Synchronous muscular co-ordination and 3-dimensional motion analysis in treatment of patients with obstetric plexus-lesion

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Introduction

Lesions of the n. plexus brachialis are one of the major causes for functional impairments in upper extremity movement. They are often caused by a birth trauma, when the whole nerve or parts of it are torn, or even eradicated off their root in the spinal channel. This ensues in improper, insufficient or no nerval supply of the affected muscles, depending on the progress of reinnervation. One very important factor for a successful treatment of plexus lesions is the correct diagnosis of the cause for the impairment. Up to date there is a lack of objective methods for the identification of the dysfunction's cause. The decision for a specific treatment is still based on subjective data as obtained in clinical examination and by visual assessment. This can result in an erroneous diagnosis and thus in an incorrect medication, for example an unnecessary operation. Furthermore, if not doctored adequately, the lesion may lead to an irreversible dysfunction in posture. At the Helmholtz-Institute, a procedure based on a synchronised analysis of the 3-dimensional upper extremity movement and the muscular co-ordination pattern detected by bipolar surface EMG has been developed, which allows the objective and quantitative assessment of the impairments cause. Depending on the source of the dysfunction, different medications like nerve transplantation, paralysing injections in affected muscles and/or gymnastics are used in treatment.

Methods

A kinematic model of the upper extremity, consisting of single rigid segments, is used for the evaluation of the data acquired by the motion analysis. Motion between the segments is assumed to be only possible within the defined joints as a sheer rotation, i.e. no transversal movement is allowed. Fig. 1 shows the applied segmentation for the kinematic model including the joints in the left picture and the arrangement of markers on the patients upper body in the right illustration. The darker markers forming a triad represent the segment definitions in 3-dimensional space for the thorax, the upper arm, the forearm and the hand. The lighter markers determine the joint axis of elbow and wrist, which are measured only within a static trial to expel erroneous data due to skin movement.

Fig. 1: Segmentation of the kinematic model (left picture) and marker configuration with segment (dark) and joint (light) markers (right picture).

The rotational centre of the shoulder joint has to be estimated, because of its location deep below the surface. The optimisation is based on the kinematic model and a certain motion of the arm. Thorax, clavicle and humerus are connected through two ball and socket joints, resulting in a point which does not change its position relatively to the bone of the upper arm. Because this is also the endpoint of the clavicle, every motion of the point results in a motion of the clavicle. The optimisation criterion is
therefore based on the motion of the clavicle. A cost function must exist which value is the higher the more the clavicle moves and which is only dependent from the position of the joint centre. The less the clavicle moves, the better the estimation of the rotation centre of the shoulder. Fig. 2 illustrates this correlation [1].

This approach requires movement of the upper arm around at least to axis of the shoulder centre. A movement that approved itself is the abduction of the 90° flexed upper arm, followed by a rotation in the transversal plane to the inside. After determination of the joint axis and the shoulder centre, the kinematic model is completed and joint angles can be calculated. Additionally the muscular co-ordination is measured non-invasively using bipolar surface electrodes which are placed on the patients body according to the SENIAM recommendations [2]. The EMG signals are amplified directly at the source and then synchronously transmitted to the motion analysis system. As an example for the feasibility of the presented procedure, twenty patients in the age range 2-10 years with a lesion of the n. plexus brachialis have been investigated. Measured muscles are the m. brachioradialis, m. bizeps brachii, m. trizeps brachii, m. deltoideus, m. infraspinatus and m. trapezious.

**Results & Discussion**

The measured 3-dimensional motion in combination with the corresponding muscular co-ordination allows a precise analysis of the movement and the detection of the dysfunction's cause. An example of a test motion performed by the patients is the so called "cookie test". This test movement involves bringing a cookie from the knee to the mouth. Fig. 3 illustrates the degree of movement restriction observed for different parts of the affected arm and compares these results to those for the healthy side. In the case of the shoulder, both irregular/jerky movements and reduced range of movement are observed. Additionally, the performance rate of elbow flexion is clearly reduced and a loss of control of movement can be recognised to a certain extent during pronation on the affected side.

![Fig. 3: Joint angles of the different involved movements calculated by marker trajectories.](image)
As an example for the combination of movement analysis and measurement of EMG data, fig. 4 shows the joint angles and the recorded EMG data for the flexion/extension of the elbow joint while the patient is performing the cookie test. The diagram clearly shows the substantial changes between the healthy and affected side. On the healthy side a clear alternation in activation can be observed between agonist and antagonist. In contrast, co-contractions of m. biceps brachii and m. triceps brachii are present on the affected side. Although the biceps of the impaired side shows a normal activation pattern, the EMG curve of the triceps shows, compared with the healthy side, a constant activation during the complete motion. This results in co-contractions and thus in restricted movement.

Fig. 4: Joint angle process and synchronously measured surface EMG with repeated inflection of the elbow joint.

Summarising all parts of the measurement procedure, the recorded motion of the elbow joint reveals the degree of impairment. The cause for the restriction can be determined objectively and quantitatively by utilising the EMG recordings. A special advantage of this procedure is contact free recording. Thus, movements are unconstrained and natural. Such measurements make a substantial contribution to the objective analysis of movement, which cannot be achieved by purely visual observation. In patients with a lesion of the n. plexus brachialis the feasibility of the presented procedure has been clearly demonstrated. However, since the procedure is not limited to a certain movement like the presented elbow flexion, it can be extended to all kinds of upper extremity movement. As another consequence not only the treatment of plexus lesions becomes possible, moreover patients with any kind of dysfunction in upper extremity movement will benefit from the presented procedure.

References

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