System for Optimal Stress during Clinical Cardiac MRS

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Introduction To induce changes in myocardial metabolism monitored by ^{31}P in vivo MR spectroscopy in patients with symptoms of coronary artery disease, handgrip stress testing is frequently used. Generating a stable, moderate level of stress in a high field MRI system during acquisition of the spectra is technically difficult. During the stress session, the patient is verbally coached to squeeze the handgrip stressor to employ about 30% of the maximal voluntary contraction (MVC) for 5 to 10 minutes: being asked to increase or decrease the grip pressure whenever the stress level departs from the predetermined level. At such a level of stress, it is critical to maintain a continuous, constant handgrip stress level. Otherwise, the phosphate metabolic alterations tend to recover quickly, and any changes would disappear with involuntary loss of the stress. In practice, it is very difficult for patients to maintain a constant handgrip pressure level due to temporal and biological lag using verbal coaching. Moreover, involuntary adaptation of the patient would interfere with the measurement of such changes. We have developed a PC-based handgrip stress control system that is executed remotely by audio-visual signals to the patient for use within a high field clinical MR scanner environment, eliminating the need and imprecision of the verbal communication.

Methods The system diagram is shown in Figure 1. A compression-load-cell handgrip was chosen to minimize any potential inductive coupling noise. The load-cell/strain-gauge provides the signal source of the system. The strain gage takes 10 to 20 sampling per second from the handgrip. The output from this handgrip was connected to a pre-amplifier and calibrated in units of either [psi] or [kPa]. In addition, a hydraulic handgrip compressor was built and was used as a reference to the load cell gage since it produces no electrical noise. The digital signal from the handgrip is primarily sent to the PC serial port through an RS-232 data interface board. The signal is received using PC's HyperTerminal and Matlab® serial port platform. Predetermined control band, typically ±12.5%, near 30% MVC was set such that an error signal would be induced when the stress level is out of the set band. By the feed-forward or feedback control, the error-signals actuate audio-visual stimulation to the subject in the magnet using a LCD screen and/or headphones. The performance of the handgrip stress control system was tested and evaluated within the high field MR milieu at 3T whole body scanner (General Electric HDx).

Results and Discussion The automatic control system successfully provided feedback to human subjects to maintain a continuous and constant stress level during the stress session. Two different time courses of the stress from the same subject are illustrated in Figure 2. In this typical case, it is shown that the stress level was far more stable during the entire session for the case with our automatic control system than that with verbal communication. In Figure 3, the fluctuations of the stress for several different stress levels were compared with and without the control system. The higher the stress level and the longer the stress session lasted, the clearer the difference between the two came out. The ^{31}P MR spectra were obtained from four healthy volunteers. Among the healthy volunteers, the PCr/ATP changes during the stress was not significantly different between acquisitions with and without the control system: -4.1%±0.08 and 3.5%±0.06, respectively (p>0.15). The spectra obtained with the control system showed better spectral resolution (< 4 Hz FWHM of PCr peak).

It was demonstrated that the automated stress control system has made the stress level more constant in the MR scanner. In light of this improvement, one can obtain more accurate measurements of the changes in metabolites, and higher spectral resolution by stabilizing movements with proactively sustained control during stress ^{31}P MRS.

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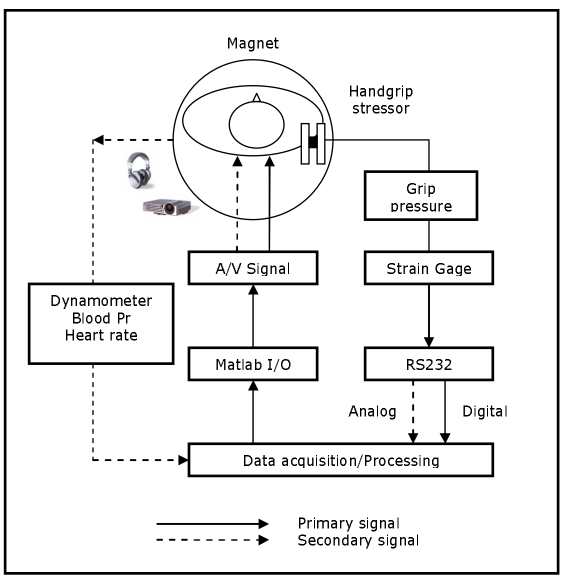

Figure 1. System Diagram

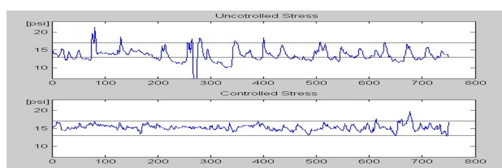

Figure 2. Typical stress time course: with verbal coaching (above), with automatic control (below)

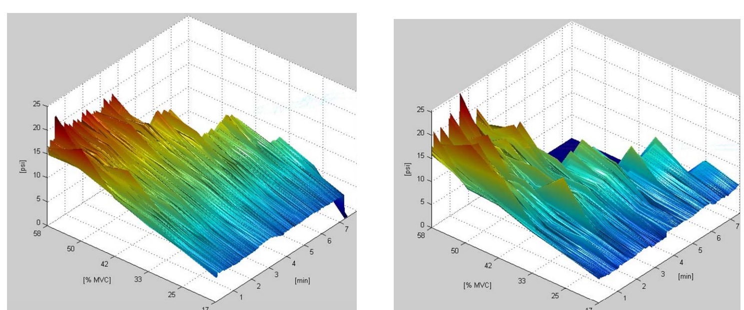

Figure 3. [**Left**] Time course of stress at different stress levels with our new control device: 17%, 25%, 33%, 42%, 50% and 58% of MVC. As anticipated, fluctuation increased as stress increased. However during the entire session, the stress levels were well maintained. [**Right**] Time course of stress at different stress levels without the feedback device. Fluctuation in stress level was very high.