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Feasibility of Temperature Sensors in Orthopaedic Implants for the early detection of Surgical Site Infections

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Introduction

Surgical Site Infections represent the second largest cause of nosocomial infections (Healthcare related infection) [1], largely caused by lacking sterile practice on the client and medical end during and after the surgery. With Orthopaedic surgeries entering the deepest level, Surgical Site Infections can be devastating to the healing process. A key characteristic of infection of tissue is the local increase in temperature at the site of the wound. Sensors have long been experimented with for use in-vivo with the earliest sensors using a percutaneous lead (External wire) as means of power and telemetry. With the mainstream take-off of NFC (Near Field Communication) for contactless mobile payments, the possibilities for wireless accurate close-range telemetry are expanded

Project Aims

- To determine a method of power and telemetry that produces an accurate temperature reading
- To validate the chosen temperature sensor through experimentation to ensure human tissue has no impedance on temperature readings
- To evaluate methods of analysis to ensure the extracted data can be used to decide the wounds current state of infection.

Methodology

A Test has been devised to simulate in-vivo conditions at varying depths of biological tissue to ensure the NFC signal is not impeded upon by the medium through which it must pass. MATLAB has been used to control an Arduino microcontroller configured as the control sensor with 0.1℃ accuracy. The NFC based sensor will use a Texas Instruments proprietary software centralised through the MATLAB script where the collected data is stored in a spreadsheet. The heating environment is fully enclosed to remove possible external uncontrolled variables. The NFC transponder system is shown in Figure 1

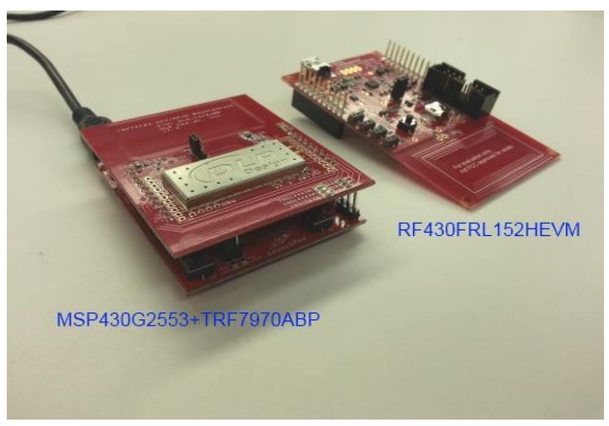

Figure 1 – Image of the development board and NFC plugin module (left) and development board for NFC based sensor (right) [2]

Results

Each depth of simulated tissue (0mm,5mm,10mm,15mm,20mm) were subjected to 3 heating and cooling cycles over 300 iterations allowing for a total of 1500 temperature readings across all mediums. Figure 2 shows the temperature differentials between the control and tested sensor for each medium. A primary observation is the increase in differential temperature between test and control as temperature increases, this is explained by different heat absorption between sensors.

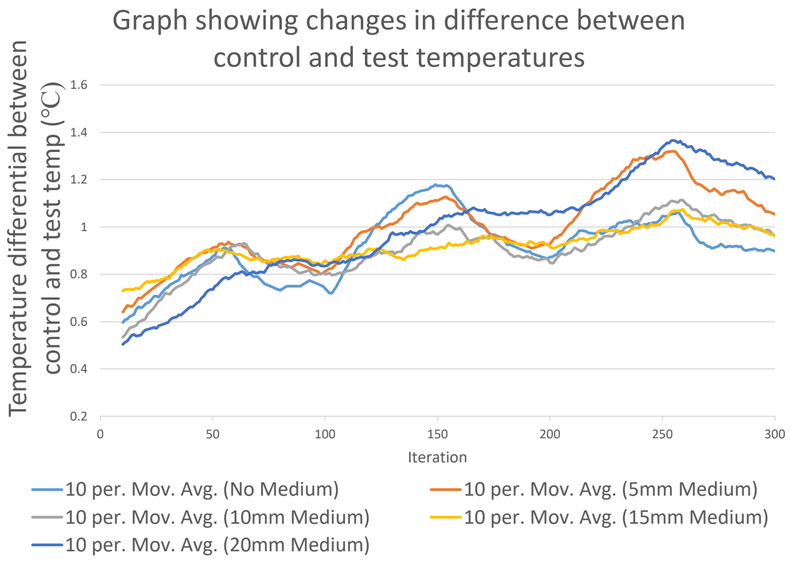

Figure 2 - Graph showing changes in difference between control and test temperatures for 5 varying mediums of simulated human tissue

Statistical Analysis:

Statistical analysis is playing two major roles in the project:

- To form an objective decision as to whether the change in temperature gradient between mediums is significant
- To explore options for determining whether a data set is indicative of an infected wound based on model datasets

The t-test was used to determine that the collected data had statistically insignificant drift between mediums based on 5% (0.05) significance level

The t-test and Wilcoxon signed rank test were used to evaluate infection determination based on randomly generated data sets through MATLAB and was determined that the Wilcoxon signed rank test identified infected data sets with key features of an infected wound using 5% significant as reported by Romano et al [3].

Conclusions

In principle, this piece of research has determined that an NFC based temperature sensing system has the accuracy and determination methods to non-intrusively detect surgical site infections, before the next stages of infection can occur, with possibility for consumer level applications to be used for logging collected temperature data, opening avenues for other sensors to be used in-vivo.

References

[1] Khan, H. A., Baig, F. K. & Mehboob, R., 2017. Nosocomial infections: Epidemiology, prevention, control and surveillance. Asian Pacific Journal of Tropical Biomedice, 7(5), pp. 478-482.

[2] Texas Instruments, 2016. Battery-Less NFC/RFID Temperature Sensing Patch, Dallas: Texas Instruments.

[3] Romano, C. L., Anchise, R. D., Calamita, M. & Manzi, G., 2013. Value of digital telethermography for the diagnosis of septic knee prosthesis: A prospective cohort study. BMC Musculoskeletal Disorders, 14(1), pp. 192-198.

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