

Cardiac Tissue Engineering: Building a New Heart

Ritu Malhotra*

Department of Tissue Engineering and Repair, Aravalli Institute of Biomedical Sciences, Udaynagar, India

Introduction

Cardiac tissue engineering represents a transformative field dedicated to restoring the function of damaged heart muscle through the fabrication of viable cardiac tissue constructs [1].

At its core, this discipline integrates principles from biology, engineering, and medicine to create functional myocardial substitutes [1].

Key approaches within cardiac tissue engineering involve the strategic selection of cell sources, such as potent stem cells and established cardiomyocytes, which form the cellular foundation of engineered tissues [1].

These cells are then meticulously seeded onto sophisticated biomaterial scaffolds, designed to emulate the intricate architecture and biochemical cues of the native extracellular matrix [1].

Furthermore, advanced bioreactor systems are indispensable for providing a controlled environment that promotes the optimal maturation and functional development of these developing tissues [1].

Significant progress is being observed in the development of engineered tissues that exhibit crucial properties like vascularization and electroconductivity, which are vital for seamless integration and effective electrical coupling with the host heart [1].

However, several formidable challenges persist, including achieving the necessary scale for therapeutic applications, ensuring adequate vascularization for nutrient and oxygen supply, and guaranteeing long-term engraftment and functional viability of the engineered constructs [1].

Induced pluripotent stem cell-derived cardiomyocytes (iCMs) have emerged as a particularly promising cell source for cardiac repair, offering a renewable and patient-specific option [2].

Biomaterial scaffolds are critical components, playing a pivotal role in guiding cell behavior, providing essential structural support, and facilitating robust integration with the host tissue [3].

The overarching goal is to engineer tissues that can precisely mimic the native heart's mechanical and electrical properties, ultimately leading to improved therapeutic outcomes for patients suffering from myocardial damage [1].

Description

Cardiac tissue engineering aims to regenerate damaged heart muscle by creating functional cardiac tissue constructs. This involves utilizing specific cell sources,

such as stem cells and cardiomyocytes, which are crucial for building the cellular architecture of the engineered tissue [1].

These cells are cultivated on biomaterial scaffolds that are engineered to mimic the native extracellular matrix, providing structural support and biochemical signals that guide cell behavior [1, 3].

Bioreactor systems are employed to create a controlled environment that supports tissue maturation, often by applying mechanical and electrical stimuli to mimic in vivo conditions [1, 5].

Progress has been made in developing vascularized tissues, which is essential for providing oxygen and nutrients to the engineered construct and for its integration with the host's circulatory system [1, 4].

Electroconductive properties are also critical for ensuring that the engineered tissue can electrically couple with the existing heart muscle, preventing arrhythmias and allowing for coordinated contraction [1, 7].

A significant challenge is achieving sufficient vascularization within the engineered tissue to support cell survival and function, as well as to enable integration with the host vasculature [1, 4].

Induced pluripotent stem cell-derived cardiomyocytes (iCMs) are a key focus, with ongoing research aimed at enhancing their maturation, electrophysiological characteristics, and differentiation efficiency for improved integration and contractile function [2].

Biomaterial scaffolds, including hydrogels, decellularized extracellular matrix (dECM), and electrospun nanofibers, are being explored for their ability to support cell adhesion, proliferation, and differentiation, and to promote vascularization [3, 8].

Decellularized extracellular matrix (dECM) from native cardiac tissue is particularly advantageous as it preserves the native microarchitecture and biochemical cues, potentially leading to better cell integration and function [3, 8].

Achieving successful integration of engineered tissues with the host myocardium is paramount, requiring careful consideration of electrical coupling for synchronized beating and mechanical synchronization for effective pumping, as well as managing immune responses [1, 6].

Conclusion

Cardiac tissue engineering seeks to repair damaged heart muscle by creating functional tissue constructs. Key components include stem cells and cardiomyocytes as cell sources, biomaterial scaffolds mimicking the extracellular matrix, and bioreactors for tissue maturation. Advances focus on vascularized and elec-

troconductive tissues for integration with the host heart. Challenges remain in scaling, vascularization, and long-term function. Induced pluripotent stem cell-derived cardiomyocytes (iCMs) are a promising cell source. Biomaterials like hydrogels and decellularized ECM support cell behavior and integration. Vascularization is a critical hurdle addressed by promoting angiogenesis. Bioreactors provide controlled environments for tissue development. Successful integration with the host myocardium ensures electrical and mechanical synchronization. Electrical properties are crucial for synchronized beating and conduction. Mechanical properties are vital for withstanding physiological forces. Advanced imaging techniques are used for evaluation.

Acknowledgement

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Conflict of Interest

None.

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***Address for Correspondence:** Ritu, Malhotra, Department of Tissue Engineering and Repair, Aravalli Institute of Biomedical Sciences, Udaynagar, India, E-mail: r.malhotra@aibsci.ac.in

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