Docket #: S21-055

Biomimetic Metamaterial Sleeve for Passive Ventricular Support and Heart Failure Management

Stanford researchers have developed an innovative biomimetic cardiac sleeve designed to provide passive external mechanical support to the heart while mimicking the natural motion and mechanical behavior of healthy ventricular tissue.

Heart failure remains a major clinical challenge, particularly in patients requiring left ventricular assist devices (LVADs), where right heart failure is a common and difficult-to-predict complication following implantation. Existing ventricular assist technologies are largely blood-contacting and associated with substantial risks, including thrombosis, embolic events, and secondary surgical interventions. In addition, prior external cardiac support devices have demonstrated limited clinical benefit due to poor replication of native ventricular biomechanics.

This technology introduces a soft, flexible epicardial sleeve composed of programmable metamaterial lattices engineered to reproduce direction-dependent and mechanically responsive behavior found in healthy heart tissue. Using computational modeling and patient-derived imaging data, the lattice geometry, stiffness, and deformation behavior can be spatially tuned to mimic healthy ventricular motion and synchronize with the cardiac cycle. The sleeve may support the left and/or right ventricle while reducing ventricular wall stress and maladaptive remodeling.

Unlike conventional ventricular assist systems, the device is entirely non-blood contacting and is designed for prophylactic or adjunct implantation alongside LVADs to support ventricular function without interfering with normal cardiac motion. The platform also enables patient-specific manufacturing through additive manufacturing techniques and may incorporate integrated strain sensors for continuous monitoring of cardiac deformation and function.

Stage of Development
Protoype

Applications

- Passive ventricular support for heart failure
- Adjunct support for LVAD implantation
- Treatment of ventricular remodeling and ischemic cardiomyopathy
- Patient-specific cardiac support devices
- Smart cardiac implants with strain sensing

Advantages

- Biomimetic auxetic and anisotropic mechanics
- Non-blood contacting support platform
- Spatially tunable stiffness and deformation, preserving physiologic cardiac motion
- Compatible with existing LVAD workflows
- Optional integrated cardiac strain sensing

Patents

- Published Application: WO2022212931
- Published Application: 20240065839

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