Cost efficient small animal monitoring and trigger device for clinical scanners

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Target Audience – Researchers interested in cost efficient small animal biomonitoring and small animal MRI on clinical scanners.

Purpose – MRI steadily gains importance for pre-clinical small animal research, especially because of it's non-invasiveness and the possibility to conduct longitudinal studies with a single group of animals, without the need to regularly sacrifice part of the animals as it is necessary for, e.g., histological methods. While the installed number of dedicated small animals is increasing, the high demand for small animal imaging leads many research groups, which have no access to high field animal MR scanners, to use clinical whole body scanners instead [1,2]. Since the animals are anesthetized during the MRI scan, monitoring of their respiration, heart rate and body temperature is necessary. A cost efficient and easy to use monitoring system to monitor respiration and heart rate in mice and rats is presented, which can also be used to generate respiratory trigger signals to improve abdominal MR imaging.

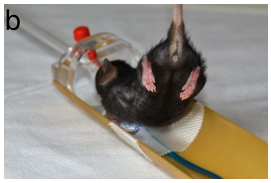

Fig 1. Mouse in head mounting and the position of the pressure pad.

Methods – The detection of the respiratory and cardiac motion is performed by a small pressure pad (see Fig. 1, Graseby Medical Limited, Watford,UK). This pad is connected through standard Luer-Lock extensions (B. Braun Melsungen AG, Melsungen, Germany) to the signal amplifier outside the RF cabin (see Fig 1). A pressure sensor (Motorola MPX 2010) converts the pressure into a balanced electrical signal, which is amplified by the first amplifier stage using an instruments amplifier (INA 118P) in difference mode. The excellent common mode rejection of the INA 118P suppresses the noise in the input signal and the added AC coupling suppresses any DC bias and slow varying trends in the signal. A further low pass filter attenuates all frequencies above 7Hz and a final amplifier stage generates an output signal in the range of several Volts. This signal can easily be visualized on a cheap USB oscilloscope or be digitized for more advanced monitoring software.

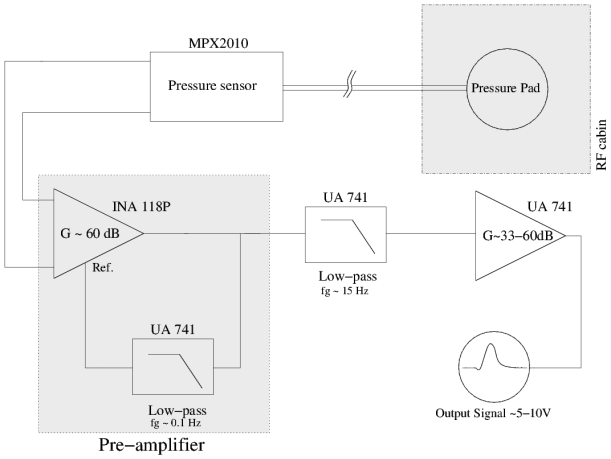

Fig. 2 Schematic of the pressure pick up, signal conversion and signal processing in the analog amplifier.

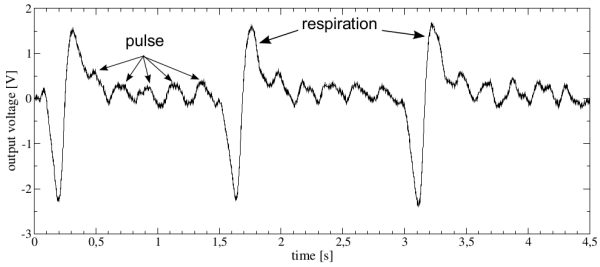

Fig. 3:Plotted is the output signal of the amplifier while monitoring an anesthetized mouse.

To test the monitoring system a mouse was subjected to an MR scan using Isoflurane as anesthetic, while recording the amplifier output with the pressure pad placed under the mouse's thorax. To evaluate the generation of a respiratory trigger, a threshold based trigger was generated and used as external trigger on a clinical 3T scanner (Magnetom TIM Trio, Siemens Healthcare, Germany). As RF receive coil a dedicated 8-channel mouse coil (Rapid biomedical GmbH, Rimpar, Germany) was used.

Results – The output signal of the amplifier is shown in Fig 3, clearly displays the respiratory and cardiac motion of the mouse. The bias and DC correction removes any long term trends and the threshold based respiratory trigger generation was successful. In Fig.4 T2-weighted MRI images are exemplarily shown with and without use of the trigger signal. Clearly the respiratory motion artifacts can be suppressed by employing the trigger, leading to almost artifact free images and reduced image blur.

Discussion – Online visualization of the amplifier output, e.g. by an oscilloscope, can serve as basic respiratory and cardiac monitoring. A more sophisticated software based signal analysis would also allow to automate monitoring the respiratory and cardiac rate as well as the creation of a cardiac trigger, enabling cardiac imaging of mice on a clinical scanners [3]. We could not detect increased noise or artifacts caused by gradient vibration during a scan. The describes system is very easy to handle as the pressure pad and the Luer-Lock tube can remain mounted in the animal holder. To switch animals the next animal is simply placed on the holder. The necessary components are either taken from clinical routine supply (pressure pad, Luer-lock extensions) or can be bought from any electronic parts department. The total cost of the pressure sensor and the amplifier is below 50$. Depending on pre-existing equipment (Oscilloscope, PC, digitizer card) basic monitoring function could already be realized with 100$. The low pass filter attenuating all higher frequencies not only suppressed the ubiquitous 50Hz noise, but also all scanner vibration in the output.

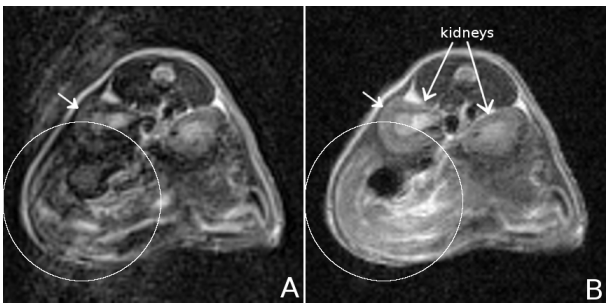

Fig. 4: T2 weighted TSE sequence, TE=82ms, TR=2500ms (2546ms triggerd) Use of the trigger improves image quality and contrast.

Conclusion – The described monitoring system is easy and cheap to build, facilitating occasional small animal imaging for clinical research groups. The biosignal amplifier can furthermore serve as the basic signal processing unit and opens access for any kind of further, more sophisticated post processing in hardware or software. The separation of all electronic parts from the MR safe pressure pad makes it inherently MR compatible.

References [1] Herrmann KH et al. Magn Reson Mater Phy 2012:25(3):233-244; [2] Yamamoto, A et al., Radio Phys technol 2009:2(1):13-21; [3] Montet-Abou K et al., Magn reson Mater Phy 2006:19(3):144-151.