Imaging of Haemodynamic Spinal Cord Activity in the Pig

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Measurement of photoplethysmographic (PPG) signal is widely used to assess metabolic conditions of monitored tissues. Probes were designed to acquire physiological changes through the spine induced by external stimulation. In vivo results demonstrate that such probes can be deployed to monitor and analyze autonomic functions of the spinal cord.

The Spinal Cord (SC) is the input of sensory information and output of the motor commands of the limbs and the trunk. Its damage can have major consequences. In addition to Magnetic Resonance Imaging [1], monitoring of haemodynamic constants in the SC is a promising technique of the neuronal activity measurement.
One way to acquire a PPG signal uses a light source and a photodetector placed on opposite sides of the tissues to collect the amount of transmitted light. Depending on the organ to be monitored, signal acquisition can be impaired by tissue light attenuation leading to a small Signal-to-Noise Ratio [2, 3]. Measurements of functional activity in the SC of small animals by Near InfraRed Spectroscopy have been performed by [4]. To study the potential transfer to humans of this imaging technique, custom probes must be designed to lead experiments on bigger animals.

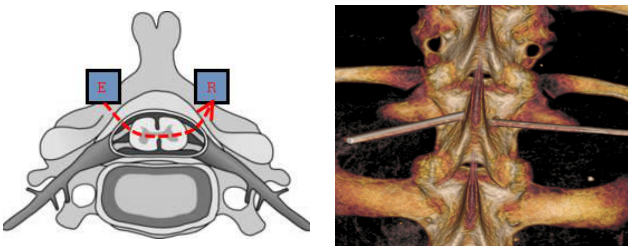

Fig. 1. a) Scheme of principle of the system; b) 3D imagery of vertebrae during experiments.

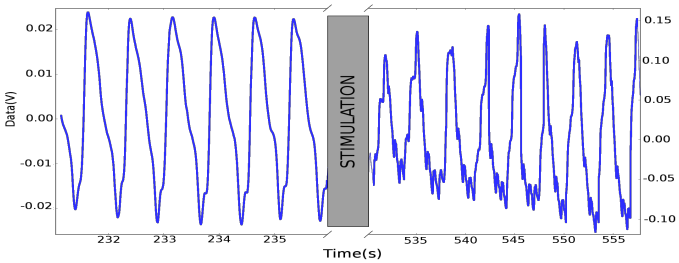

Fig. 2. PPG of the SC with IR LED.

Due to its anatomic proximity with humans, pigs have been chosen for in vivo experiments. As show in Fig. 1, emitter and receptor are placed on either side of the T14 vertebra. On its optical path, light is altered passing by various materials (bone, dura mater, etc.), including the SC.

The PPG acquisition system is composed of a photodetector and two LEDs (624nm and 880nm). Analog signal pre-conditioning is achieved before digital conversion and signal processing. The overall system functions on battery to reduce parasitic signals and a LabVIEW interface is used to record real-time data.

Preliminary results on Fig. 2 show the effectiveness of this non-invasive technique into delivering haemodynamic induced changes. High quality data acquired assess the performances of such a complementary monitoring tool for the SC. Moreover, vital signs, including blood pressure, respiratory rate and oxygen saturation can be extracted.

References

[1] J. Cohen-Adad, R.D. Hoge, H. Leblond, G. Xie, G. Beaudoin, A.W. Song, G. Krueger, J. Doyon, H. Benali, S. Rossignol, “Investigations on spinal cord fMRI of cats under ketamine”, *Neuroimage*, 2009, 2, 44: pp. 328-339.
[2] G. Webster, “Design of Pulse Oximeters”, Ed. Taylor & Francis, New York, 1997.
[3] P. Bingger, J. Fiala, A. Seifert, N. Weber, K. Foerster, C. Heilmann, F. Beyersdorf, P. Woias, H. Zappe, “In vivo monitoring of blood oxygenation using an implantable MEMS-based sensor”, *IEEE MEMS conf.*, pp. 1031,1034, 24-28 Jan. 2010.
[4] A. Goguin, F. Lesage, H. Leblond, M. Pelegrini-Issac, S. Rossignol, H. Benali, “A low-cost implantable near-infrared imaging system of spinal cord activity in the cat”, *IEEE Trans. Biomed Circuits Syst.*, 2010, 4, pp. 329-35.

The measurements were performed with veterinaries of XP-MED, after obtaining permission from the local ethical committee of Cr2i (INRA, Jouy-en-Josas, France) under authorisation number 03-1405.
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