NovaCardia: A Novel, Optimized Total Artificial Heart for Destination Therapy

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Background Heart failure affects 64 million people annually. Transplants are in chronic shortage, especially for pediatric patients. Total artificial heart (TAH) promises a solution; however, they are only used as a bridge to transplant. For destination therapy, the hemodynamics, self-containment, efficiency, and sizing problems of TAH must be solved, in addition to offering pediatric sizing. Methods Prototype Three (P3) was based on a vortex pump that biomimics natural vortices in the heart. Impeller was designed to prevent stasis and minimize blood contact. Reinforcement learning-based controller (RAC) was developed to provide life-like responsiveness to activity and optimize power consumption, and proof-of-concept transcutaneous power system (TPTS) was created. Results P3 provided a cardiac output of up to 16 l/min while still maintaining a pediatric-sized mediastinal volume of 123.3 cc. Computational flow dynamics (CFD) simulations showed an average fluid shear rate of 3.44 Pa and peak of 41.3 Pa, far less than 150 Pa that causes thrombosis and 95.2% less than existing TAHs. RAC provided lifelike responses to a simulated cardiac stress test, and decreased power consumption to 12 Watts at peak activity levels. TPTS could provide 5.6 Watts during bench testing, supporting baseline activity. Conclusion NovaCardia optimized hemodynamic performance by using novel vortex pumping technology, satisfying ISO 10993-4, 14708-5, and 5840 for blood safety and significantly reducing risk for thrombosis and immune responses. It fits pediatric patients but provides adult-level flow, minimizing re-operation. Power consumption is within the range for wireless transmission, preventing driveline infections. As promising as this research is, more investigation is required.

Awards Won:
International Council on Systems Engineering - INCOSE: Certificate of Honorable Mention, a 1-year free student membership to the INCOSE, and free virtual admission to the 2022 International Symposium of the INCOSE