump (Maquet Cardiopulmonary, Hirrlingen, Germany) mounted on a single pole trolley (Figure 1). The Rotaflow has an ultrasonic bubble detector and flowmeter integrated with its 32 mL disposable head. It is capable of delivering flows up to 10 L/min at 5000 rpm. It weighs 32 lbs and has built-in battery back-up of 1 hour when fully charged. Further, we have adapted a handle to facilitate removal from the trolley during transport. This allows the pump to be carried or placed on the patient's bed during transfer.

The single pole trolley also contains a removable hand crank, sechrist blender (Sechrist, Anaheim, CA) with gas lines, DLP pressure box (Medtronic Cardiopulmonary, Minneapolis, MN), removable HKH holder (Maquet Cardiopulmonary, Hirrlingen, Germany), and M3 monitor

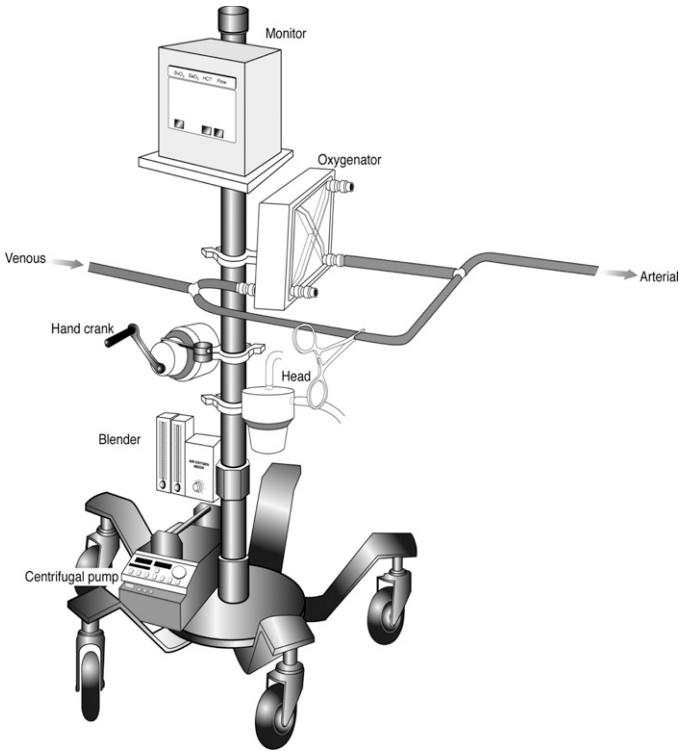

Figure 1. MLS illustrating key components.

(Spectrum Medical Inc., Columbia, SC). The M3 monitor is a non-invasive, real time monitoring device for SaO2, SvO2, and Hct and does not require calibration prior to use. This device is also capable of measuring flow, detecting micro-emboli, and collecting data for electronic charting.

The disposable circuit contains the Quadrox D oxygenator (Maquet Cardiopulmonary, Hirrlingen, Germany) with polymethylpentene fibers that are resistant to plasma leakage during long-term support. It also contains a hydrophobic filter at its apex, which facilitates priming and removal of air that may be inadvertently delivered to the oxygenator. The circuit utilizes 3/8th inch venous and arterial lines that are heparin bonded. Other components of the circuit are DLP pressure display set (Medtronic Cardiopulmonary, Minneapolis, MN) and high flow stop cock used for the attachment of a hemoconcentrator as needed. In the event we use MLS for right or left heart support we bypass the oxygenator while maintaining its integrity to be used as circumstances dictate. The MLS system was designed for flows up to 7 L/min and has a dynamic priming volume of ~200 mL to ~450 mL depending upon the components used.

RESULTS

We have used MLS for 25 procedures over a 1 year period from February 1, 2008 to February 1, 2009. Fourteen procedures were conducted as left ventricular support without an oxygenator (Table 1). Eleven procedures were conducted with an oxygenator (Table 2). Three of the procedures were converted to an alternate modality. One procedure was right ventricular support transition to ECMO, one was left ventricular support transition to ECMO, and one was ECMO support transition to conventional CPB for coronary artery bypass grafting X3.

DISCUSSION

We hypothesize that MLS may be suitable for many other procedures that we have yet to exploit. Such procedures include liver transplantation, thoracoabdominal aortic aneurysm repair with left heart bypass, and lung transplantation. These are just a few procedures that we use to routinely provide some form of extra-corporeal support where technology and/or techniques have advanced to the point that support is not often required. This results in a situation where many times we simply standby and would use the device if needed. Other procedures that may be suitable for MLS include hypothermic resuscitation, trauma with flash pulmonary edema, and pulmonary embolism.

There have been some studies conducted to evaluate the impact of cardiopulmonary support on survival rates following cardiac arrest (7–10). One such study reported the median survival to discharge after emergency medical services to be 6.4% for out-of-hospital cardiac arrest and 13.4–17% for in-hospital arrest (10). This may be the most prudent application where systems such as MLS may have the largest impact for the perfusion community as a whole, and may present many unforeseen opportunities. This being most evident with portable miniaturized

Table 1. Data and demographic information related to the 14 left ventricular support procedures.

Procedure (n)	Age (years)	BSA	Flow (L/min)	Pump Time (mins)	ACT (sec)	EF (%)	IABP (% of n)	Transports
High Risk PCI (10)	66 ± 13	2.10 ± 0.27	2.84 ± 0.55	90 ± 44	267 ± 23	20 ± 7	55%	0
Valvuloplasty (1)	63	1.8	2.1	39	303	20	0	0
VSD Closure (1)	74	2.0	2.4	110	280	25	100%	0
Cardiogenic Shock (2)	52 ± 6	2.1 ± 0.08	3.8 ± 0.6	3096 ± 996	300 ± 28	5 ± 0	100%	3.5 ± 2

VSD, ventricular septal defect; BSA, body surface area; ACT, activated clotting time; EF, ejection fraction; IABP, intra-aortic balloon pump.

Table 2. Data and demographic information related to the 11 ECMO support procedures.

Procedure (n)	Age (years)	BSA	Flow (L/min)	Pump Time (mins)	ACT (sec)	EF (%)	IABP (% of n)	Transports
High Risk PCI (7)	63 ± 11	2.0 ± 0.3	3.5 ± 1.0	885 ± 1596	238 ± 29	22 ± 9	57%	3.3 ± 1.5
Post Cardiotomy (2)	42 ± 10	2.1 ± 0.07	3.5 ± 0.9	660 ± 85	263 ± 24	15 ± 0	100%	3 ± 1
Cardiogenic Shock (2)	53 ± 30	1.93 ± 0.2	3.6 ± 1.9	978 ± 1035	284 ± 117	7.5 ± 3	100%	2.5 ± 2

BSA, body surface area; ACT, activated clotting time; EF, ejection fraction; IABP, intra-aortic balloon pump.

cardiopulmonary support devices such as Lifebridge B_2T (Lifebridge, Munich, Germany), and Cardiohelp (Maquet Cardiopulmonary, Hirrlingen, Germany) on the horizon. As our current system does not facilitate the incorporation of a cardiotomy or venous air handing devices for air removal, we feel it un-suitable for routine CPB at this time. Our future hopes are for a design adaptable to meet all of our extracorporeal support needs.

CONCLUSION

There are many options available today to perform CPS, ECMO, and VS. Depending upon the modality and circumstance there are a multitude of devices to select from that work exceptionally well for a given application. The crux of the situation lies in the ability to maintain multiple hardware, disposable supplies, and personnel to operate the equipment. The MLS system is not only rapidly deployed, user-friendly, portable, safe, and economical but it can be used for many therapies including ECMO, cardiopulmonary resuscitation-supported cardiogenic shock, high risk PCI, valvuloplasty, right heart failure, left ventricular assist device transition to ECMO, and post cardiotomy. While our future hopes are to have one system to perform all of our extracorporeal needs, the MLS system in its current configuration is not recommended for routine CPB, due to lack of adequate gross air handling apparati. Future studies of portable cardiopulmonary support devices should include the ability to handle air, which may assist with transition to routine CPB therapies.

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