Research Square

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Nerve transfer in the spastic lower limb: anatomical feasibility study

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Research Article

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Abstract

Purpose

We want to evaluate the feasibility of transferring a motor branch of the the anterior tibial muscle (ATM) on the extensor digitorum longus (EDL) in order to evaluate this procedure in patients with spastic Equino Varus Foot (EVF) following a post-stroke hemiplegia.

Methods

Ten cadaveric dissections from five fresh frozen human cadavers were performed in order to establish the anatomic feasibility of transferring a motor branch of the deep peroneal nerve with is usually destinated to the Anterior Tibialis Muscle (ATM) onto the branch of the Extensor Digitorum Longus (EDL), to manage spastic equinovarus foot (SEF).

Results

Six cases (60%) presented 3 branches detonated to the ATM, one case (10%) presented 5 branches, 3 cases (30%) had 4 branches. In all specimens, the coaptation between the motor branch to the anterior tibial muscle, referred as the 'effector' branch, and the branch of the EDL 'receiver' branch was feasible without tension and did not require any intra-neural dissection.

Conclusion

This anatomical study confirms the feasibility of transferring a motor branch from the ATM to the EDL to correct a spastic EVF.

Introduction

The number of young hemiplegics surviving after a stroke is steadily increasing [1]. These stroke patients classically develop a spastic equino varus foot (EVF). The management of this neuro-orthopaedic deformity is a challenge for rehabilitation teams [2, 3]. The equinus position, plantar flexion and inversion, results from an imbalance of forces on the hindfoot due to muscle hypertonia associated with an overactive osteotendinous reflex. This varus equinus position poses significant problems when wearing shoes, standing, transferring and walking. Most of the time, non-surgical measures are not able to treat this deformity satisfactorily. Neuro-orthopaedic surgery is known to be an effective treatment for improving foot position in spastic varus equinus [4, 5]. Split Anterior Tibialis Transfer (SPLATT) is the most commonly performed procedure [6]. All the procedures currently performed aim to transfer a hypertonic muscle or part of it in order to rebalance its forces to obtain a good inverting balance while maintaining an active dorsal flexion. Recently, in the upper limb, teams have been evaluating the nerve transfer of a motor branch of a hypertonic muscle to an inactive muscle [7]. If this transfer concerns two muscles with a combined action, this would allow contraction of the inactive muscle, allowing dynamic rebalancing of the foot. During dorsal flexion, which most of the time occurs only in syncretic co-

contraction with the hip flexors, only the Anterior Tibialis Muscle (ATM) muscle contracts, which causes the dynamic varus. A co-contraction of the Extensor Digitorum Longus (EDL) made it possible to preserve the dorsal flexion motor force by rebalancing the foot in the frontal plane. To achieve this, the transfer of a motor branch of the ATM to the EDL seems to be an interesting option. However, it is important to be sure that this transfer does not weak the AT too much, so that if the transfer fails, the function of the only active foot-lifting muscle is not lost.

We want to evaluate the feasibility of transferring a motor branch of the ATM on the extensor digitorum longus (EDL) in order to evaluate this procedure in patients with EVF following a post-stroke hemiplegia.

Methods

Ten cadaveric dissections from five fresh frozen human cadavers were performed in order to establish the anatomic feasibility of transferring a motor branch of the deep peroneal nerve with is usually destinated to the ATM onto the branch of the extensor digitorum longus (EDL), to manage spastic equinovarus foot (EVF).

All subjects had given informed written consent prior to deceasing. All specimen were free of any traumatic or surgical scar on the lower limbs. During dissection, each limb was positioned in supination. The following anatomical landmarks were identified: the head of the fibula, the anterior tibial tuberosity and the tibial crest. Dissections were per- formed from proximal to distal in order to expose the motor branches emerging from the deep peroneal nerve.

We evaluated the number of motor branches for the ATM. We measured the point of emergence from the deep peroneal nerve of each branch, and its entry point into the target muscle. Considering this line as zero on a reference value at the intersection point between the superficial peroneal nerve and the deep peroneal nerve which emerge from the common peroneal nerve. We measured the length of each motor branch and its diameter using a ruler tool. We identified the branch of the EDL and measured it from our zero reference.

The dissection was conducted through a longitudinal and oblique anterolateral incision on the leg. Proximally, the incision is posterior to the fibula. Then, the incision continues anterior to the neck of the fibula and stays between the fibula and the crest tibial to expose all branches of the deep peroneal nerve.

First, we identify proximally the commun peroneal nerve which lies on the posterior border of the biceps femoris after incising the deep fascia and continue to expose it as it winds around the neck of the fibula in the substance of the peroneus longus. We identify the space between the peroneus muscle laterally and the anterior tibial muscle medially. The common peroneal nerve divides into the superficial peroneal nerve and the deep peroneal nerve. Dissection of the deep peroneal nerve permit to identify all branches to the anterior tibial muscle and the branch of the ECL.

After completion of the dissection of all motor branches, we selected the ideal motor branch to the anterior tibial muscle, referred as the ‘effector’ branch, and the branch of the EDL corresponding to a potential ‘receiver’ branch for a nerve transfer. Our selection criteria were the proximity of the branches, the length and an equal caliber allowing a satisfactory coaptation. The ‘effector’ branch was sectioned as distal as possible and the ‘receiver’ was sectioned as proximal as possible from its emergence. The two nerve extremities were approximated in order to allow a micro- suture without tension.

In case there was excessive length at the level of the suture, we reduced the length of the ‘receiver’ branch until obtention of a straight and tension- free nerve transfer.

Results

Ten lower limbs were dissected, including 5 left and 5 right ones from 5 different specimen. All the results are summarized in Table 1.

Motor branches to the ATM

We excluded the first proximal branch from the deep peroneal nerve which is destinated to intra-articular knee. Six cases (60%) presented 3 branches, one case (10%) presented 5 branches, 3 cases (30%) had 4 branches. In 3 cases, individual branches divided into 2 to 3 secondary rami before entering the muscle (3 cases: 2 rami–one case: 3 rami).

The first motor branch for the anterior tibial muscle arose from the subdivision between the superficial and the deep peroneal nerves at a mean distance of + 8.8 mm (range + 4 / + 22).

Their diameter varied greatly from 0,4 to 1,5 mm. We categorized them in three groups according to their diameter at the entry point into the muscle. There were 3 branches with a diameter higher or equal to 1 mm (Group 1) (8.57%), 27 branches between 0.5 and 0.9 mm (Group 2) (77,14%), and 5 branches with a diameter smaller than 0.5 mm (Group 3) (14,29%).

Motor branches to the EDL and EHL

The EDL arose at a mean distance of + 17.2 mm (range + 5 / + 30) rom the subdivision between the superficial and the deep peroneal nerves.

The EHL arose at a mean distance of + 54.2 mm (range + 30 / + 76) from the subdivision between the superficial and the deep peroneal nerves.

Concerning the diameter of the EDL: 6 cases in group 2 (between 0.5mm and 1 mm) and 3 cases in the group 1 (> 1mm).

Concerning the diameter of the EHL: 6 cases in group 2 (between 0.5mm and 1 mm) and 3 cases in the group 1 (> 1mm).

In all specimens, the coaptation between the motor branch to the anterior tibial muscle, referred as the ‘effector’ branch, and the branch of the EDL ‘receiver’ branch was feasible without tension and did not require any intra-neural dissection. In 3 cases, because of a difference between diameter of the receiver and the effector, we had to do bi-transfert.

As the ‘effector’ branch, we chose in most of the cases, the second or the third motor to the anterior tibial muscle. Thus, we are sure that the proximal and distal innervations are preserved. In some cases, we chose a branch more distally to match in diameter.

As the ‘receiver’ branch, we selected the single branch available effector branch to the EDL. In some cases, we use the branch to the EHL. Because of excess in length, we were able to shorten the ‘receiver’ branch in 4 cases (40%) still allowing a safe coaptation. And in 2 case we were able to shorten the effector.

Discussion

In EVF following a stroke, there is frequently hypertonia of the ATM, possibly associated with a complete deficit of the extensors of the toes and the eversors. Currently, the surgical management of the spastic EVF is based on the realization of tendinous gestures: in particular the SPLATT [8] possibly associated with nervous gestures limited to the selective neurectomy [6, 9, 10]. The choice of the techniques used and their possible combination is based on the clinical examination of the patient through a multidisciplinary approach [5, 6]. The selective neurotomy concern most of the time the branches of the tibial nerve and, by reducing its caliber by half, make it possible to reduce spasticity while maintaining good motor strength [11–13]. Nowadays peripheral nerve transfer allow successful management of foot drop due to deep peroneal nerve injury [14]. Moreover, partial tibial nerve transfer to the tibialis anterior motor branch to treat peroneal nerve injury after knee trauma [15].

Nerve transfers in patients with spastic paralysis secondary to cerebral damage have never been studied. Recently, the team of Waxweiler et al. considered this technique in the upper limb [7]. This type of intervention could be of significant interest in spastic EVF. On the one hand, it would allow active dorsiflexion without dynamic varus, as does SPLATT, but it would also reduce spasticity of the ATM which can participate in the functional impairment. However, the specifications for this transfer in the "central" patient are different from those of the patient with peripheral damage. In most cases, the patient no longer has voluntary control. There is mainly a syncretic co-contraction of the elevators of the foot during the contraction of the hip flexors. It is therefore necessary to consider a transfer of a branch of a muscle that is synergistic with the targeted muscle. Indeed, the effect produced will be the origin of a simultaneous contraction without the possibility of integration of the transfer at the cerebral level. On the other hand, insofar as the branch used comes from a hypertonic muscle, care must be taken not to weaken it too much if the other agonist muscles are completely paralyzed. For this reason, the transfer of a branch of the ATM, which has at least 3 branches, to the EDL is a strategy that meets these different criteria.

Conclusion

By showing that the ATM has several motor branches, whose situation and caliber make it possible to envisage a nervous transfer on the motor branch of the EDL, this anatomical study confirms the feasibility of transferring a motor branch from the TMJ to the EDL to correct a spastic EVF.

Declarations

Ethics approval and consent to participate

Our study was approved by the Research and Innovation Committee of the hospital. No consent was needed for this cadaveric study.

Consent for publication

I, the undersigned, give my consent for the publication of identifiable details, which can include photograph(s) and/or videos and/or case history and/or details within the text ("Material") to be published in the above Journal and Article.

Availability of data and materials

All data are available, and included in the manuscript

Authors' contributions

Constance Diner wrote the article and participated in the dissections

George Pfister, Romain Mourtialon participated in the dissections

Philippe Denormandie participated in the conception and correction of the article

Laurent Mathieu participated in the conception of the article, the dissections and the writing

Nicolas de l'Escalopier participated in the conception of the article, the dissections and the writing

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Disclosures

Conflict of Interest: The authors declare that they have no conflicts of interest.

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Tables

Table 1 is available in the Supplementary Files section.

Figures

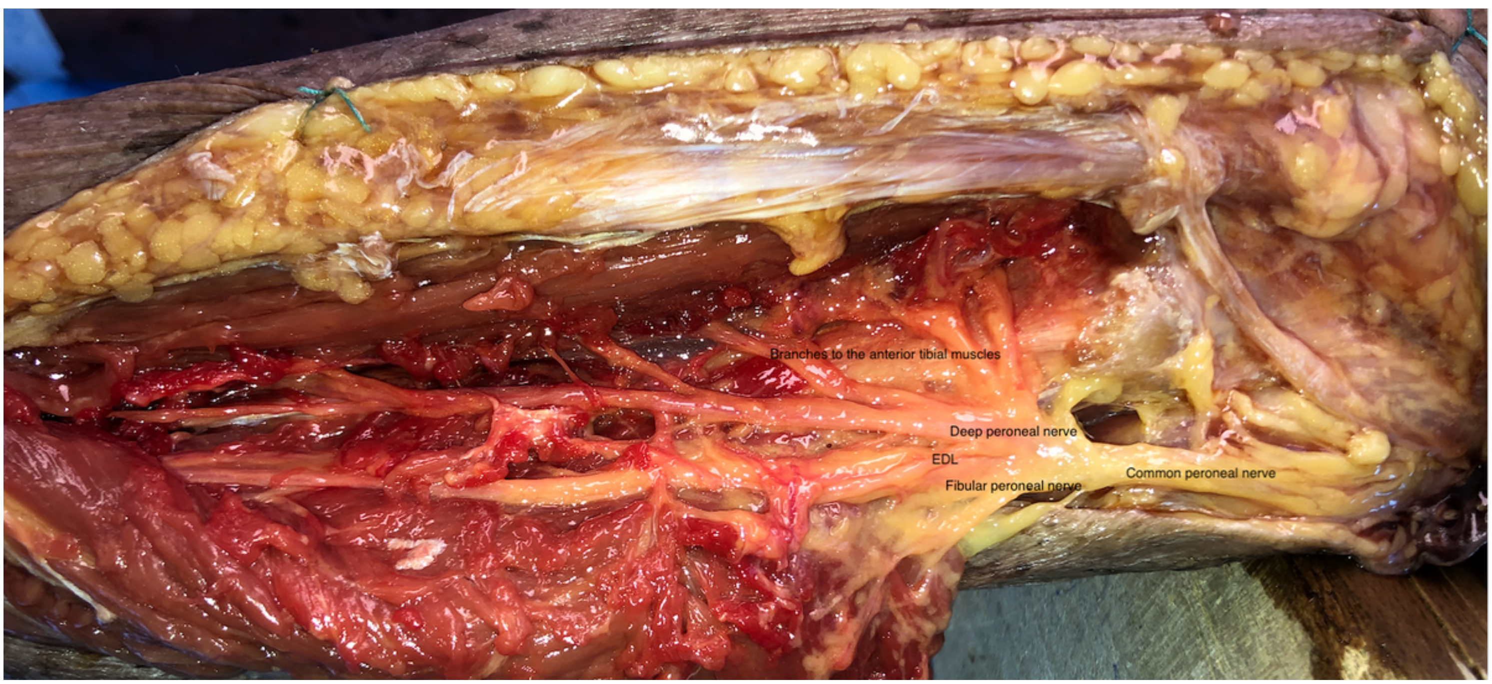

Figure 1

Identification of Deep peroneal nerve, motor branches of Anterior Tibialis Muscle, Extensor Digitorum Longus

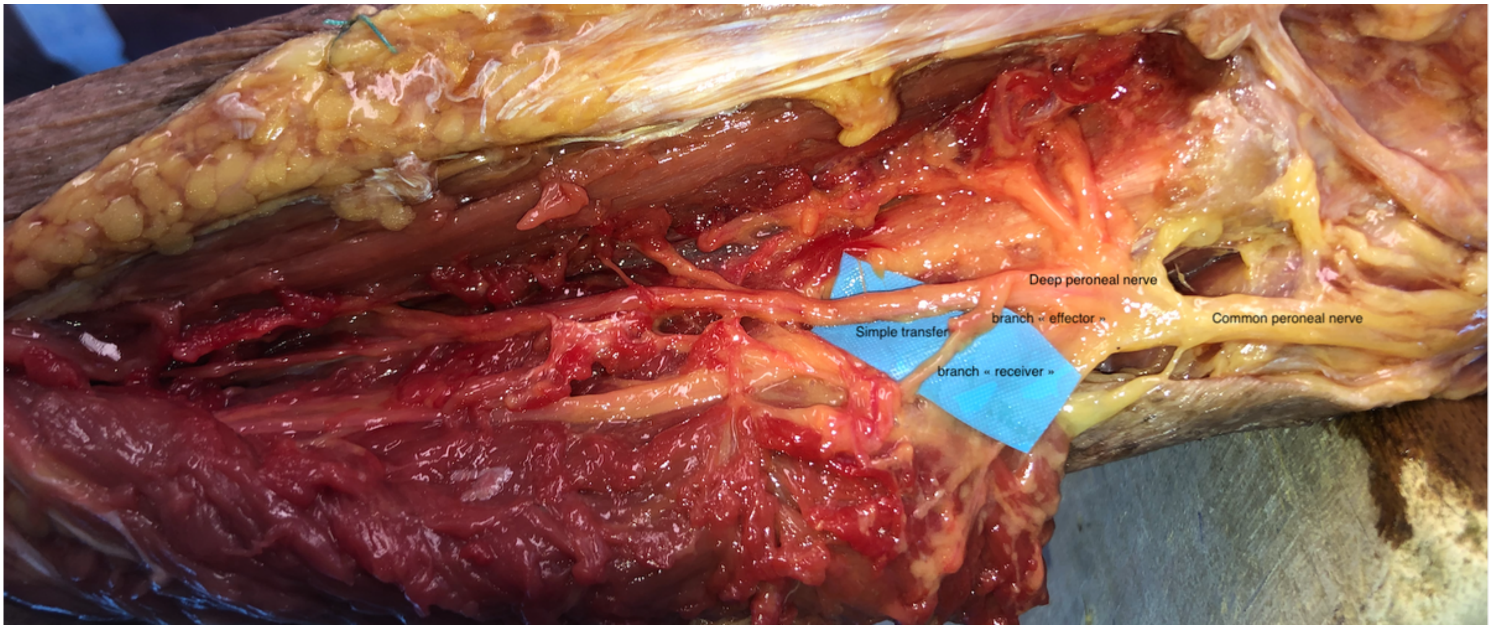

Figure 2

Example of feasibility of a nerve transfer between a motor branch of Anterior Tibialis Muscle to Extensor Digitorum Longus

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Table1.xlsx