Electrotactile feedback for trans-femoral amputee gait re-education

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1. Introduction

There has been renewed interest in the application of biofeedback for gait and posture re-education. Electrical stimulation is one means of presenting feedback stimuli to patients and has been used with amputees to provide knowledge of gait event timing through implanted and surface stimulation of discrete anatomical regions [1, 2].

Electrotactile displays (ETD) use an array of electrodes to present information through transcutaneous electrical stimulation, thus providing spatial resolution for information coding. ETDs have found various uses. For example Vuillerme has developed a device to present information about ankle orientation to the tongue [3].

2. Aims

This paper briefly describes the development of a prototype stimulator and electrode array that will provide real-time electrotactile feedback to trans-femoral amputees undergoing gait re-education.

3. Method

During treadmill training, for example to minimise circumduction or abduction gait patterns, amputees will receive feedback about thigh orientation through an electrode array worn around the circumference of the residual stump. Thigh kinematics will be determined using a ProReflex motion capture system (Qualisys, Sweden). A programme has been written in LabVIEW to read marker coordinates from the Qualisys software in real-time via a TCP/IP connection. Joint angles are then calculated and will be used to drive a surface sensory stimulator. The flexible electrode array will consist of a ring of active electrodes surrounded by a single reference, to allow the sense of stimulation to move across the thigh surface. Sixteen channels are being considered. To account for variations in afferent sensitivity, patient feedback will be acquired during a static calibration process. During operation stimulation will occur if the patient's gait moves outside limits set according to individual clinical goals. Information will be conveyed through stimulus intensity and the spatial location of the active electrode. Figure 1 shows a graph of hip joint flexion / extension against abduction / adduction, at an instance in the gait cycle, with a transverse section of a thigh electrode ring. An example is shown of a patient within a standard deviation band for normal flexion, but with excessive abduction, as may be seen in an amputee circumducting through swing. The active electrode is selected according to the angle of the vector connecting the two crosshairs. Stimulus intensity is proportional to the vector magnitude.

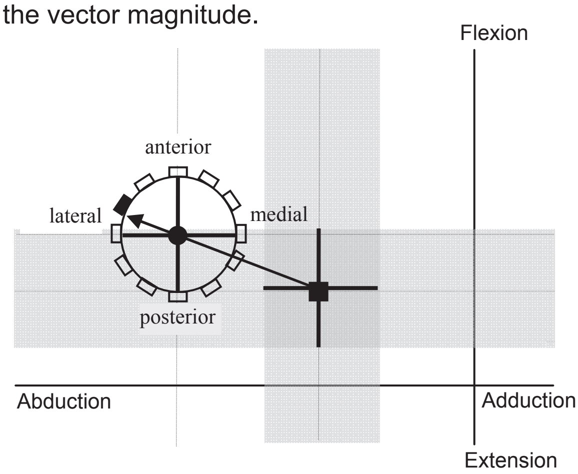

Figure 1: Scheme for electrode selection and stimulus intensity. The cross with the square represents the mean and standard deviation of normal sagittal and coronal hip angles at an instant in the gait cycle. The cross with the circle represents the patient undergoing training. For clarity a reduced number of electrodes are shown.

4. Discussion and Conclusions

Factors being considered before practical implementation include: the trade off between electrode resolution; pain threshold and the spatial information content; flexible array materials; and the overall stimulus presentation in accordance with theories of motor learning.

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