Extending the TET System for Improved Patient Comfort

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INTRODUCTION

The growing patient population with advanced heart failure - and the limited number of donor organs - has stimulated the use of ventricular assist devices (VADs).

However, postoperative management of VADs and their support systems can be challenging and costly. The current design tethers the patient to an external system controller which connects via a percutaneous cable from the outside of the body through the skin to the implanted pump as shown (Figure 1). The percutaneous cable is a leading cause of infection for VAD patients.

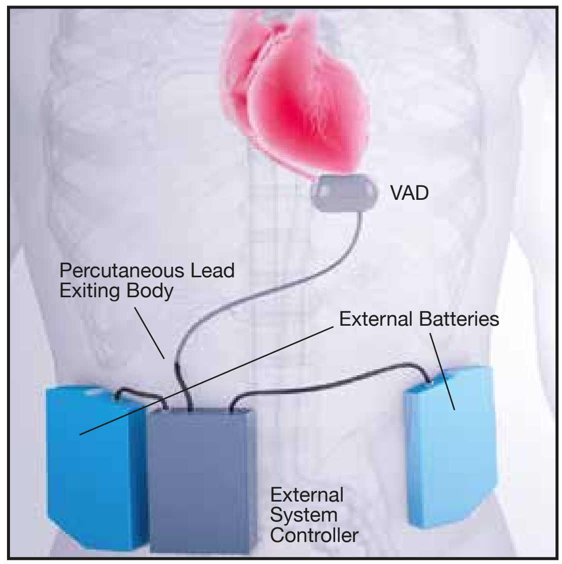

Fig. 1 **Percutaneous VAD Configuration**

HISTORY

Minnetronix has been working with Penn St. University since 1996 to develop transcutaneous energy transmission systems (TETS) initially to support the electronic total artificial heart (ETAH) [1]. Recently, Minnetronix and Penn St. University developed an implantable motor controller and transcutaneous energy transmission system to support continuous flow VADs (Figure 2). The following improvements have been made to this system [2].

TETS SYSTEM AND COILS

Performance Specifications		
	ETAH	**VAD**
Input Supply Voltage	12-17 VDC	12-15 VDC
Output Voltage	16 VDC	18 VDC
Power Delivered	15-80 W	0-22 W
Startup Power	80 W	22 W
Operating Frequency	200 KHz	790 KHz
Primary Coil Diameter	115 mm	95 mm
Primary Coil Volume	33 cm^3	26 cm^3
Secondary Coil Diameter	95 mm	55 mm
Secondary Coil Volume	29 cm^3	10 cm^3
Min. Coil Separation	0 mm	0 mm
Max. Coil Separation	25 mm	30 mm

Improved TETS Coils

Implant Controller

Fig. 2

A totally implantable VAD System eliminates the need for a percutaneous cable by using a set of coils to transfer power (Figure 3).

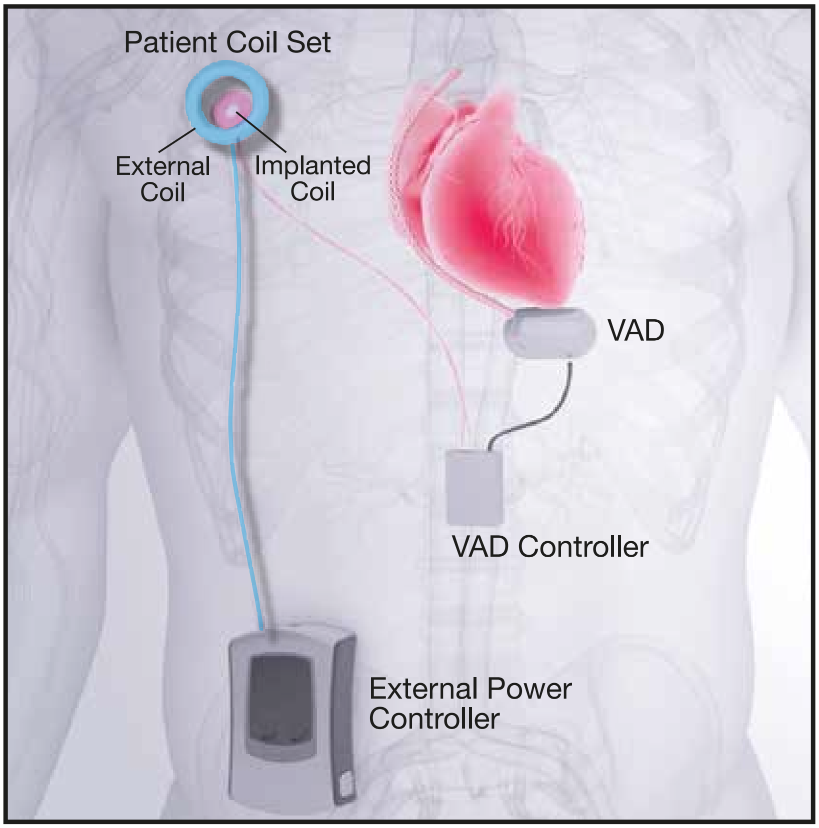

Fig. 3 **Totally Implantable VAD System**

IMPLEMENTATION

The patient coil set implements the inductors in an “air” gap power transformer where the “air” gap is replaced by the skin barrier (Figure 4).

One inconvenience with the TETS configuration is the need for the patient to continue carrying an external controller. This is especially annoying when sleeping. The goal of this work was to improve the TET system to enhance patient comfort, especially while sleeping.

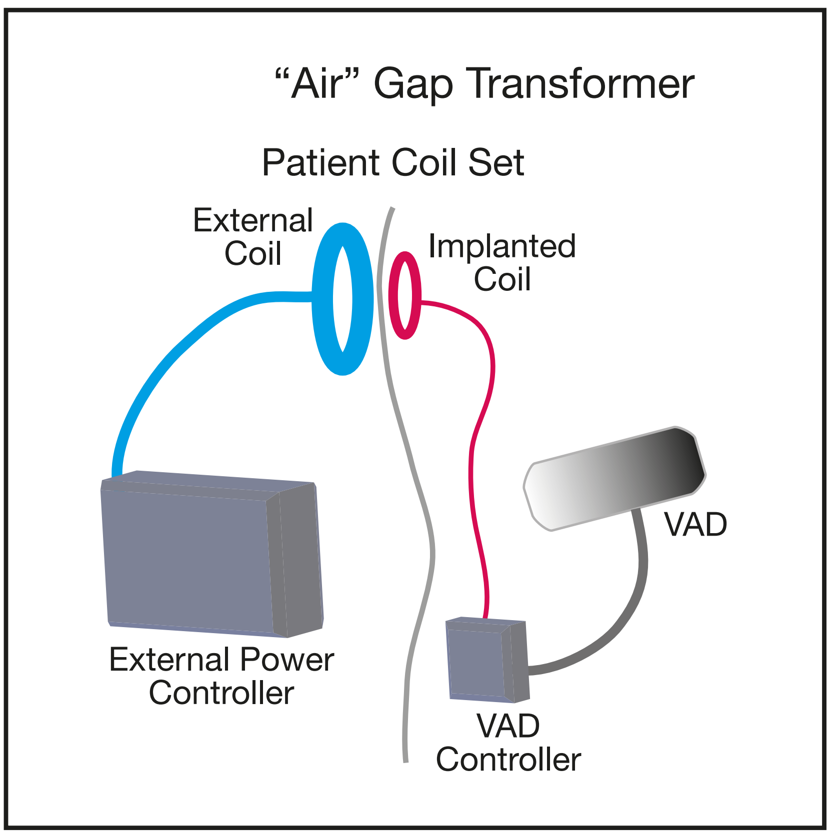

Fig. 4 **TET System Schematic**

METHOD

Using a distributed transformer, it is possible to extend the power transfer to other parts of the body. The distributed transformer has the following attributes (Figure 5):

- Patient coil set and configurable coil set
- Coils are connected by a capacitor network
- The patient wears only coils
- External power controller is remote from patient

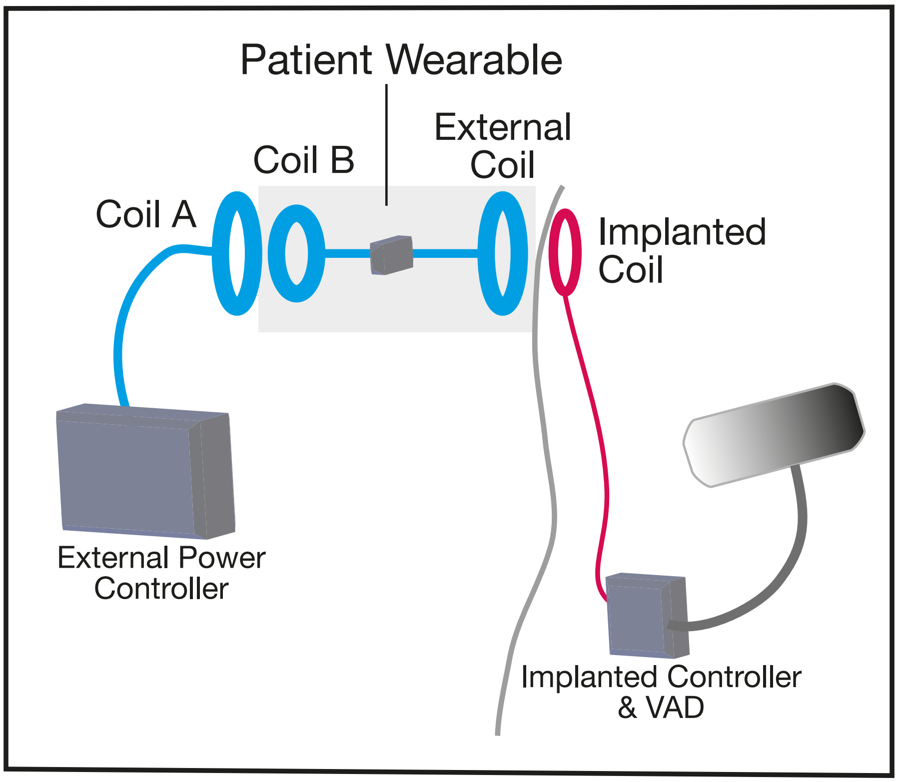

Fig. 5 **Single Cable Wearable**

The advantage with this system is that the second set of coils no longer has a fixed physical size. They can be designed in multiple configurations to allow the patient freedom from the direct connection to the power controller.

IMPROVING PATIENT COMFORT

With the distributed transformer approach it is now possible to design a system that allows freedom from a direct cable connection to an external controller (Figures 6 and 7). A patient could now easily roll over and adjust body position while sleeping without losing power to the VAD. For this to work properly, the configurable coil set is designed as follows:

- Coil B is a large coil, wrapped around the patient's waist to form a belt
- Coil A is an array of coils connected to the external power controller
- Power transfers between coil array A and coil B
- Power transfers between the patient coil set

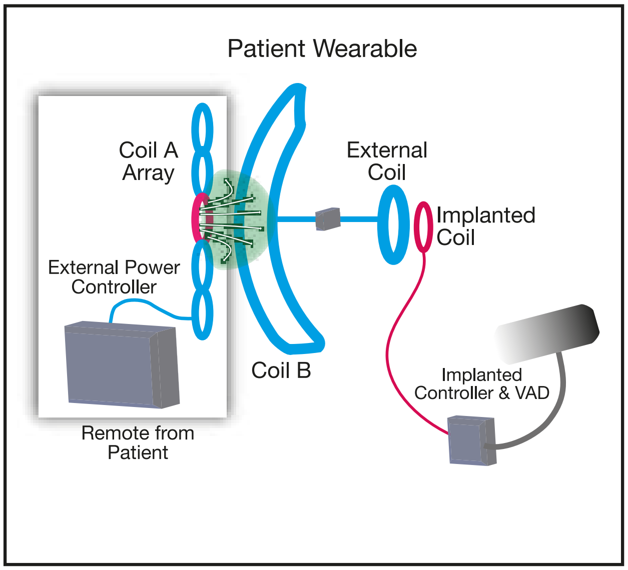

Fig. 6 **Multi-coil Solution**

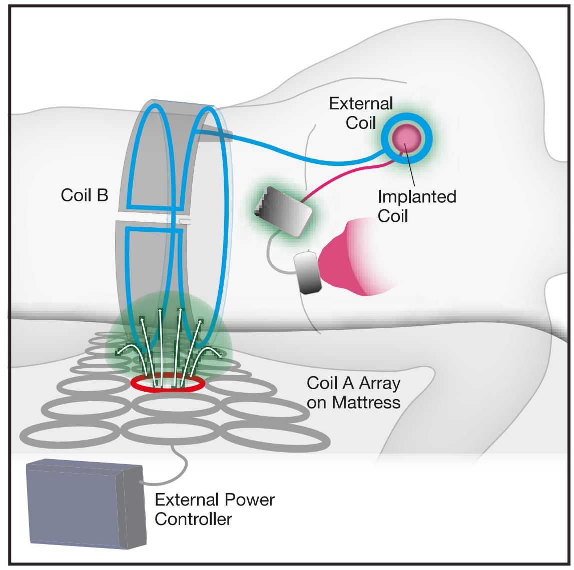

Fig. 7 **Patient Sleeping Configuration**

RESULTS

Advantages of the Sleeping Configuration

- Full rotational freedom for the patient
- No cable from the patient to the external controller
- Improved patient comfort
- Magnetic fields are limited to the coil pairs, no excessive field exposures
- Compatible with single coil pair, patient can choose to wear controller instead of belt

EXTENSIONS

Other configurations are possible

- Chair with embedded controller
- Backpack or purse application
- Wearable vest application

REFERENCES

[1] A. Snyder, G. Rosenberg, J. Reibson, J. Donachy, G. Prophet, J. Arenas, B. Daily, S. McGary, O. Kawaguchi, R. Quinn, W. Pierce, "An Electrically Powered Total Artificial Heart Over 1 Year Survival in the Calf", ASAIO Journal, July/Sept 1992.
[2] V. Bluvshtein, L. Lucke, W. Weiss, "Wireless Power Transmission for Ventricular Assist Devices", ASAIO Annual Conference, June 2013.

DISCLOSURES

Minnetronix SBIR grants with Penn State were used to develop the Tesla system and TETS system

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