Development of a Cardiac Patch for Post-Myocardial Infarction Treatment

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INTRODUCTION

- Myocardial infarction (MI) is a condition that is caused by blood vessel obstructions that prevent sufficient levels of blood and oxygen from reaching the heart, which is known as coronary heart disease[1].
- Cardiac cells are deprived of the materials needed to sustain them and they quickly die off, which results in excess scar tissue developing on the heart's surface[2].
- The heart loses its proper shape and elasticity, preventing it from pumping blood as effectively as it should.
- In this research project, the potential of a hydrogel-based cardiac patch was investigated.
- This study focused on the implantation of this multilayer patch on an *in vivo* test subject and determining the ability of the device to record various cardiac parameters.

METHODS

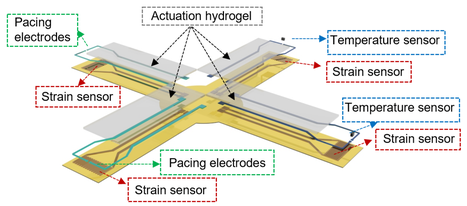

Fig. 1A. Cardiac Patch Prototype Design

Fig. 1B. In-Vivo Test of the Cardiac Patch

- The cardiac patch was designed as a T-shaped, four-armed device.
- The main structure was comprised of a UV laser-cut, bilayer structure consisting of gold film and polyimide (PI).
- Temperature, strain, and, ECG pacing sensors were attached to the patch and covered with a protective parylene coating.
- The PNIPAM hydrogel was made from a mixture of the following solutions: N-isopropylacrylamide (NIPAM), N,N'-Methylenebisacrylamide (BIS), Ammonium persulfate (APS), Tetramethylethylenediamine (TMEDA).
- The hydrogel was cured, cut, and glued onto each cardiac patch arm with biocompatible glue (Fig. 1A).
- Preliminary and *in vitro* tests were conducted to confirm the general functionality of the patch.
- *In vivo* tests were performed on a live mouse heart (both healthy and post-MI), where strain, temperature, and ECG readings were collected and analyzed (Fig. 1B).

ABSTRACT

- Designing protocols to deal with heart attacks has always been a challenge, especially after they have occurred.
- Myocardial infarction (MI) events typically result in some form of structural deformation, which decreases the heart's functionality.
- To address this problem, this research aimed to develop a hydrogel-based cardiac patch, which was inspired by other cardiac patch designs like Schaefer and his colleagues' 2017 cell-based approach[3].
- As this study covered the early stages of this device's development, only the patch's ability to record cardiac parameter data in terms of strain, electrocardiogram (ECG) pacing, and temperature within an *in vivo* murine model was evaluated.

RESULTS

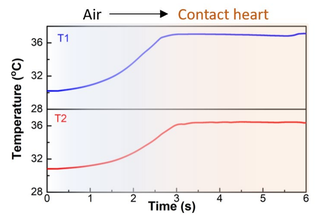

Fig. 2. Temperature of the Cardiac Patch From Channels T1 and T2

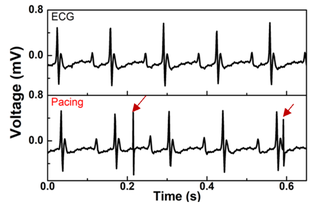

Fig. 3. Electrocardiogram (ECG) Readings With and Without an Electrical Stimulus

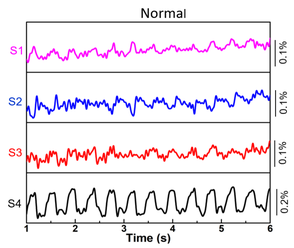

Fig. 4. Strain of Each Cardiac Patch Arm For a Healthy Mouse Heart

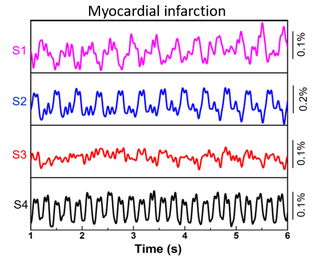

Fig. 5. Strain of Each Cardiac Patch Arm For a Post-Myocardial Infarction (MI) Mouse Heart

- The cardiac patch started around 30°C (close to room temperature) and increased to about 36°C (internal body temperature of the mouse) in roughly 3 minutes for both channels (Fig. 2).
- When the pacing electrodes were stimulated at around 0.2 s, the ECG waveform immediately following this event was slightly delayed but had a taller P (atrial contraction) wave than its normal ECG counterpart (Fig. 3)
- For a healthy heart, each arm of the cardiac patch had short, less clearly defined peaks for strain except for S4 (Fig. 4).
- For a post-MI heart, there were tall, distinct peaks for strain for all arms except for S3 (Fig. 5).

CONCLUSION

- From the results, this cardiac patch prototype shows promise as the foundation of a new MI treatment.
- It quickly adapted to the temperature of the mouse's heart, as reflected by the way it folded onto its surface.
- The patch also showed how it could influence heart rate with the use of pacing electrodes and electrical stimuli.
- Most importantly, the device was able to discern and visualize the key differences between the strain rates of a normal and post-MI heart.
- The ability of the cardiac patch to provide real-time information about heart activities from different perspectives allows one to better understand the changes that the heart undergoes after being subjected to sizeable trauma.

FUTURE DEVELOPMENT

The main future objective is to make the cardiac patch completely functional with the following features:

- More types of sensors beyond the ones currently tested (ex: sensors to determine heart contractility).
- The ability to be controlled remotely and send automatic or manual electrical pulses to encourage cardiac cell regeneration and have greater control over device folding respectively.
- Being constructed out of more robust materials to make the patch more durable, allowing the device to be used within a patient's body for a long time.

REFERENCES

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