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Micro-Nanofluidics for Medicine on-Earth and in Space

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Unprecedented development in controlled delivery systems have allowed for mimicking of endocrine glands responsive to biological cues for the treatment of hormonal and metabolic disorders. In this context, micro and nanofluidic systems represent unique platforms that can be exploited to recapitulate organ functions or enable superior control of drug administration.1 By implementing cutting-edge microfabrication techniques, we created nanofluidic membranes with dense arrays of monodisperse nanochannels as small as 2.5 nm with accuracy of ± 2 Å.2 Two implantable platform technologies were developed based on these membranes, which leverage new fluid physics at the nanoscale: a nanochannel drug delivery system and a surface-modified 3D-printed polymer system for cell transplantation. Implantable drug delivery devices were created by incorporating these nanochannel membranes within bioinert metallic or polymeric capsules serving as drug reservoirs. The drug delivery system utilizes adaptable nanochannel sizes to constrain molecular transport and achieve constant and linear (zero-order) release of drugs and biomolecules.3 Depending on therapeutic indication, minimally invasive device implantation could occur subcutaneously or intratumorally. Notably, our subcutaneous implants allow for transcutaneous drug refilling to extend treatment duration, as demonstrated in non-human primates whereby clinically-relevant dosage of TAF for HIV pre-exposure prophylaxis were achieved over 83 days. Using the same drug delivery platform for GC-1 delivery in pre-diabetic obese non-human primate, normalization of glycaemia, insulin and cholesterol levels and complete clearance of fatty liver were observed in conjunction with substantial adipose tissue loss.4,5 Additionally, intratumoral immunotherapy6 delivery via the nanochannel platform resulted in immune activation and tumor growth inhibition in a murine model of triple negative breast cancer. Ongoing innovations include active, on-board control systems to permit remote manipulation or activation, enabling telemedicine or chronotherapy regimens.7,8 The 3D-printed polymeric cell transplantation system was developed for encapsulation of endocrine cells.9-11 The system provides an immune protective environment for bioactive allografts by releasing drugs for local immunosuppression while permitting graft vascularization. This presentation will provide an overview of our platform technologies for medical applications on-Earth and in Space on the International Space Station.

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