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MEMS implant for cardiovascular applications

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Intracardiac pressures are used in the diagnosis and treatment plan of patients with congestive heart failure, valvular abnormalities, and congenital heart diseases. This demand indicates a growing need for non-invasive continuous monitoring of cardiac physiological parameters. MEMS technology, therefore, has the potential to enable clinicians to continuously monitor cardiac physiology. This paper reports the results of initial animal studies of a wireless, batteryless, miniature pressure sensing implant in which its feasibility and accuracy for monitoring a wide range of cardiac pressures is assessed.

The animal study method used was an open chest model that was performed in three canines. The batteryless, wireless MEMS sensors were implanted and were anchored by sutures in the right atrial appendage of one canine and the descending aorta of the remaining two. The MEMS sensors communicated and were powered via wireless magnetic telemetry that was equipped with an external handheld readout unit. Millar solid-state catheters were used to record reference pressure data from the right atrium and from the descending aorta adjacent to the sensor location. Blood pressure waveforms derived from the MEMS sensor and Millar catheters were compared. Fig. 1 (above) shows the results of a test where the MEMS implant and the control Millar catheter are placed in the aorta. There is a good correlation between the two signals. The lower pressures in the waveform are the same, but the Millar catheter shows higher pressures at the waveform peak. It is hypothesized that this occurred because the Millar catheter obstructed the blood flow and as a result, at high blood flow rates, the pressure increased accordingly.

Overall, the MEMS implant provided outstanding performance in the studies, as demonstrated in these findings:

- Significant data correlation was found between the MEMS implant and Millar catheter tracings, as well as the expected waveforms.
- Dicrotic notch was clearly visible.
- Continuous heart pressure waveform was present as was a real-time heart pressure waveform.
- Heart pressure measurement at a sampling rate of 400 samp/sec occurred.
- Pressure dynamic range was from -200 to +300 mmHg.
- High accuracy was <1 mmHg.
- Heart rate of up to 200 beats/min was observed.
- Breathing pattern was observed.
- Telemetry distance was 3-4 cm.
- Telepowering distance was 3-4 cm.

The first-generation devices offered excellent performance that surpassed most of the application's needs, but there were three major shortcomings: communication distance was limited (<4 cm); sensor shape was not optimum for catheter delivery and chronic anchoring; and anchoring method was not incorporated into the implant design.

Second-generation sensors are being developed to satisfy all of the application's requirements to become a viable product. These MEMS implants will provide several improvements:

- Distance for telecommunication and telepowering will be >15 cm.
- Anchor for chronic implantation will last >10 years.
- Custom designed catheter will deliver implant.
- Implants will provide accurate pressures of <0.5 mmHg at a high sampling rate >200 samp/sec.

In collaboration with cardiologists, a top-down approach is being followed to develop implantable cardiology pressure sensors.

MEMS implant & Millar catheter

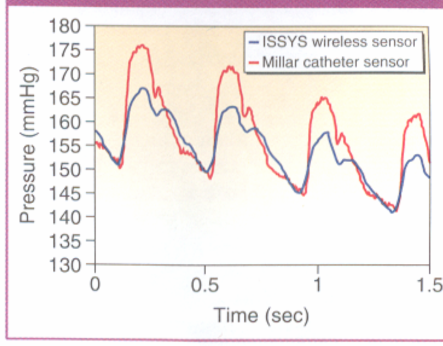

Fig. 1. Comparison of MEMS implant and control Millar catheter. *Source: ISSYS, Ypsilanti, Mich.*

Nader Najafi will discuss "BioMEMS for Closed Loop Medical Treatment Systems," at the Micro/Nano Conference sponsored by Micro/Nano Newsletter *and* R&D Magazine, *Oct. 14-15, Chicago.*

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