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Retrospective Study

Anatomy and Clinical Application of Suprascapular Nerve to Accessory Nerve Transfer

SCN to AN Nerve Transfer

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Abstract

BACKGROUND

Loss of motor function in the trapezius muscle is one complication of radical neck dissection after cutting the accessory nerve (AN) during surgery.Nerve repair is an effective method to restore trapezius muscle function, including neurolysis, direct suture, and nerve grafting.The suprascapular nerve (SCN) and AN are next to each other in position.The function of the AN and SCN in shoulder elevation and abduction movement is synergistic.The SCN might be considered by surgeons for AN reanimation.

AIM

This study aimed to obtain anatomical and clinical data for partial suprascapular nerve to AN transfer.

METHODS

Cadavers for research

Ten sides of cadavers perfused with formalin through the femoral artery were obtained from the Department of Human Anatomy, Histology and Embryology, Peking University Health Science Center. This study was approved by the Peking University Institutional Review Board (IRB00001052-21011-Exempt). The age range of cadavers was 60–80 years. All cadavers had no visible scars, deformities, or obvious trauma to the face, neck, or shoulders.

Cadaveric dissection

Cadavers were dissected, and the SCN (n = 10) and AN (n = 10) at the lateral cervical region were exposed. The SCN and AN were carefully dissected in the posterior triangle of the neck as follows. First, the SCM was exposed after removing the

superficial tissue. Second, the SCN from C5 of the brachial plexus could be found beneath and close to the lower belly of the omohyoid muscle and AN emerges in the posterior triangle at the anterior margin of the trapezius (Figure 1). Third, the SCM was elevated, beneath which we found that the accessory nerve at the anterior edge of the trapezius muscle, and the suprascapular nerve from the beginning to the scapular notch segment (Figure 2,3). Fourth, trapezius muscle was dissected to fully display the accessory nerve (Figure 4).

Measurements

The length and branches of AN in trapezius muscle, the length of the SCN from the origin of the brachial plexus (**a** point, figure 2) to the scapular notch (**b** point, figure 2), and the distance of the SCN from the origin point (**a** point, figure 2) to the point (**c** point, figure 3) where AN to the border of the trapezius muscle were measured. When measuring the data, the specimen faced upwards, and the face and neck were in the median position. The chosen marker points were relatively fixed during measurement, and they were less affected by the rotational movement of the head.During the measurement process, each data was obtained from multiple measurements by the same surveyor to reduce the occurrence of errors.

The length and branches of AN in trapezius muscle was measured. The trapezius muscle was divided into three portions: descending portion, horizontal portion, and ascending portion. The division was based on two horizontal lines: one was through the vertex of the angle between the acromiom and the spine of the scapula at the lateral dorsal edge of the scapula, the other was through the uppermost edge of the plane of the deltoid tubercle at the medial edge of the scapula(Figure 4). We measured the number of branches of the accessory nerve in three portions, respectively. The branch whose diameter was less than 0.5 mm was considered as the end branch and was not dissected any more.

Data analysis

Data was analyzed using t-tests with SPSS 19.0 software to determine the relationship between the length of the SCN and the linear distance. A P value of <0.05 was considered statistically significant.

Clinical application

A female patient aged 55 years underwent surgery for partial SCN to AN transfer at Department of Oral and Maxillofacial Surgery, Peking University School, and Hospital of Stomatology. All procedures were approved by the Biomedical Ethics Committee of Peking University School and Hospital of Stomatology (PKUSSIRB-2013040). The patient suffered recurrent upper gingival cancer, which demonstrated lymphatic metastasis in the right cervical region. Radical neck dissection in cervical regions I, II, III, IV, and V was performed on the right side and the SCM muscle was removed. On the left side, selective neck dissection in cervical regions I, II, and III was performed without AN injury. The right AN was removed at the intersection between the nerve and the posterior border of the SCM muscle. The SCN was dissected along the branch of the brachial plexus. Groups of fascicles of the SCN were identified. One third of the diameter of the SCN was cut off and combined epineurial and perineurial sutures were applied between the distal end of the cutting-off fascicles of the SCN and the proximal end of the AN without tension (Figure 5,6). Nylon suture (8-0) was used for nerve transfer.

Both subjective and objective evaluations were performed before, three months after, and nine months after surgery. For the subjective evaluation, the questionnaire included the Neck Dissection Impairment Index (NDII) and the Constant Shoulder Scale[15, 16]. Thirty-five points on the Constant Shoulder Scale were recorded in this section. For the objective evaluation, two methods were used. One was to examine the movement of the shoulder and upper arm and record the 65 points of objective evaluation using the Constant Shoulder Scale before, three months after, and nine months after surgery. Another was to carry out electromyography of the trapezius, supraspinatus, and infraspinatus muscles before, three months after, and nine months after surgery. Electromyography (Dentec Keypoint, Natus Medical Incorporated, Denmark) was used for the examination. The descending, horizontal, and ascending parts of the trapezius muscle were detected in this study, according to the method used by Krause *et al*[17]. The middle was placed at the line from the level of the second thoracic vertebra to the suprascapular angle, 3cm from the longitudinal axis of the spine. The ascending portion was placed at the horizontal line of the inferior corner of the shoulder, 3cm from the longitudinal axis of the spine. During examination of the trapezius muscle, electromyography was performed when the patient shrugged shoulders and closed shoulder blades with maximum strength and abducted the upper arm to 90° for two seconds, respectively. For supraspinatus and infraspinatus electromyography, external rotation of the upper arm around humerus bone with maximum strength and abduction of the upper arm to 90° for two seconds were performed, respectively. Surface electrodes were placed on the supraspinatus and infraspinatus just above and below the scapular spine and at the middle of the supraspinous and infraspinous fossa of the scapula, respectively[18, 19]. The ratio, R, of the amplitude of electromyography before and after surgery was calculated as follows:

R =(amplitude of EMG before surgery-amplitude of EMG after surgery)/amplitude of EMG before surgery

The range of R was 0–1. The lower the value, or the closer it was to 0, the smaller the degree of loss of muscle function.

RESULTS

The whole length of AN in trapezius muscle was 16.89 cm. The average number of branches distributed in the descending, horizontal and ascending portions were 3.8, 2.6 and 2.2, respectively. The diameter of the AN was 1.94 mm at the anterior border of the trapezius. The length of the suprascapular nerve from the origin of the brachial plexus to the scapular notch was longer than the distance of the suprascapular nerve from the

origin point to the point where accessory nerve to the upper edge of the trapezius muscle.

The amplitude of trapezius muscle electromyography indicated that both the horizontal and ascending portions of the trapezius muscle on the right side had better function than the left side nine months after surgery. The results showed that the right-sided supraspinatus and infraspinatus muscles did not lose more function compared with the left side.

CONCLUSION

Based on the anatomical data and clinical application, partial suprascapular nerve to AN transfer could be achieved and be prone to improving innervation of the affected trapezius muscle after radical neck dissection.

Key Words: suprascapular nerve; accessory nerve; nerve transfer; trapezius; supraspinatus; infraspinatus

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Core Tip: We perform the dissection and measurement of ten sides of cadavers to obtain the data of suprascapular nerve and accessory nerve. In the posterior cervical triangle, we found that the suprascapular nerve could obtain enough nerve length, from its origin to the suprascapular notch, to perform SCN-AN partial nerve transplantation, and achieve tension-free suture, suggesting the feasibility of transplantation of the suprascapular nerve as a donor. Nerve transfer from the partial suprascapular nerve to the accessory nerve was performed on one patient and did the electromyography examination three months and nine months after surgery. Our research showed that suprascapular nerve transfer could be prone to improving the trapezius muscle function, less loss of function in the supraspinatus and infraspinatus muscles after suprascapular nerve transfer.

INTRODUCTION

Iatrogenic injury is one of the major causes of human nerve injury. Approximately 94% of accessory nerve (AN) injuries are iatrogenic[1,2]. Injury to the AN, can cause weakness or paralysis in the sternocleidomastoid (SCM) and trapezius muscles[3]. Loss of motor function in the trapezius muscle leads to a painful and disabling condition[2],this syndrome is frequently observed after radical neck dissection. Pain and dysfunction associated with a loss of innervation by the AN have been reported[4, 5].

Anatomic information and the precise position of the AN is very important for the protection of the AN during the surgery. AN is generally accepted as being a motor nerve. It mainly innervates the sternocleidomastoid and trapezius muscles. AN is classically described as having a spinal root and a cranial root. The spinal root originates from the spinal nucleus of cervical vertebrae C1 to C5. The cranial root originates from the dorsolateral surface of the medulla oblongata. The spinal and cranial roots merge into a total stem and exit the skull. Then, it passes through the posterior cervical triangle, inlateral to the vagus nerve, ahead of the internal jugular vein (IJV), sending out the muscle branches to the SCM and the trapezius muscle. In the posterior cervical triangle region, its position is relatively superficial and vulnerable to injury[6, 7]. Previous studies have shown that the AN passes through the SCM in three ways[8]. Besides AN, one study showed that the branches of the cervical plexus to join the main AN or separate branches innervated the trapezius muscle[9], which are conducive to the protection of the AN or other branch nerves and the function of the trapezius muscle during surgery.

Current surgical treatment for trapezius paralysis mainly includes two strategies. First, fascial muscle transplantation mainly includes static and dynamic transplantation. A static procedure involves fixing the scapula to the spinous process by fascia transplantation, but it could lead to a weakened fascia due to a prolonged stretch. The dynamic approach is used to restore the function of the scapula through muscle transfer[2]. Another surgical strategy is nerve repair[10, 11], which includes neurolysis, direct suture, and nerve grafting. A key point in nerve transplantation for the treatment of trapezius paralysis is finding the appropriate donor nerves. It has been reported that trapezius muscle function can be restored by directly transplanting a nerve in the upper trunk of the brachial plexus and suturing the distal end of the AN[12]. According to Tubbs's anatomical study, the suprascapular nerve (SCN) could be used as a donor nerve for nerve repair[13]. SCN mainly originates from the C5, C6, and occasionally C4 nerve roots. It contains motor and sensory nerve fibers. It walks in the posterior triangle of the neck, then passes through the scapular notch and walks on the back of the scapula. Its main function is motor innervation of the supraspinatus and infraspinatus muscles. In addition, it also sends out sensory branches to the acromioclavicular, glenohumeral joints, and the coracoacromial ligament[14].The accessory nerve and suprascapular nerve are adjacent to each other and have similar functions. To further explore the feasibility of transplanting the suprascapular nerve, as a donor nerve to the accessory nerve, to restore the trapezius muscle function, we conducted exploratory studies of both human anatomy and clinical application.

MATERIALS AND METHODS

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R = (amplitude of EMG before surgery-amplitude of EMG after surgery)/amplitude of EMG before surgery

The range of R was 0–1. The lower the value, or the closer it was to 0, the smaller the degree of loss of muscle function.

RESULTS

The anatomic data of SCN and AN

The length of the SCN from origin of the brachial plexus(a point, figure 3) to the scapular notch(b point, figure 3) was about 5.64±0.78cm(n = 10), The linear distance from the SCN origin point(a point, figure 3) to the point(c point, Figure 2) where AN to the border of the trapezius muscle was about 4.30±0.79cm(n = 10), the length of the SCN from origin of the brachial plexus to the scapular notch(a-b) was longer than the linear distance(a-c) between two points ($p < 0.01$) (Table 1).

The whole length of AN in trapezius muscle was 16.89 cm with the length range of 12.70-20.50 cm. The average number of branches distributed in the descending portion was 2.6 with the number range of 0-5; the average number of branches distributed in the horizontal portion was 2.6 with the number range of 1-4; The average number of branches distributed in the ascending portion was 2.2 with the number range of 1-4. There were still 1.2 branches with the number range of 0-3 distributed in the descending portion before AN entered into the trapezius muscle. Therefore, there were 3.8 branches distributed in the descending portion of the trapezius muscle.

The clinical outcomes of nerve transfer surgery

The NDII of the patient was 37.5 points three months and 47.5 points nine months after surgery. The results of the Constant Shoulder Scale are shown in Table 2, and suggested that the shoulder function recovered better at nine months after surgery than at three months. The amplitudes of electromyography of the trapezius, supraspinatus and infraspinatus muscles are shown in Table3,4. Even though muscle function did not recover completely three months and nine months after surgery, more function was regained within nine months than in three months. Excluding the descending portion, both the horizontal and ascending portions of the right-sided trapezius muscle had larger amplitude than the left side nine months after surgery, which demonstrates the effect of SCN transfer in this patient. The amplitude of right-sided supraspinatus and infraspinatus electromyography revealed that the right side did not lose more function than the left side three months and nine months after surgery, which indicates less loss of function in the supraspinatus and infraspinatus muscles after SCN transfer. Electromyographs of the trapezius, supraspinatus, and infraspinatus muscles are shown in Figure 7, 8. The results are similar to the amplitude of the muscles demonstrated in Table 3,4. The patient's clinical manifestation of upper limbs movement was shown in Figure 9, which indicated the similar recovery behavior between right and left sides.

DISCUSSION

The spinal AN would usually be sacrificed during radical neck dissection. Therefore, trapezius muscle paralysis often results in destabilization and dropping of the shoulder girdle[20].Several patients experience severe upper extremity impairment with deficits in functional movement and continuous shoulder pain[21].

Understanding the anatomical information of the accessory nerve is very important to protect the accessory nerve during neck dissection. Some studies have disclosed the anatomy of the accessory nerve in detail. Shiozaki K *et al* found that the AN passed through the SCM in three ways[8]. Another study showed that the branches of the cervical plexus to join the main AN or separate branches innervated the trapezius muscle[9]. There were also some studies revealing the relationship between AN and the IJV[7, 22]. The results of these studies[7-9,22] were conducive to the protection of the AN or other branch nerves and the function of the trapezius muscle during surgery.

There are several approaches to repair the injured AN, including nerve transfer from the upper trunk[12], which is much thicker than the SCN. Taking a fascicle from the upper trunk might cause more side effects than the SCN. Considering the number of myelinated axons, 6004 for the SCN and 1500–3000 for the AN, partially splitting the SCN could be used to transfer to the distal stump of the AN[23, 24]. The SCN could be an attractive substitute donor for some nerve graft procedures. Lanisnik *et al* found that the AN could give off the branches before entering the SCM muscle and joining the cervical plexus at the posterior part of the SCM muscle in some cases[25]. The function of the AN and SCN in shoulder elevation and abduction movement is synergistic. This synergistic function implied that SCN could be an alternative donor nerve to restore AN function. Tubbs *et al*.[13] reported a cadaveric study related to the SCN connection with the facial nerve. They measured the length and diameter of the SCN in 10 human cadavers. They believed using the SCN might be considered by surgeons for facial nerve reanimation. Besides above, parts of SCN and AN located in the same region of the neck[26]. They are next to each other in position, which is conducive to nerve transplantation to achieve no tension suture. We found that the length of the a-b segment of SCN was greater than the distance length of the a-c segment with a significant difference. It indicated that sufficient suprascapular nerve length could be achieved to realize a tension-free suture during the SCN-AN partial nerve transplantation procedure. The a-b segment of SCN was chosen because the other part of SCN was covered by the supraspinatus and infraspinatus muscles, which would increase the difficulty of surgical exposure. In the present study the SCN was split longitudinally and partial nerve transfer was performed in one patient. The results of clinical outcomes showed that supraspinatus and infraspinatus muscle function were not affected much three and nine months after surgery.

The AN to SCN transfer has been proven as a valid strategy to repair nerve injury[27-30].The AN could be used as a donor nerve in brachial plexus injury, especially injury to the SCN[31]. One advantage of transfer between these two nerves is the greater proximity to the muscle to be reinnervated[30]. Although transfer from AN to SCN does not completely recover the strength of the shoulder, it still improves pain control and shoulder stability[32]. Bertelli and Ghizoni described a unique approach to identify and harvest AN, for nerve transfer in brachial plexus injuries[33].These studies indicated that the spinal AN had a similar histological compatibility with the SCN[27-33]. Therefore, the SCN could be a suitable donor to recover AN function when iatrogenic injury or resection occur during surgery.

Although the results showed that the descending portion of right trapezius muscle did not recover better than the left side, the result of electromyography indicated that the horizontal and ascending portions in right side had larger amplitude than the left side nine months after surgery. The possible reason for this result is that the SCN transfer improved trapezius muscle innervation. Meanwhile, partial nerve transfer maintained the original function of the supraspinatus and infraspinatus muscles in the patient. Therefore, shoulder function was enhanced. Trapezius muscle has the main dominant nerve of the AN. There are also C2 ~ C4 nerve branches into the AN trunk or directly into trapezius muscle. However, the location of the branches from the cervical nerve is often not constant. Some branches may contain sensory nerve, even it plays a role on innervation of trapezius muscle[9] . Therefore, the partial SCN transfer was not the only factor which improved the amplitude of trapezius muscle. The feature of this SCN transfer is “partial”, which did not sacrificed the SCN totally and maintained the function of the nerve. In addition, neck dissection can expose the SCN well, which is one benefit of this technique. However, the evidence for clinical promotion was insufficient in our study due to limited number of clinical cases performed.

CONCLUSION

Based on the anatomical data and clinical application, partial suprascapular nerve to accessory nerve transfer could be achieved and be prone to improving shoulder function after radical neck dissection. Further basic research and clinical evidence is necessary to elaborate on the findings presented in this study.

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