Upper Extremity Reconstruction

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Motivation

The conference was focalized on reconstruction of upper extremity due to loss or injury, as well as on upper extremity/hand rehabilitation, taking into account that the loss or injury of arm and hand function results in the immediate inability to perform even simple activities of daily living. Prof. Aszmann showed in his conference the role of bionics in hand reconstruction in order to promote advanced designs in this area of neurorehabilitation. In addition, the lecturer presented some example of arm/hand reconstruction according to the scenario of the patient, as well as his collaboration work with the company Otto Bock to explore the possibilities and limits of bionic reconstruction, which has now led to the establishment of a Center for Extremity Reconstruction and Rehabilitation.

Extremity reconstruction process

The procedure for reconstructing the arm or hand starts with the implant of part of another muscle in the upper limb damaged, creating a bridge between the body and the restored arm/hand. Then, the patient trains with a virtual hand to strengthen the muscles where the biometric reconstruction will be located. Afterwards, muscle identification is done and to obtain the biosignals of the muscles, some interdigitated microsensor electrodes (IMEs) are implanted on them. The muscles' biosignals are used for controlling the reconstructed arm. Among all nerves, the ulnar nerve is one of the most important due to its learning process.

The more time the patient has the biometric reconstruction, the more learn the ulnar nerve and more biosignals are acquired, letting the patient to have a better control of the restored arm.

Limitations

The extremity reconstruction and the implementation of prosthesis have some limitations regarding the adaptation process of the device to the limb of the amputee or the technical characteristics of the prosthesis. Inefficient adaptation results in high pressures above the remaining limb where the prosthesis is fixed, causing skin damage.

Surface electrodes main limitations are their variable position due to rotational movements and the signal quality. For instance, a contact loss of the electrodes may appear when lifting projects. The signal quality of these electrodes is poor and difficult for being detected, resulting in a long rehabilitation process of the amputee.

No feedback is provided by sensors to the amputees when using some of the prosthesis. The sound of the motors included in the mechanisms of these devices are said to enhance the proprioception sense of the amputee.

Future work

Because of the functional and anatomical diversity in the amputees population, in the near future research will not tend towards a universal solution for upper-limb functional restoration, but rather towards a set of specific advanced solutions, that will leverage medical, technological and rehabilitative advancements.

Despite the potential impact of the possibility of using nerve or brain signals for control, the use of muscle signals for decoding motor intention remains the most robust and accurate interface for upper-limb prostheses.

The majority of transradial unilateral amputees will probably be fitted with mechatronic prostheses controlled using IMES sensors.

To deal with the lack of a sufficient number sites from which it is possible to extract enough distinct EMG signals, future clinical systems will also be based on surgical reconstruction in conjunction with the recently developed surgical procedure of targeted muscle reinnervation (TMR), which allows for the interfacing of nerves via muscle recordings. Nerves that formerly innervate the missing limb will be redirected to remaining muscles in the region of the stump, the latter being used as biological amplifiers of specific nerve activity.

In case of impossibility of using standard sockets because of the small dimension of the stump, the direct integration of the prosthesis into the bone of the remaining limb will be realized by means of a procedure called osseointegration. Besides replicating the normal anatomical structure, osseointegration realizes a stronger coupling with the body through direct transmission of forces between the prosthesis and the bones. Future research will focus on reducing the risk of infection remains owing to the need for the boneanchored interface to pass percutaneously.

Current research is showing that it may be possible in the future to find new ways to deal with transplant rejection without using immunosuppressant. In a not so far future, hand transplantation could therefore become a standard procedure for bilateral amputees.

The increase of bionic substitution and the advancements in all of these fields combined substantially will decrease the relatively high current abandonment rate of active prostheses and ideally restore the lost functionality for all kinds of amputees.

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