Lunenfeld-Tanenbaum Research Institute
Sinai Health System

TECHNOLOGY TRANSFER & INDUSTRY LIAISON
600 University Avenue, Room 843
Toronto, Ontario, Canada, M5G 1X5
www.lunenfeld.ca/techtransfer

TECHNOLOGY ABSTRACT

Microfluidic Device and Impeller Pump System for Physiological Perfusion of Human Vascular Beds and 3D Tissues (VIVOS)

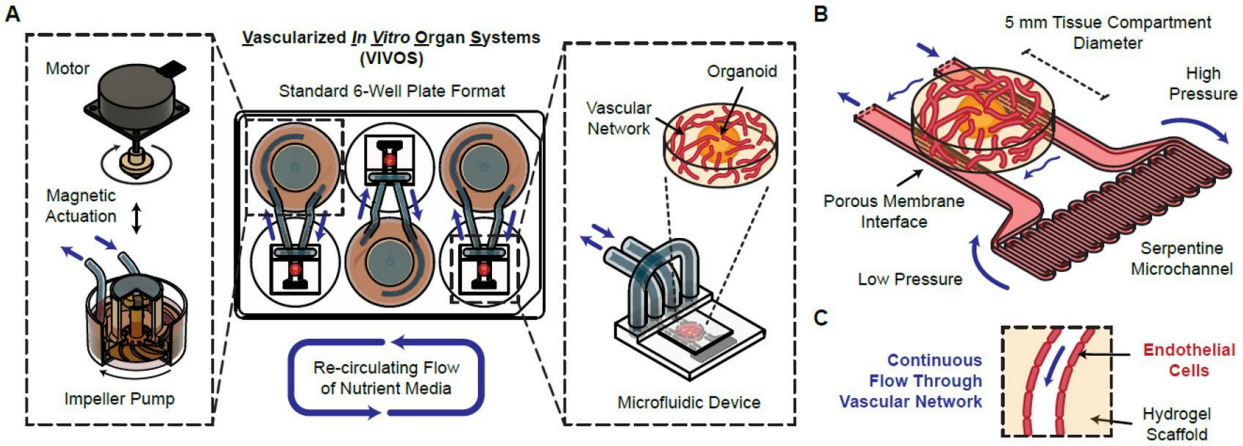
Reference No.: Sinai Ref. INV-2018007

BACKGROUND

Vascularized organoids are crucial for accurately modeling human tissues and organs because they mimic the natural blood supply, ensuring proper oxygen and nutrient distribution, waste removal, and cellular signaling. Current organoid systems, however, face significant limitations, such as inadequate vascular networks, which lead to hypoxia, nutrient deprivation, and cell death in the organoid's core. These deficiencies hinder the organoids' ability to fully replicate the complexity and functionality of native tissues, limiting their utility in disease modeling, drug testing, and regenerative medicine. Addressing these challenges is essential for advancing organoid technology and its applications in biomedical research.

TECHNOLOGY OVERVIEW

Our researchers have developed a novel pump-based system for culturing perfusable blood vessels and vascularizing organoids called VIVOS (Vascularized In Vitro Organ Systems). The system consists of an impeller pump connected to a microfluidic device housing a tissue compartment (Figure 1). The pump pushes media from a reservoir into the microfluidic device. A pressure differential between the spanning channel arms of the microfluidic device (caused by a serpentine channel) allows the transverse passage of media through the tissue compartment. In the presence of endothelial cells in a hydrogel, this results in vascularization in the tissue compartment; in the additional presence of an organoid, this results in a vascularized organoid. The pump and microfluidic device use minimal tubing and three independent units can be accommodated in a 6-well plate, with up to 48 units in a standard incubator.



Arlene Yee
Technology Manager
ayee@lunenfeld.ca

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Figure 1. VIVOS device for vascularization of organoids. (A) The device is composed of a magnetically actuated impeller pump and a microfluidic channel containing a tissue compartment that sits on top of and spans the two arms of the channel. (B) The presence of a serpentine microchannel creates a pressure differential in the arms of the channel allowing for the transverse flow of media through the tissue compartment, (C) enabling the formation of a vascular network in the absence or presence or organoids.

Competitive Advantages:

- Produces perfusable human vascular beds and supports vascularized organoid/tissue implantation workflows.
- Continuous, tunable, physiologically relevant intraluminal vascular flow (pressure and shear treated as experimental inputs).
- Large ~1 mm × 5 mm × 5 mm tissue compartment compatible with many organoid types and sizes.
- Direct quantitative assays for vascular flow velocities/flow rates, vascular permeability, and vascular morphology in the same bed.
- Optimized modular impeller pump system and microfluidic chip design for reproducibility, robustness, and user friendliness.
- Minimal tubing and high parallelization: 3 units per 6-well plate; up to 48 independent units per incubator.

Applications:

- Mechanistic vascular biology and mechanotransduction under controllable laminar shear and perfusion.
- Flow-conditioned endothelial remodeling and cell-state transitions (single-cell profiling and perturbations).
- Drug discovery and preclinical evaluation where compound delivery and barrier function can be quantified.
- Human disease modeling in perfused vascular beds (e.g., AVM/HHT-relevant remodeling phenotypes and therapeutic testing).
- Organoid and tissue integration studies requiring perfused delivery (e.g., cerebral organoids and other implanted 3D tissues).

Stage of Development:
Prototypes of the device have been built and validated. Endothelial vessels grown in hydrogel display key features including lumenization and deposition of basement membrane components, and support continuous intraluminal perfusion. VIVOS enables quantitative measurement and tuning of vascular hemodynamics and transport, supports implantation of tissues (including human cerebral organoids), and has been applied to single-cell profiling of flow-conditioned vascular remodeling programs and modeling of vascular disease-relevant phenotypes in a fully human setting.

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ayee@lunenfeld.ca

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Research Team:

- Laurence Pelletier, Liliana Attisano, and Jeff Wrana
- Profiles of Laurence Pelletier, Liliana Attisano, and Jeff Wrana
- Lab Websites Laurence Pelletier and Liliana Attisano and Jeff Wrana

Patent Status:

- PCT application filed (Sept 2024)

Commercial Opportunity: Technology available for licensing and partnering with industry.

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Technology Manager
ayee@lunenfeld.ca