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Synthetic Modulation of Audio Feedback for electromyographic display in continuous intraoperative neuromonitoring

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SAFE (Synthetic Audio Feedback for EMG-display)

The purpose of this study was firstly to verify our hypothesis that “Synthetic audio feedback transmits the change in EMG-amplitude better than currently used analog systems to the surgeon”; during continuous intraoperative neuromonitoring. The second aim was to identify the most appropriate sound characteristics to modulate.

Material and Methods: A computer-based quantitative signal analysis was performed. Previously intraoperative recorded vocal cord EMG data from routine thyroid surgeries constituted the basis for EMG-analysis and synthetic sound modulation. EMG- Signal changes were defined as amplitude changes and the signal changes were represented by a change in a synthetic sound.

A synthetic sound is a sound which was generated by computer via either envelope modulation or modulation of harmonic spectrum or both. Inclusive the native EMG sound (analog tone) it makes a total of 4 different audio feedback sounds:

1. Envelope modulation,
2. Harmonic spectrum modulation,
3. Combined modulation (envelope and harmonic together)
4. The analog tone generated by the EMG- Signal directly.

Three different EMG intervals were chosen from intraoperative recorded vocal cord EMG-data: The EMG-Signal interval which decreases fast, was chosen as the “fast course”. The EMG-Signal interval which decreases slowly, was chosen as the “slow course”. The EMG-Signal interval which increases and decreases continuously was chosen as the “alternating course”. Four different modulation of these 3 courses

generated a total of 12 scenarios. They were presented twice in a randomized order to participants, consisting of surgeons and assistant physicians.

The participants were requested to register on the computer via mouse of the laptop, from which the sounds were played, whenever they recognized a change in the sound. Detection threshold, delta A (mean amplitude difference between any two consequent clicks), delta t (time interval between any two consequent clicks) and the number of recognized changes (number of clicks) were compared among four modulations. The subjective interpretation of participants were also evaluated through a questionnaire at the end of the experiment. According to the results of frequency analysis of environmental noises in the operating room, the frequency interval between 300-600 Hz (Herz) was free. A constant frequency of 320 Hz was determined for all of the sounds.

Results: Detection threshold (the first recognized change in EMG-amplitude) was significantly less in combined modulation and in harmonic modulation than in analog tone (~7% vs. 28%, p=0,0000003; ~10% vs. 28%, p=0,00000517, respectively). The mean amplitude difference (delta A) was almost twice as much as in analog tone than in combined and harmonic modulation (70% vs. 33%, p=0,000002; 70% vs. 35%, p=0,000008, respectively). The mean delta t (time interval any two consequent registrations) in combined modulation was significantly less (23%) than in analog tone (5977,68 vs 7788,63; p=0,009).

The mean number of recognized changes (number of clicks) was significantly higher in combined and harmonic modulation than in analog tone (Mean: 8,5 vs. 5,5 p=0,0005; 7,8 vs. 5,5 p=0,005). The results of envelope modulation was not significantly different from that of analog tone. Although the results of combined modulation were slightly better than harmonic modulation, the differences were not statistically significant. Subjective evaluation of questionnaires revealed almost equal ranking of harmonic and combined modulation which were succeeded by envelope modulation and analog feedback respectively (Mean 16,70; 16,13; 15,53; 13,60 respectively).

Conclusion: The first change in EMG amplitude was recognized earlier by synthetic audio feedback than by currently available analog feedback. Synthetic modulation facilitated detection of smaller changes in EMG amplitude. Synthetic modulation allowed recognition of EMG changes in shorter time intervals than analog tones. Significantly more number of changes was recognized by synthetic audio feedback than by analog feedback. Synthetic tones (harmonic and combined modulations) were evaluated to have a higher alarming capacity than analog tone and were interpreted as “more likely to cause change of attitude”. Our hypothesis was verified; synthetic audio feedback (except envelope modulation) transmit the change in EMG amplitude better than the currently available analog audio feedback ($p < 0,005$).