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Optimization of Artificial Vascular Tissue Bioreactor for Use with Peristaltic LVAD

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Study: Cardiovascular disease is the largest source of mortality in the world, and has been projected to reach an annual death toll of 20 million by the year 2030. A substantial demand exists for a source of tissue engineered vascular tissue for the replacement of vessels. Traditional sources of tissue engineered vascular tissue are low-throughput and require several weeks to prepare. This makes tissue engineered vascular grafts infeasible for emergency situations where surgery must take place in a short time span. In this study, our team investigates a method for optimizing 3D endothelial cell culture to remove unnecessary culture time, and to allow for the accurate projection of time to confluence and implantation viability. In addition, this is a preliminary study for a novel LVAD developed by our team that utilizes a robust vascular graft for peristaltic pumping, which requires a continuous stream of uniform vascular tissue for experimentation.

Methods: We characterize free ICAM concentration using ELISA. We further measure metabolism of ATP, ADP, and AMP per unit mass of cells under variable growth conditions using HPLC and Bradford assay, under both continuous flow and static growth conditions. Time to confluence projections are confirmed using image processing and whole cell stains. Two variable conditions are examined, achieved by 3D printing cell growth environments using an inert polymer. The first is angled planar growth of cells on 0, 5, 10, 20, 30, and 40 degree slopes with separate metabolic analyses performed at three increasing topographical elevations. The second variable condition is cylindrical section growth of cells at 1, 2, and 3 cm diameter, with three separate metabolic analyses performed on the valley and sloped walls. Measurements performed at 1–4 day incubation time.

Results: We demonstrate cell growth and variable metabolism at all variable growth conditions. Our data can be used to project time to confluence for all growth conditions investigated.

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Flow Distribution Analysis in Peripheral VA ECMO By Interposition Graft

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Study: The most common sites for establishing peripheral ECMO are femoral artery and vein. The main goal of ECMO cannulation is to provide the least traumatic and most durable and simplified method for delivering the blood to and from the circuit. During peripheral VA ECMO, one of the complications of retrograde flow into femoral artery is lower limb ischemia. One method to avoid this is to anastomose end-to-side a Dacron graft to the common femoral artery. However, its upward and downward flow distributionIs is not clear.

Methods: A computational approach was employed to carry out the investigation on a 3D patient-specific femoral artery model by means of Computational Fluid Dynamics (CFD) simulations. In our model we compared the blood flow distribution of the interposition graft for AV ECMO simulating different grade of Superficial Femoral Artery (SFA) and Profound Femoral Artery (PFA) caliber reduction.The pump output was set at 2.5 L/m^2/min and the anastomosis site was at the common femoral artery with 10 mm diameter straight dacron tube in all cases.

Results: With no caliber reduction of SFA and PFA, we had only 78% of the blood flow towards the Common Femoral Artery (CFA) (tab. 1). Interestingly, closure of the SFA and progressive reduction of caliber in the PFA, obtained with external snare provided the best flow distribution. Actually, total occlusion of SFA and 50% to 70% caliber reduction of PFA, achieved up to 91% forward flow without the need of excessive augmentation of the pump output. The use of interposition graft allows limb perfusion but with significant blood loss central perfusion (22%). A better central blood flow support can be achieved by external manipulation of peripheral vascular resistances rather than by escalating the pump output.

Flow distribution for different degree of SFA and PFA stenosis

	SFA Stenosis [%]	PFA Stenosis [%]	CFA flow [%]	SFA flow [%]	PFA flow [%]
Case1	0	0	78	15	7
Case2	50	50	80	14	6
Case3	70	70	83	11	6
Case4	100	50	87	0	13
Case5	100	80	91	0	9