Applications for Implantable SAW Pressure Sensors

Chris McLeod[*], Robert Dickinson[#], Aimen Sabkha[*], Chris Toumazou[#]
[*]School of Technology, Oxford Brookes University, Oxford UK
[#]Bioengineering Department, Imperial College, London, UK

Introduction.

The last decade has witnessed a rapid surge of interest in new sensing and monitoring devices for healthcare and the use of wearable/wireless devices for clinical applications. One key development in this area is implantable monitoring devices. For implants, the problem of long-term stability and biocompatibility must be addressed, and several promising prototypes are emerging for measuring pressure, amongst other parameters, in patients with chronic cardiac and cardiovascular diseases..

Background

An ongoing collaborative project to develop an implantable pressure sensor raises the possibility of the safe monitoring of localised pressure within the body over a number of years. The need for such a device arose from the needs of cardiac and cardiovascular surgeons to get prior warning of pressure changes at the site of some previous surgery before other clinical signs became apparent. This is particularly important for heart transplants where a gradual weakening of the cardiac muscle is the first indication that some further intervention will be required. It is also important where an arterial graft has been performed or where an arterial stent has been placed to repair an aneurysm because raised local pressure will increase the strain on the joints between the original artery and the graft or stent. It is also becoming apparent - now that there are patients who have had an arterial stent for a number of years - that some develop a collateral circulation which reintroduces blood at arterial pressure into the space between the stent and the original aneurysm In all cases the local pressure is more important than the general systemic pressure.

The procedure of implanting and the implant itself should involve no increased risk to the patient. The sensors will be implanted at the time of the transplant or repair surgery and are expected to work for the lifetime of the patient. Therefore a zero-power sensor which can be interrogated remotely- i.e. from outside the body - offers the best solution. SAW sensors have all the required attributes; similar devices have recently become available for automotive applications, measuring tyre pressure[2]. In the context of healthcare, measurements may be made in hospital, at home, continuously or intermittently, for acute or chronic conditions.

Applications

1. Intra-cardiac.

The walls of the heart chambers are surprisingly tolerant of foreign bodies. Tubes for cardiac-assist devices can be sewn in; intra-cardiac pacemakers are producing good results in clinical trials. The case for implanting one or more pressure sensor in heart transplant or valve replacement patients can be made on the basis of providing the optimal diagnostic data without further catheterisation, at any time and in any place. The number of patients is not very great, but still significant, hundreds per year in the UK.

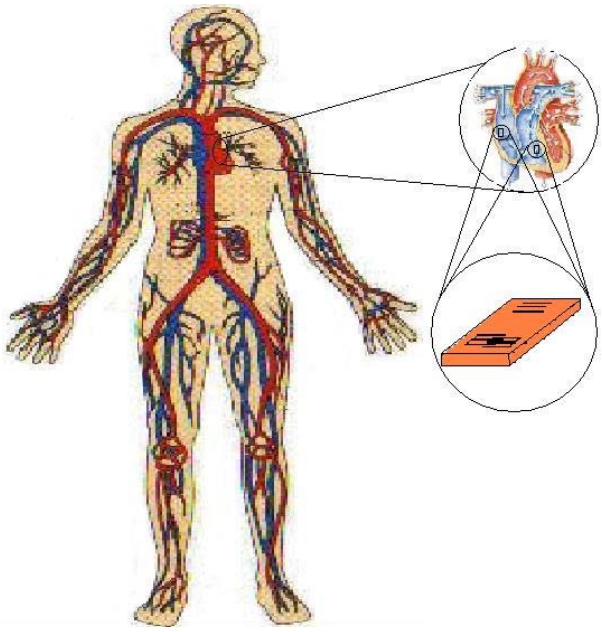

Figure 1. Schematic: intra-cardiac pressure monitoring

2. Intra-vascular

Abdominal Aortic Aneurysm (AAA) repair operations are carried out on 8-10000 patients per year in the UK, with increasing success[1]. The operation involves the insertion of an artificial tube which has been developed to the point of being fully tolerated. The usual blood-pressure measurements are made at subsequent follow-up clinic appointments: a spot measurement of

systemic systolic and diastolic pressures. Implanting a pressure sensor at the time of the repair surgery would again allow measurement of pressure through the complete cardiac cycle during normal activities in the hospital, clinic or home. The step-change in the quality and value of blood-pressure data would be comparable to that caused in ECG monitoring by the introduction of the 24-hour ECG data-logger.

3. Hypertension

The examples above involve existing surgical interventions. Any instances of arterial catheterization would allow pressure sensors to be placed within one of the larger arteries and to subsequently derive the improved pressure data. With appropriate external signal processing, this would form the core of a 24-hour alarm system for hypertensive patients.

For patients not scheduled for catheterization, the risk associated with the process of implanting and of the implant itself has to be weighed against the gains from the data:-

Alarms, as mentioned

Control, in the sense that the patient would now be able to exercise or engage in other activities while knowing that their blood pressure remained within a prescribed limit. This should lead to safely accelerated rehabilitation programmes and much better tailoring of drug treatments to each individual.

The number of Hypertensive patients in the UK is estimated at about one million. If only 1% of these were assessed as being at lower risk of a life-threatening episode through monitoring, this would mean a further 10000 implants would be needed.

4. Hypotension

The same reasons can be given for implanting a pressure sensor for hypotensive patients. Risk analysis will determine the value of implanting.

5. Etc.

The pressures encountered in the soft tissues of the rest of the body are lower than within the cardiovascular system but are as amenable to measurement using an implanted sensor. The balance of risk will be determined by the need for a localized measurement and the non-availability of an alternative method.

The Interrogation Unit.

SAW sensors are transponders; that is, they require no local power source but are interrogated by an RF pulse which travels through the tissue from –and back to- an external interrogation unit (IU). The IU needs to be as close to the sensor as possible as the attenuation of RF by tissue is very high. The IU should therefore be a wearable device which in the various monitoring modes outlined above would either be

A worn continuously as an alarm device

B Worn for 24 hours (as a Holter type monitor)

C Hand-held for intermittent clinic or hospital appointment spot-checks.

The connection from the IU into a larger data-collecting system could be through any of the routes described elsewhere: hard-wired, Bluetooth, GSM etc.

References

1. Charing Cross Symposium:Vascular and Endovascular Challenges. Imperial College, 3-6 April 2004.

2. Pohl, A. et al "The 'Intelligent Tire' utilising Passive SAW Sensors- Measurement of Tire Friction". IEEE Trans on Instrumentation and Measurement 48(6) 1041-6 (1999)

3. Pohl A. "A Review of Wireless SAW Sensors" IEEE Trans Ultrasonics ferroelectrics & frequency control 47(2) 317-332 (2000)