DESIGN OF A MICROFLUIDICS DEVICE FOR FACILE PROCESSING OF ENCAPSULATED STEM CELLS

INSIGHTS FOR RESPONSIBLE AND RAPID ADOPTION OF EMERGING MEDICAL TECHNOLOGIES

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By

Cole Latvis

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SOCIOTECHNICAL SYNTHESIS

Emerging biomedical technologies are urgently needed to address the defining clinical challenges of our time, such as heart disease, stroke, and cancer. To achieve efficient translation into the clinic, the development process for these new devices and therapeutics must take into account their ease of dissemination and application in the healthcare system. Toward this end, the technical project of this thesis focuses on designing a device that will facilitate the adoption of one emergent medical technology, stem cell therapeutics. However, practical design alone does not guarantee societal acceptance. These technologies exist within a broader socio-technical context which the science, technology and society (STS) research topic seeks to understand and provide recommendations for navigating. The tight coupling of the technical and STS topics derives from a shared interest in promoting the development and diffusion of much needed emerging medical technologies.

The technical report describes the design and development of a high-throughput device that aims to expand the applicability and accessibility of stem cell therapies. Stem cells offer the potential to regenerate lost tissue, including nervous and cardiac, following injuries such as those resulting from ischemic stroke. However, these regenerative agents are limited by immune rejection of non-self cells, thus necessitating time consuming culture of patient derived cells to maximize therapeutic potential of treatments. The proposed device addresses this complication by using micro-level fluid flow to automate the process of layer-by-layer individual stem cell encapsulation in thin coats of polymer, which hide the cells from the immune system. This is accomplished through inertial trapping of the cells in microvortices while sequentially exposing them to coating solutions. The creation of the device involved modeling in computer-aided design software, Autodesk Fusion 360 and AutoCAD, simulation in computational fluid dynamics software, Autodesk CFD, and fabrication via 3D-printing in resin.

Computational simulations were completed for several variants of the device and revealed theoretical flow parameters necessary for the formation of microvortices. This informed the design of a photomask, which was crafted for use in micro-level device fabrication. Further, the simulations confirmed that the device could be scaled to larger geometries while maintaining flow characteristics using the Reynold's number of the channels. With this validation, several scaled-up prototypes were successfully 3D-printed, connected to syringe pumps, and infused with solutions containing hydrogel beads. Although fluid flow through the scaled-up device could be visualized, the device was unable to withstand the high pressure required to maintain adequate fluid velocity for vortex formation. A micro-level device was not produced due to time constrains, training delays, and lab availability, but the simulations and scaled-up models provide a rough proof-of-concept, as well as a solid starting point for future students to continue this effort.

In addition to technical challenges, there are a great number of interacting socio-technical actors that can aid or delay development and diffusion, and must be appropriately navigated, for an emerging technology to reach clinical use. To address this web of complications, the STS research took the form of a historical analysis of the influences on the adoption of new medical technologies, and reviewed perspectives from sociologists, engineers, medical professionals, and technological historians over time. This information was organized through an Actor Network Theory lens, which allowed for the identification of changes in the network actors over time and elucidated the driving mechanisms of adoption or rejection of technologies in the modern day.

Two important determinants of successful adoption were identified as societal values around medicine and the approval of the end-user. Both of these factors shifted in the 1970s as society became increasingly aware of rising healthcare costs, lack of safety standards for medical devices, and feelings of lost patient autonomy over their health. These changes altered the arrangement and influence of various actors, resulting in the expansion of regulatory power and demands for increased patient involvement in medical decision making. Three recommendations are provided for navigating the modern actor-network: engage the end-user, educate the public in a manner which emphasizes patient autonomy, and establish early and continual connections with regulatory bodies.

Medical devices do not typically follow linear trajectories from the conception of an idea to its application in the healthcare system. Instead, it is necessary to design with clinical applicability in mind and understand the broader societal context these technologies exist within. The technical project and STS research presented in this thesis address both of these considerations in order to foster rapid and responsible development and diffusion of much needed medical technologies.

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