ChiroSensor-An Array of Non-Invasive sEMG Electrodes

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Abstract-It is shown that the statistical analysis of the sEMG signals recorded by the ChiroSensors along the paraspinal muscles during Network Spinal Analysis (NSA) provides objective confirmation of the physiological reality as perceived by the practitioner as it relates to levels of care and spinal injury recovery.

1. Problem

The *problem* is to develop objective confirmation, via statistical analysis of the sEMG signals recorded along the paraspinal muscles, of the existence of the so-called Network Spinal Analysis (NSA) wave, and, probably most importantly, the amount of recovery of a spinal injury patient receiving NSA care. So far, this has been left to the subjective judgment of the practitioner, who was relying for the most part on visualization of the rocking motion of the spine.

2. Background

The spinal cord is pivotal in the movement of the human body, and as such it needs to be kept in proper alignment. Chiropractors have developed solutions for people suffering from back pain and injuries, among other disorders. Network Spinal Analysis (NSA) is one such technique [5-7], which has been demonstrated to relieve physiological stress by generating a somatosensory wave along the spine. This wave originates in the cervical and sacral areas, where the dural-vertebral attachments [2] at C2-C4 and the attachment of the filum terminale to the coccyx create sensory-motor loops, which by digital contact elicit oscillations, first localized in the neck and sacral areas, and then propagating along the whole spine in a rocking, involuntarily-controlled movement, accompanied by the respiratory wave. This evolution is concomitant with increased burstyness of the sEMG signals [4,7]. The NSA wave, while primarily located in the spinal region, bears some commonality with the cycling style repetitive motion that produced some Central Nervous System (CNS) regeneration in the well-publicized case of Christopher Reeve [9]. In fact, as a recent study has shown, a patient who had sustained an injury similar to that of Reeve did recover some sensory and motor function after NSA care [6]. Both cases are *activity based* recovery programs with the difference that in the Reeve case the activity is generated by the

Functional Electric Stimulation (FES) bicycle, whereas with NSA the body is entrained to reactivate a Central Pattern Generator (CPG).

3. Methods

The *method* consists in acquiring sEMG signals from an array of non-invasive electrodes at the C, T, L, and S levels during NSA entrainment. The raw signal is recorded by an Insight Millenium machine, sampled at a rate of 4000 sec^{-1} by a DAS16/16 board and stored on a PC compatible computer. Then various analyses are performed: (ia) The spatio-temporal analysis [6], which correlates the signals at various points along the spine in order to positively establish a traveling wave settling in a stationary wave, as already called up by the practitioner; (ib) For a spinal injury patient [6], the correlation is measured on sEMG signals across the injury area; (ii) Dynamical modeling of the neck signals revealing structural changes [7], called up by the practitioner as changes in the level of care, that is, number of rhythmically entrained spinal oscillators (sacral, cervical, and thoracic-sternal).

4. Results

The *results* are (ib) 99% confidence level correlation between signals across injury area for a quadriplegic patient who has been under NSA care, and observation of an extra phase shift in the correlation involving signals across injury area [6]; it is however unclear what kind of regeneration this points to. (ii) Objective confirmation of practitioner's visual evaluation of NSA wave by dynamical modeling of sEMG signals as examplified by the staircase diagram of best fitting ARIMA model of cervical sEMG signal versus progression through NSA entrainment [5].

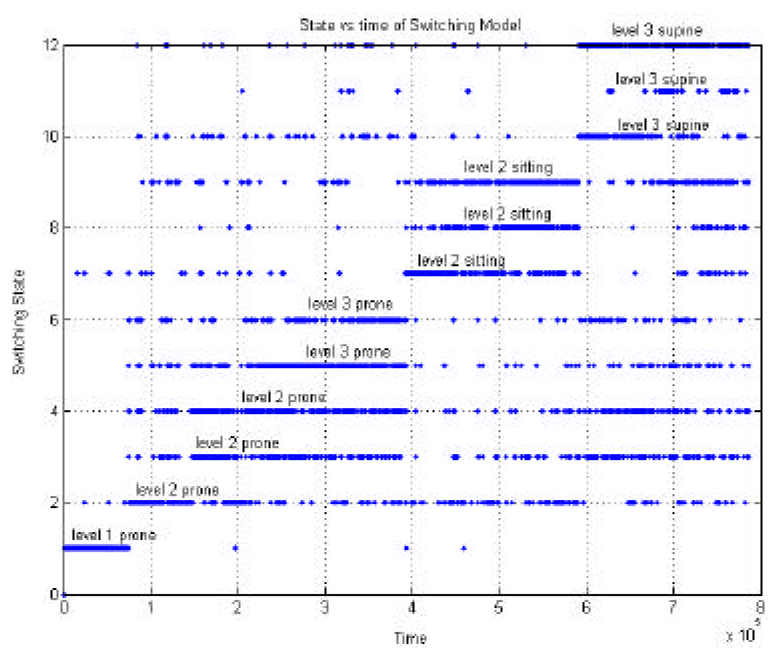

Figure1: Best fit mathematical model of cervical sEMG signal versus progression towards entrainment. The abscissa is the entrainment time and the ordinate is the ARIMA model chosen among 12 of them.

5. Discussion

Since the NSA wave has been objectively confirmed by mathematical analysis, it appears the time has come to correlate the visual observation with the motor pathways involved.
The cutaneous cervical receptors receive sensory input from the skin and reach the cervical plexus at level C2-C3. The cervical plexus at level C2 sends motor outputs to the accessory nerve and the sternomastoid muscle of the neck and at level C3-C4-C5 sends motor output to the phrenic nerve, which innervates the diaphragm (which is one of the major muscles of inspiration). The accessory nerve in turn innervates the sternomastoid muscles of the neck and the trapezius muscle of the shoulders. These sensory-motor pathways explain the NSA wave to the extent of involvement of the neck and shoulder muscles which may give rise to the somatosensory wave in the spinal cord and the diaphragm muscles which may give rise to the respiratory wave. It is conjectured that the sensory-motor loop closes via the dural mechanoreceptors [1,3,8].

From another point of view, the electrophysiological bursts at the neuronal level [4] appear to synchronize to produce the bursts at the sEMG level [7]. It is also observed that the accrued burstyness under neurotransmitters at the neuronal level appears similar to the one at the sEMG level at higher levels of care.

6. Conclusions

The spinal wave pattern that can be observed during NSA has been confirmed by statistical analysis of the signals and a tentative explanation of the wave as a sensory-motor loop oscillation has been proposed.

7. References

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