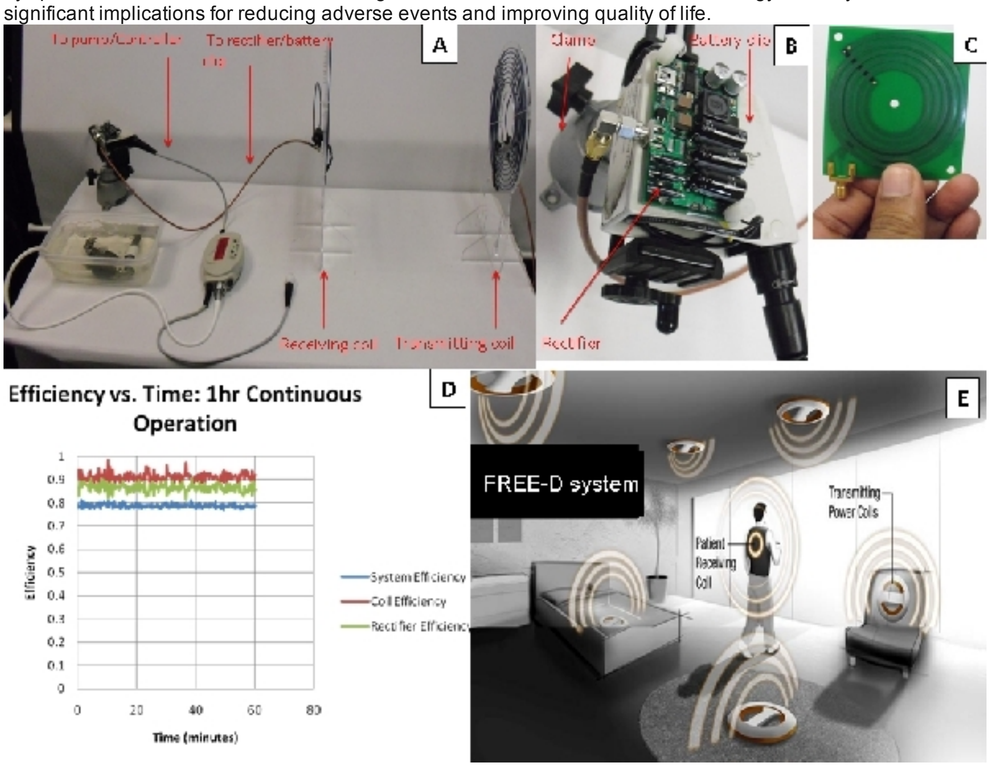
Wireless Power for Ventricular Assist Devices: Innovation with the Free-Range Resonant Electrical Energy Delivery System (FREE-D) for Mechanical Circulatory Assist

Pramod Bonde[1], Alanson P. Sample[2], Benjamin Waters[2], Emily Cooper[3], Yoshiya Toyoda[1], Robert L. Kormos[1], Joshua R. Smith[2,4]

[1]Department of Cardiothoracic Surgery, University of Pittsburgh Medical Center, Pittsburgh, PA; [2]Department of Computer Science and Engineering, University of Washington, Seattle, WA; [3]Intel Labs, Seattle, WA; [4]Department of Electrical Engineering, University of Washington, Seattle, WA

Objective(s): Ventricular assist device (VAD) therapy has radically improved CHF survival by smaller rotary pumps that show improved reliability and lower morbidity over earlier larger pulsatile pumps. However, the mandatory need for transcutaneous drivelines undermines the full potential of these newer VADs. Infection, traumatic damage, and re-hospitalizations are considered an inevitable consequence of the driveline. The initial enthusiasm provided by earlier TETS based technologies rapidly waned due to limitations of reliable power delivery even over a few millimeters, and problems with alignment and efficiency. Wireless Resonant Energy Link (WREL) uses resonant coupling to transfer power from a transmitter to a receiver. An adaptive frequency tracking method refines efficiency upwards of 70% for nearly any angular orientation over a range of distances. We report our results of powering an axial pump using FREE-D system.
Methods: The experimental design (Fig 1A) consisted of a single turn drive loop and multi-turn spiral coil as a transmitter and receiver coil (26 cm) attached to the AC mains via hardware. An RF-DC rectifier converted the initial oscillating RF signal at 13.56MHz to DC power mounted on a battery clip (Fig 1B), to directly power the pump and/or to charge an implantable battery. The axial pump was set at 9400rpms before being connected and submerged in water. A series of 240 samples at 15 sec intervals were collected at F=13.43 MHz and RF gain=2900. Instrumentation for voltage (Fluke 287) input current (Agilent U1252A) output current (Fluke 8842A) were used. System, coil and rectifier efficiency were plotted against time.
Results: The FREE-D system powered the pump without any interruptions or failure of the circuitry. The pump worked without interruption even when the receiving coil diameter was reduced to 4.3cm (Fig 1C). The system, coil and rectifier efficiency plotted against time is shown in Figure 1D. The coil efficiency was 91.8% and system efficiency 79.2% with rectifier efficiency of 86.2%. A FREE-D system designed to overlap fields can be used to power an implanted VAD within an unrestricted space as depicted in Figure 1E.
Conclusions: A FREE-D system based on a WREL principle affords an exciting avenue to power a totally implantable VAD unrestricted by space constraints. This has an advantage over the older induction based technology of totally tether free function which can have significant implications for reducing adverse events and improving quality of life.



A: Experimental design with transmitting (connected to AC mains) and receiving coil, note the pump in continuous operation. B: Modified battery clip held in place by a clamp, with the RF-DC rectifier mounted directly on the top and output connected to the pump controller. C: Depicts a smallest inner coil mounted on a PC board (4.3cm in diameter) that was used to power the pump. D: System, coil and rectifier efficiency plotted against time. E: An image depicting a proposed FREE-D system in operation to give a tether free and cord free existence with fully implantable VAD system.