MAPPING OF FACIAL MOTOR UNITS BY MEANS OF HIGH-DENSITY SURFACE EMG

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Objectives

(1) To develop an easily adaptable and minimally obstructive sensor that allows the application of high-density surface electromyography (sEMG) in the face, and (2) to map and characterize motor unit (MU) action potentials (MUAPs) from the facial musculature.

Background

The facial musculature is a complex, 3-dimensional assembly of small muscular slips (Ref. 1) performing a variety of complex and important orofacial functions (e.g. speech, mastication, swallowing, mediation of emotional and affective states). The topographical profile and the electrophysiological behavior of facial MUs have not been studied yet. Important factors in this respect are:

(1) limitations of technical and signal processing tools
(2) relatively large methodological demands in the facial area (Ref. 2).

The main limitations of construction principles and application techniques of conventional surface electrode array systems are:

(1) large sensor dimensions (especially the height of several cm) which hinder the (e.g. orofacial) functions to be studied
(2) limitations regarding mechanical flexibility resulting in missing electrical contacts (rigid arrays cannot follow the patient's anatomy)
(3) necessity of external fixations (e.g. Velcro tied around a limb) for skin attachment. Such a technique cannot be employed in the face.

Methods

13 (specially trained) healthy subjects performed selective contractions of 9 different facial muscles at different activity levels. 120 sEMG signals were simultaneously recorded using thin and highly flexible multi-electrode sEMG grids (Figs. 1+2). The inter-electrode distance (IED) was 4mm in both directions. The grids were attached to the skin using double-sided adhesive tape which has been specially prepared by creating regular patterns of 2.2-mm and 1.2-mm holes. These allow the selective application of conductive cream only directly below the detection surfaces and facilitate sensor attachment procedure (Ref. 3).

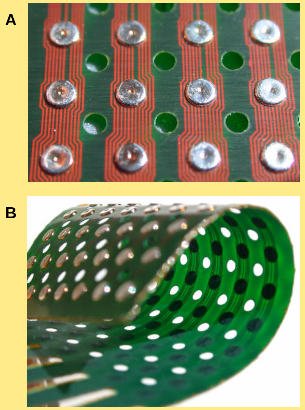

Fig.1: (A) Electrode grid manufactured using flexprint techniques. (B) The 50µm thin, highly flexible electrode carrier material (Polyimid®) allows grids to be cut out in different sizes.

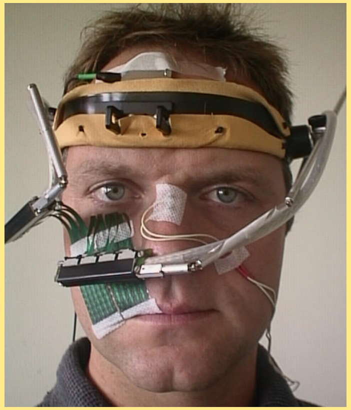

Fig.2: Measurement set-up for high-density sEMG in the upper facial area. Signals from 120 electrodes were simultaneously sampled at 2000Hz using two 5 by 12 electrode grids positioned side by side.

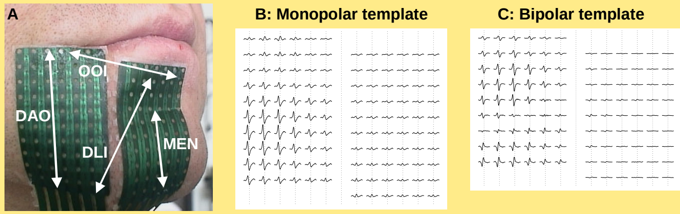

Fig.3: (A) Two 6 by 10 electrode grids attached to the lower face. The position and fiber direction of the underlying facial muscles are indicated by white arrows. (B) Monopolar or (C) bipolar templates showing the spatio-temporal characteristics of individual MU action potentials (MUAPs). These "MU fingerprints" were decomposed from data recorded during a selective, moderate contraction of the depressor anguli oris (DAO) muscle. Bipolar montage was constructed in vertical direction.

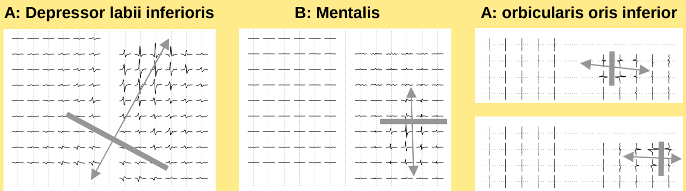

Fig.4: Different bipolar templates of MUs belonging to (A) the depressor labii inferioris (DLI), (B) the mentalis (MEN), or (C+D) the orbicularis oris inferior (OOI) muscles. According to the main fibre direction of the contracted muscle, construction of the bipolar montage was either vertically (A+B) or horizontally (C+D). The grey bar in each template indicates the location of the innervation zone.

Results

High signal quality is achievable with our new electrode grid type. This is mainly due to relatively low electrode-to-skin impedances, also in skin areas with very uneven contours. The introduced technique allowed to map the highly variable facial muscle structure. The decomposed MUAPs (Figs. 3+4) are in good agreement with the anatomical literature (Ref. 1) and histo-chemical studies (Ref. 4). The templates reveal some of the distinctive characters of facial MU topography; the occurrence of

- overlapping territories of MUs belonging to different muscles (resulting in unidentified cross-talk in regular EMG recordings).
- asymmetrically located endplate zones (Fig. 4A+B)
- MUs with small territories and neuromuscular junctions in distinct locations of individual facial muscle subcomponents (Fig. 4C+D).

<u>Further plans for clinical application:</u>

- the study of topographic aspects of neuromuscular diseases (e.g. in patients with facioscapulohumeral dystrophy and Möbius syndrome)
- the observation of regeneration and reinnervation of MUs after peripheral nerve injuries or muscle transplantation
- the determination of endplate zones prior to botulinum injection.

Conclusion

Information about facial MU topography is of great interest from anatomical, neurological and maxillo-facial surgical respects. This knowledge is also indispensable in establishing guidelines for placement of conventional (surface or needle) electrode configurations.

The newly developed high-density sEMG grid is flexible, easily adaptable, does not change the muscle's contour, and results in high quality recordings – even in the most challenging anatomical places, such as the face. These are, together with the possibility of mass/series production, significant positive features for the development of more broad clinical application of high-density sEMG.

References.

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