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Original Research Paper

Cardiovascular

BIOHYBRID PUMPS: FUTURE CONCEPTS

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KEYWORDS :

INTRODUCTION

Creating a biohybrid pump involves integrating living cardiac cells (cardiomyocytes) with synthetic materials and microelectronics. A new branch where integration of living cells with engineering scaffolds is done. Emergence of properties like adapting to environment cues in real time, self-healing, self-assembling, dynamic sensing and responding hold great promise for future developments in this arena. Scaling up cardiomyocyte culture, improving scaffold biocompatibility, enhancing microelectrode durability, and integrating sensors and control systems are future challenges (1,2).

Materials Required:

1. Cardiomyocytes (primary or stem cell-derived)
2. Biocompatible polymers (e.g., PDMS, PLGA)
3. Hydrogels (e.g., collagen, alginate)
4. Microelectrodes (e.g., gold, platinum)
5. Soft robotics components (e.g., silicone, elastomers)
6. Bioreactor or incubator

Fabrication Steps:

1. Cell Culture: Isolate and culture cardiomyocytes. Cell source for Primary cardiomyocytes (e.g., rat, mouse) or stem cell-derived cardiomyocytes (e.g., hiPSC-CMs). Culture medium used is DMEM/F-12, M199, or specialized cardiomyocyte media. Specifications for Seeding density is 1-5 × 10 ^ 5 cells/cm ^ 2 with incubation conditions of 37°C, 5% CO2, 95% humidity

2. Scaffold Preparation: Create biocompatible scaffolds using 3D printing or soft lithography. Scaffold Materials used are Biocompatible polymers (e.g., PDMS, PLGA, PCL). Techniques of 3D printing (e.g., SLA, DLP), soft lithography, or electrospinning is utilised. The pore size ideally should be 10-100 m with a scaffold thickness of 100-500 m.

3. Cell Seeding: Seed cardiomyocytes onto scaffolds.

4. Hydrogel Encapsulation: Encapsulate cells in hydrogels. The materials required include collagen, alginate, or synthetic hydrogels (e.g., PEGDA) with concentration: 1-5% (w/v) and crosslinking achieved by chemicals like glutaraldehyde) or photo-crosslinking.

5. Microelectrode Integration: Integrate microelectrodes for stimulation and recording. For this step the materials needed are Gold, platinum, or conductive polymers (e.g., PEDOT: PSS). With an electrode design: Interdigitated electrodes (IDEs) or microelectrode arrays (MEAs) and electrode spacing: 10-100 m.

6. Soft Robotics Assembly: Assemble soft robotic components. Silicone elastomers (e.g., PDMS, Ecoflex) are the materials needed with actuation mechanisms that include Pneumatic, hydraulic, or shape-memory alloy (SMA).The chamber design may be single or multiple.

7. Bioreactor Setup: This can be perfusion or static bioreactors with flow rate: 1-10 mL/min and oxygenation: 20-40% O2.

8. Pump Performance Metrics: The current available metrics include a pressure output: 1-10 mmHg with flow rates ranging from 1-100 L/min and an efficiency: 10-50%.

Biohybrid Pump Design:

Here chamber design does create chambers for cardiomyocyte contraction with valve design that regulates directional flow and an actuation mechanism that works by the integration of microelectrodes for electrical stimulation.

DISCUSSION.

Biocompatibility to ensure materials are non-toxic, sterilization of the components and assembly with maintenance of cell viability are key factors with scalability for design for commercial production.

Techniques

1. 3D printing
2. Soft lithography
3. Microcontact printing
4. Electrospinning
5. Bioprinting

Future directions of development revolve around living material engineering concepts, multiscale modelling with 3 D printing for manufacture and development of multifunctional robotic systems. Future directions of research would focus on development of in vivo testing, personalized pumps, wireless control, and artificial intelligence (AI) optimization. Bottom-up approach gives more flexibility in design with environmental robustness and more precise control mechanisms. Biohybrid robotic right and left heart simulators which utilises a myocardial substitute can recreate cardiovascular biomechanics in future soon (3,4,5).

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Patents

1. US Patent 10,857,122: "Biohybrid cardiac pump" (2020).
2. US Patent 10,425,196: "Soft robotic cardiac assist device" (2019).