Synchronization and directionality in cardio-respiratory oscillations in anaesthesia: a preliminary observational study in human males

M. Entwistle[1]*, A. Bandrivskyy[2]*, B. Musizza[3]*, A. Stefanovska[4]*, P. McClintock[2]* and A. Smith[1]*
[1]Department of Anaesthesia, Royal Lancaster Infirmary, UK.
[2]Department of Physics, Lancaster University, UK.
[3]Jozef Stefan Institute, Ljubljana, Slovenia.
[4]Faculty of Electrical Engineering, University of Ljubljana, Slovenia.

Previous analyses of cardiorespiratory coupling in anaesthesia have used linear methods.[1] A different approach based on wavelet transform[2] and synchronization indices revealed a marked increase in synchronization between the rhythmic oscillations of respiration and the ECG[3] in rats given ketamine and xylazine. The direction of interaction also changed with changing depth of anaesthesia. Do these phenomena also occur in humans?

We studied 10 healthy men aged between 20 and 40 undergoing elective surgery. Standard clinical monitoring was supplemented by forehead BIS Quatro electrodes (Aspect Medical Systems, Leiden) for EEG capture and a TSD201 respiratory effort transducer (BIOPAC Systems Inc., Goleta, CA) for ventilator frequency (f). A standard anaesthetic (midazolam 2 mg, fentanyl 1.5 μg kg^{-1}, sleep-dose propofol and isoflurane 1% in 40% oxygen in air) was administered by the same anaesthetist. Recordings were made for 30 min in the anaesthetic room before surgery. Waveforms were digitalized at 1000 Hz and stored on a PC for later analysis using the above non-linear techniques.

There appears to be an increase in cardiorespiratory synchronization in these anaesthetized men. The direction of interaction was such that respiration was 'driving' the heart (Fig. 3).

We now plan to monitor patients throughout surgery and into recovery to explore how synchronization and directionality alter with changing depth of anaesthesia.

Acknowledgements: J. Petrovčič, Y. Shiogai and A. Pershakova (equipment and measurements) and Mr I. Crighton (flexibility in surgical scheduling).
Keywords: anaesthesia, depth; cardiovascular system, cardio-respiratory oscillations
References:
1 Galletly DC, Larssen PD. *Br J Anaesth* 1997; **79**: 35–40
2 Stefanovska A, Bračič M. *Contemp Physics* 1999; **40**: 31–55
3 Stefanovska A, Haken H, McClintock PVE, et al. *Phys Rev Lett* 2000; **85**: 4831–4

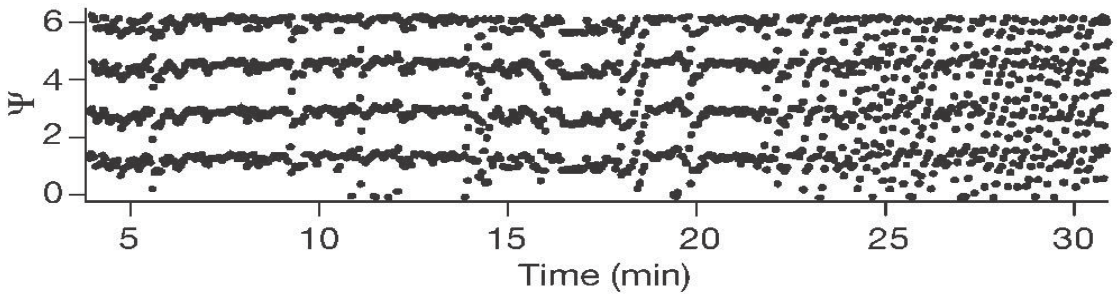

Fig 1 Cardiorespiratory synchrogram for anaesthetized patient showing the phase relationship of heartbeat relative to a fixed point in the breathing cycle (Ψ relative phase). Horizontal (flat) portions of the trace reveal synchronization.