Using posterior part of the deltoid muscle as receptor and quality control with intra-operative electrophysiological examination in targeted muscle reinnervation for high-level upper extremity amputees

Hua-Wei Yin[1], Jun-Tao Feng[2], Yun-Dong Shen[3], Yan-Song Wang[4], Ding-Guo Zhang[4], Wen-Dong Xu[1,2,3,5,6]

[1]Department of Hand Surgery, Huashan Hospital, Shanghai Medical College, Fudan University, Shanghai 200040, China;
[2]Department of Hand and Upper Extremity Surgery, Jing'an District Central Hospital, Shanghai 200040, China;
[3]National Clinical Research Center for Aging and Medicine, Huashan Hospital, Fudan University, Shanghai 200040, China;
[4]State Key Laboratory of Mechanical System and Vibration, School of Mechanical Engineering, Shanghai Jiao Tong University, Shanghai 200240, China;
[5]Priority Among Priorities of Shanghai Municipal Clinical Medicine Center, Shanghai 200240, China;
[6]Institute of Engineering and Application Technology, Fudan University, Shanghai 200433, China.

To the Editor: Targeted muscle reinnervation (TMR) is a surgical technique of multiple nerve transfers, providing a potential of improved intuitive prosthetic control via surface electromyography (sEMG) in the high-level upper extremity amputees.[1] However, there is a risk that some of the reinnervations might be unsuccessful, especially for the ulnar nerve.[2] Both the quality control of nerve stumps and the receptor are important factors for the surgery. Assessing the nerve stumps during the surgery and finding more muscles as receptor might address the problem. Biceps, triceps, and brachialis muscles were mostly chosen as receptors for reinnervation in the trans-humeral amputees. Pectoralis major and pectoralis minor were mostly chosen as receptors for reinnervation in the shoulder disarticulation patients.[3] The deltoid muscle, which is composed of anterior, middle, and posterior parts, and supplied respectively by different branches of the axillary nerve, might be an addition option to increase the amount of receptor muscles.[4] During the surgery, assessment of the location of residual nerve stumps with good quality or the specific branches dissected for receptor reinnervation is challenging.[5] We conducted a study of two trans-humeral level amputees, who underwent TMR using posterior part of the deltoid muscle as one of the receptors and performing nerve assessment with intra-operative electrophysiological examination.

The study was approved by the Institutional Review Board of Fudan University (No. 2016-329) and in compliance with the principles of the *Declaration of Helsinki*. Written consents were received from the participants.

Two right side trans-humeral level amputees, with phantom limb sensation, were recruited in the study. Characteristics of the two cases are listed in Supplementary Table 1, http://links.lww.com/CM9/A399. The main complains of both patients were affected upper limb functions. However, neuroma pain could be triggered when the nerve stumps were touched.

General anesthesia was applied to the patients in supine position. The nerves were exposed from the front side of the axillary region or at the quadrilateral foramen from the back side of the axillary region [Figure 1]. Because these surgical incisions were in the flexible upper arm, the anterior approach could be completed with shoulder abduction, and the posterior approach could be completed with shoulder flexion and adduction, without changing patient position.

First, somatosensory evoked potential (SEP) test was used to detect the point of residual stumps with acceptable function with an intra-operative electromyography device (Keypoint, Alpine Biomed ApS, Denmark). With the receiving electrodes attached to scalp of the patient, SEP test was performed for each stump from the most distal part, while the stimulating bipolar probe was moved gradually to the proximal part [Supplementary Figure 1, http://links.lww.com/CM9/A399], with the parameters of 5.0 mA, 5 HZ,

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Hua-Wei Yin, Jun-Tao Feng, and Yun-Dong Shen contributed equally to this work.

Correspondence to: Wen-Dong Xu, Department of Hand Surgery, Huashan Hospital, Fudan University, Shanghai 200040, China
E-Mail: wendongxu@fudan.edu.cn

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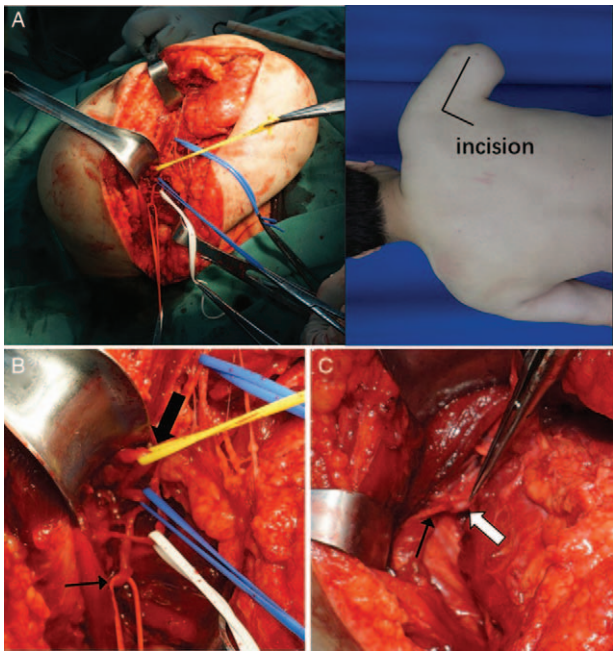

Figure 1: (A) Incision from the back of quadrilateral foramen; (B) Exposure of branches of the axillary nerve (thick arrow, anterior branch; thin arrow, posterior branch); (C) After nerve anastomosis (white arrow, ulnar nerve; thin arrow, posterior branch of the axillary nerve).

sweeps number over 100 to obtain an average. A second run was acquired to check reproducibility. The available nerve point was chosen where a SEP was detected from the scalp electrodes [Supplementary Figure 2, http://links.lww.com/CM9/A399]. Second, the receptor nerves and their branches were assessed with compound muscle action potential (CMAP) with the parameters of 3.0 mA, three times for average [Supplementary Figure 3, http://links.lww.com/CM9/A399]. When performing the SEP and CAMP test, the point of the receiving electrode is maintained unchanged, and the stimulating probe is placed at different points or nerve branches for stimulation.

In case 1, the median nerve was transferred to the medial head of the biceps. The distal radial nerve was transferred to the lateral head of the triceps. In addition, the CMAP test of deltoid muscle indicated that the posterior part was innervated mainly by the posterior branches of the axillary nerve [Supplementary Table 2, http://links.lww.com/CM9/A399]. Thus, the ulnar nerve was transferred to the posterior branches of axillary nerve, innervating the posterior deltoid.

In case 2, CMAP could be elicited in only one head in either biceps or triceps, which could not be partial sacrificed as receptor. Fortunately, good CMAPs were elicited in all the three parts of the deltoid, in which the posterior part of the deltoid muscle was innervated mainly by the posterior branches of the axillary nerve [Supplementary Table 2, http://links.lww.com/CM9/A399]. Thus, the median nerve was transferred to the clavicular head of pectoralis major. The radial nerve was transferred to the sternal head of pectoralis major. The ulnar nerve was transferred to the posterior branches of axillary nerve, innervating the posterior deltoid.

After the surgery, the patients were instructed to frequently attempt to open and close the phantom hand and abduct the phantom fingers. After approximately 3 months, SEP, CMAP, and sEMG test indicated all the targeted muscles had been reinnervated. For these two patients, five bipolar EMG electrodes were placed on the skin over the muscles with the guidance of the surgeons, especially, including the skin surface of posterior deltoid. The myoelectric controlled multifunctional prostheses were designed by the engineers in the cooperative team.

Action research arm test (ARAT) score was used to evaluation of the prosthetic control. The ARAT scores of both the patients improved one year after the surgery [Supplementary Table 1, http://links.lww.com/CM9/A399]. Patients were easy to grasp object with different shape [Supplementary Video 1, http://links.lww.com/CM9/A400]. All the patients were satisfied with the treatment.

The anatomical characteristics of deltoid muscle meet the requirement of receptor muscles for target muscle regeneration. Based on the anatomy, posterior part of the deltoid muscle could be used as a receptor of reinnervated unit, while the anterior and middle parts could be preserved to avoid loss of function.

The conventional method to get to the position of proximal stump with good function, other than SEP, is to section the nerve until healthy appearing fascicles were found. However, in most cases, it was hard to tell whether the fascicles were healthy enough for transfer, which is a potential risk of failed reinnervation. In addition, the CMAP is quite essential to check the fascicles to determine the branches used for reinnervation and preserved during the surgery.

The study indicated that the posterior part of the deltoid muscle could be used as an option of the receptors in TMR, and electrophysiological examination could be a necessary tool for quality control of the residual nerve stumps during the procedure.

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Conflicts of interest

None.

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