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Original article

Robot-assisted C7 nerve root transfer from the contralateral healthy side: A preliminary cadaver study

Transfert robot-assisté de la racine C7 du côté controlatéral sain : étude de faisabilité sur cadavre

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Abstract

Patients with cerebral palsy and spastic hemiplegia may have extremely poor upper extremity function. Unfortunately, many current therapies and treatments for patients with spastic hemiplegia offer very limited improvements. One innovative technique for treating these patients is the use a contralateral C7 nerve root transfer to neurotize the C7 nerve root in the affected limb. This may result not only in less spasticity in the affected limb, but also improved control and motor function vis-a-vis the new connection to the normal cerebral hemisphere. However, contralateral C7 transfers can require large incisions and long nerve grafts. The aim of this study was to test the feasibility of a contralateral C7 nerve root transfer procedure with the use of a prevertebral minimally invasive robot-assisted technique. In a cadaver, both sides of the C7 root were dissected. The right recipient C7 root was resected as proximally as possible, while the left donor C7 root was resected as distally as possible. With the use of the da Vinci ® SI surgical robot (Intuitive Surgical ™, Sunnyvale, CA, USA), we were able to eliminate the large incision and use a much shorter nerve graft when performing contralateral C7 nerve transfer.
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Keywords: Cerebral palsy; Spastic hemiplegia; Contralateral C7 transfer; Da Vinci; Robot-assisted microsurgery

Résumé

Les patients présentant une paralysie d'origine centrale et une hémiplégie spastique ont des fonctions très limitées du membre supérieur. Malheureusement, les thérapeutiques actuelles de l'hémiplégie spastique n'apportent que très peu d'amélioration. Une technique innovante pour traiter ces patients consiste à utiliser la racine C7 controlatérale pour neurotiser la racine C7 du côté lésé. Ce transfert aboutit non seulement à diminuer la spasticité du côté lésé, mais aussi à améliorer la fonction motrice et son contrôle par les connexions avec l'hémisphère cérébral sain. Toutefois les transferts controlatéraux de C7 peuvent nécessiter de grandes incisions et de longues greffes nerveuses. Le but de ce travail était d'étudier la faisabilité d'un transfert de la racine C7 du côté gauche sur la racine C7 du côté droit par une voie d'abord prévertébrale mini-invasive robot-assistée. Les 2 racines C7 ont été disséquées sur un cadavre. La racine C7 droite receveuse a été sectionnée le plus proximalement possible. La racine C7 gauche donneuse a été sectionnée le plus distalement possible. Grâce à l'utilisation d'un robot Da Vinci® SI (Intuitive Surgical ™, Sunnyvale, CA, États-Unis), il a été possible d'utiliser de petites incisions et d'utiliser une greffe nerveuse de plus petite longueur pour réaliser un transfert controlatéral de C7.
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Mots clés : Paralysie cérébrale ; Hémiplégie spastique ; Transfert controlatéral de C7 ; Da Vinci ; Microchirurgie assistée par robot

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1. Introduction

Contralateral C7 nerve root transfer was first used to treat a severe brachial plexus injury in 1986 [1]. This technique allowed some motor and sensory function to be restored in the hand of a patient who had suffered a total brachial plexus root avulsion injury. Since that time, several groups have reported encouraging results using contralateral C7 nerve root transfer for treating patients with otherwise devastating brachial plexus injuries [2,3]. Because contralateral C7 nerve root transfer requires that a normal nerve root be sacrificed, the possibility of donor site morbidity and loss of function in the normal arm has been a serious concern [4]. However, proponents of the technique argue that no single muscle in the upper extremity is innervated solely by the C7 nerve root, and if done properly, division of C7 causes no permanent loss of motor or sensory function [5].

In fact, the group who performed the first contralateral C7 transfer have expanded the indications of their technique and reported on the benefits of contralateral C7 transfer in a young patient with spastic hemiplegia [6]. In a 4-year old with cerebral palsy and spastic hemiplegia, they performed contralateral C7 nerve root transfer to the C7 root of the affected side. At 2 years' follow up, the patient showed significant improvements in gripping and reaching. As with brachial plexus injury patients, some patients with cerebral palsy and spastic hemiplegia have severe disabilities. Unlike brachial plexus injuries, cerebral palsy is fairly common with infantile spastic hemiplegia estimated to occur in 1 of 1388 infants [7,8]. Current treatments for patients with spastic hemiplegia include botulinum toxin and functional rehabilitation [9,10], tendon transfers, arthrodesis, and selective rhizotomy [11,12]. However, all of these treatments have significant limitations. Contralateral C7 transfer in these patients offers the possibility of better cortical integration of the hemiparetic limb [13–16].

Although innovative and exciting, one limitation of the cross-over C7 transfer to treat spastic hemiplegia is that it requires a large incision and long nerve grafts, resulting in larger scar, and greater nerve regeneration distances. Our group has been investigating the use of the da Vinci robot for peripheral nerve surgery. We posit that with robotic assistance, the surgery could be done with smaller incisions, shorter nerve grafts would be needed, and possibly lead to better functional outcomes. The aim of this cadaveric study was to test the feasibility of nerve transfer from a contralateral healthy C7 root to a paralyzed C7 root with the use of a minimally invasive robot-assisted technique.

2. Materials and methods

In a fresh-frozen Caucasian female cadaver, two 4-cm incisions were made at the right and left supraclavicular regions. The C7 nerve roots were identified (Fig. 1). A workspace was prepared in the anterior cervical space by separating the skin from the subcutaneous tissues; this space was maintained using two custom self-retaining retractors. The recipient side C7 root (right) was cut as proximally as possible, close to the intervertebral foramen (Fig. 2). The donor side C7 root (left) was resected as distally as possible, 6 cm distal from the corresponding foramen. A 20-mm length of nerve graft was sutured using loupes to the distal end of the donor side of C7 root with 10/0 nylon (Fig. 3).

Fig. 1. Front view of the cervical region after brachial plexus supraclavicular dissection. C7 roots were set with loops on both sides.

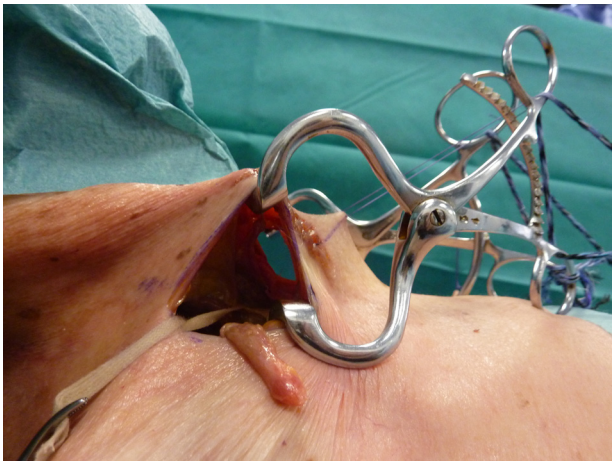

Fig. 2. Right lateral view of the cervical region after creating a workspace. The right C7 root is visible in the foreground.

The surgical robot (da Vinci® SI, Intuitive Surgical ™, Sunnyvale, CA, USA) was brought in and set up at the head of the cadaver (Fig. 4). The 30° oblique 3D camera was used. An instrumental arm attached with microsurgical forceps (Black Diamond®, Intuitive Surgical™, Sunnyvale, CA, USA) was inserted into the working space through the right side of the incision. A second instrumental arm with attached microsurgical forceps was inserted into the working space through the left side of the incision.

The senior surgeon sat in the surgical console located 3 meters away from the cadaver and controlled the movements of the camera and the two instrumental arms. A scrubbed assistant inserted a 10/0 nylon suture into the workspace. Neurorrhaphy between the proximal end of the recipient (right)

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