

MR-compatible normobaric gas mixer for hypercapnic vasoreactivity studies on humans

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Purpose/Introduction: Hypercapnic challenges provide a means to explore cerebral vasoreactivity. The latter is key to approach quantitative fMRI¹. By itself, it is a bio-marker of several cerebral diseases^{2,3}. To improve hypercapnic BOLD or ASL perfusion fMRI experiments, SMTEC (Nyon, Switzerland) developed a normobaric gas mixer system, called VarioCap, respecting our specifications to allow safe operation in a 3 T environment with performances compatible with block-designed stimuli. We describe and demonstrate functionality of the developed device in a BOLD vasoreactivity experiment. The VarioCap mixes air and CO₂ to prescribed CO₂ fraction, FiCO₂. To reduce dead gas volume and speed up transitions, it was designed to operate close to the magnet. FiCO₂ can be chosen from 0 % up to 10 % and changed with short response time (T₉₀ < 10 sec). An airtight mask covering mouth and nose administers the gas and receives physiologic monitoring canula. The system allows remote operation through a USB link to the controlling PC. The driving software recognizes trigger pulses from the scanner, and sequentially maintains FiCO₂ values for specified numbers of pulses, as prescribed in a programmable list. An emergency button allows aborting program execution. Internally measured control parameters including respiratory flow rate can be continuously logged.

Subjects and Methods: A healthy volunteer gave informed consent to participate to the protocol, approved by the institutional review

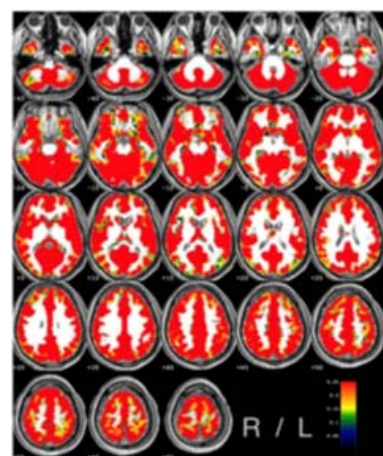


Fig. 3: BOLD vasoreactivity maps [ΔBOLD (%) / ΔEtCO₂ (mmHg)]

realignment, coregistration to anatomy, 6 mm spatial smoothing, temporal filtering. Physiologic regressor as in Ref.2.

Results: Fig. 1 and 2 show FiCO₂ and EtCO₂, and BOLD, signals vs dynamic scan time (in TRs) while Fig. 3 illustrates vasoreactivity maps obtained.

Discussion/Conclusion: BOLD time course (fig. 2) shows that rapid transitions between hypercapnia and normoxia states are achieved. Good quality BOLD vasoreactivity maps (fig. 3) are obtained. Monitored inhaled/end-tidal CO₂ values demonstrate effective regulation of applied gas mixture by the VarioCap (fig. 1).

References: 1) Mark et al., NeuroImage 54:1102-11 (2011); 2) Cantin et al., NeuroImage 58:579-87 (2011); Attyé et al. Human Brain Map. doi:10.1002/hbm.22255 (2013)

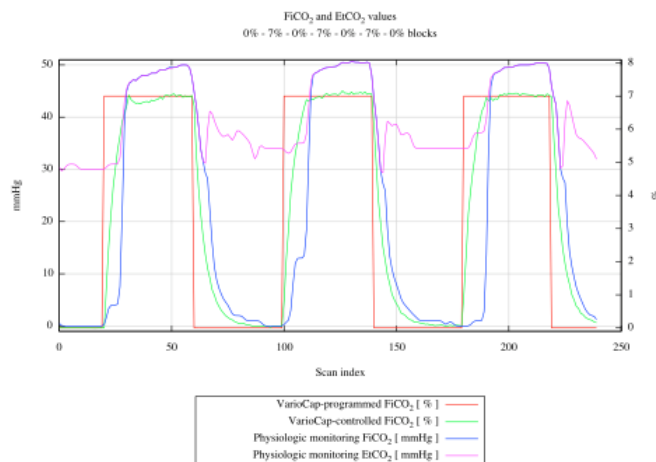


Fig. 1: Example of FiCO₂ and EtCO₂ values measured vs dynamic scan index (TR = 3 s) for a 0% - 7% - 0% - 7% - 0% - 7% - 0% CO₂ concentration block-designed stimulus. VarioCap target (programmed) and internally measured control FiCO₂ values are in %, while values measured with the physiologic monitoring unit are in mmHg.

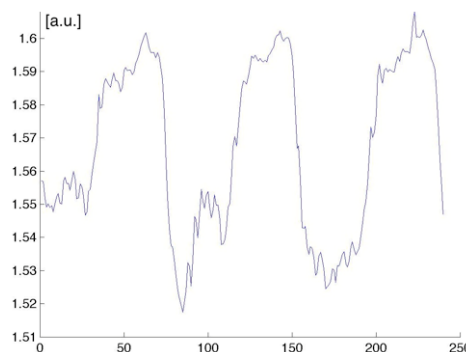


Fig. 2: BOLD signal variations [a.u.] vs dynamic scan index (TR = 3 s)