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Hand Surgery and Rehabilitation 35 (2016) 68–80

Hand Surgery & Rehabilitation

Recent advance

Principles of tendon transfers

Principes des transferts tendineux

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Received 10 August 2015; received in revised form 19 December 2015; accepted 21 December 2015
Available online 14 March 2016

Abstract

Tendon transfers are carried out to restore functional deficits by rerouting the remaining intact muscles. Transfers are highly attractive in the context of hand surgery because of the possibility of restoring the patient's ability to grip. In palsy cases, tendon transfers are only used when a neurological procedure is contraindicated or has failed. The strategy used to restore function follows a common set of principles, no matter the nature of the deficit. The first step is to clearly distinguish between deficient muscles and muscles that could be transferred. Next, the type of palsy will dictate the scope of the program and the complexity of the gripping movements that can be restored. Based on this reasoning, a surgical strategy that matches the means (transferable muscles) with the objectives (functions to restore) will be established and clearly explained to the patient. Every paralyzed hand can be described using three parameters. 1) Deficient segments: wrist, thumb and long fingers; 2) mechanical performance of muscles groups being revived: high energy–wrist extension and finger flexion that require strong transfers with long excursion; low energy–wrist flexion and finger extension movements that are less demanding mechanically, because they can be accomplished through gravity alone in some cases; 3) condition of the two primary motors in the hand: extrinsics (flexors and extensors) and intrinsics (facilitator). No matter the type of palsy, the transfer surgery follows the same technical principles: exposure, release, fixation, tensioning and rehabilitation. By performing an in-depth analysis of each case and by following strict technical principles, tendon transfer surgery leads to reproducible results; this allows the surgeon to establish clear objectives for the patient preoperatively.

Keywords: Tendon transfer; Hand; Palsy; Principles

Résumé

Les transferts tendineux permettent de restaurer une fonction déficitaire en détournant des muscles restés intacts. À la main, ils sont d'autant plus intéressants qu'ils ont pour but de restituer la préhension. En cas de paralysies, les transferts tendineux ne vivent que des échecs ou contre-indications d'un geste à visée neurologique. Quelle que soit la nature du déficit, la stratégie de restauration fonctionnelle est établie suivant les mêmes principes. Dans un premier temps, la distinction précise entre muscles déficitaires et potentiellement transférables constitue la base de la réflexion. Ensuite, le type de paralysie dictera l'ambition du programme et la complexité des prises pouvant être restituées. À l'issue de cette réflexion, une stratégie chirurgicale en adéquation entre les moyens (muscles transférables) et les objectifs (fonctions à restaurer) sera établie et clairement explicitée au patient. Chaque main paralysée peut être schématisée selon 3 paramètres : 1) les segments déficitaires : poignet, pouce et doigts longs ; 2) les performances mécaniques de groupes ou systèmes musculaires à réanimer : a) haute énergie : extension du poignet/flexion des doigts, nécessitant des transferts forts avec une course importante ; b) basse énergie : flexion du poignet/extension des doigts mécaniquement moins exigeants pouvant parfois être activés par la seule pesanteur ; 3) le statut des deux grands systèmes moteurs de la main, extrinsèque (fléchisseurs/extenseurs), et intrinsèque facilitateur. Quel que soit le type de paralysie, cette chirurgie de transfert suit les mêmes principes techniques, d'exposition, de libération, de fixation, de réglage de la tension et de rééducation. À partir d'une analyse précise de chaque cas et en suivant des

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http://dx.doi.org/10.1016/j.hansur.2015.12.011
2468-1229/

principes techniques stricts, la chirurgie de transfert conduit à des résultats reproductibles, permettant d'établir avec le patient des objectifs préopératoires clairs.

Mots clés : Transfert tendineux ; Main ; Paralysie ; Principes

1. Introduction

Tendon transfers are carried out to restore functional deficits by using the remaining intact muscles. This is one of the most interesting fields within hand surgery because it aims to restore the hand's primary function—the ability to grip.

For a long time [1,2], surgeons have been fascinated by tendon transfers, with multiple techniques having been developed to address various types of palsy. In contrast to primary procedures aimed at neurological function, tendon transfers provide more reproducible results, but require a more detailed clinical analysis of the deficit to establish an "a la carte" strategy to restore function.

Articles on this topic are as plentiful as the surgical techniques, making it difficult and tedious to describe each in detail. The objective of this review is to provide a framework as to how to construct a tendon transfer strategy appropriate for each type of case through a systematic analysis of each type of palsy.

2. Review of anatomy and biomechanics

2.1. Motor innervation of hand

The motor innervation of the hand involves three major nerves with specific territories (Table 1):

- the radial nerve opens the hand through extension of the elbow, wrist and fingers;
- the median nerve allows precise thumb-finger pinching through motricity of the thumb and index, along with independence of the long fingers through the *flexor digitorum superficialis* (FDS);
- the ulnar nerve is the nerve of forceful grasping as it controls the *flexor digitorum profundus* (FDP), intrinsic muscles in the long fingers and deep thenar muscles.

Although this schematization only applies to trunk palsy cases, it helps to frame the broad objectives and limitations of a functional restoration program.

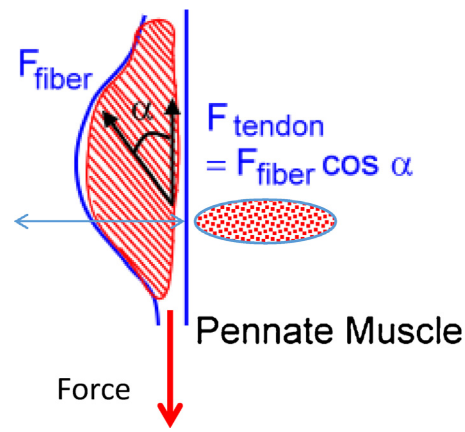

Fig. 1. Basic muscle biomechanics. The muscle's mechanical outputs are its excursion and its force-generating ability. Excursion is a function of the length of the muscle fibers and the pennation angle (α). Force is a function of the muscle's volume (V) and its length (ℓ). The cross-sectional area (CSA) is equal to V/ℓ. The physiologic CSA (PCSA) takes into account the pennation angle (α): PCSA = V.cos α / λ.

2.2. Muscle biomechanics

Like a cylinder in a motor, the mechanical performance of a muscle is determined by its volume. It corresponds to the product of the piston diameter or muscle cross-section area (CSA) and its excursion or the shortening of its fibers during contraction, with the fibers themselves being proportional to muscle length [3,4]. Thus, a larger muscle can produce more force and a longer muscle will have a greater excursion. Other parameters such as muscle fiber type must be added to this simplistic model, as it affects contraction speed and the muscle's ability to withstand prolonged efforts [5]. These concepts are modulated by pennation angle, which is the angle between the axis of the muscle fibers and that of the terminal tendon. A larger pennation angle increases the contraction strength but reduces the excursion, similar to a gearbox (Fig. 1).

The force-generating ability of muscles in the upper limb have been studied extensively, particularly by Brand [6], who

Table 1
Best muscles to transfer.

Nerves	Motor territories	Main transferable muscles in territory
Radial	High (humerus): BR, ECRL, ECR BLow (PIN): ECU, EDC, EPL, EPB, EIP, LAP, EPD	BR, ECRL, EPB, EIP
Median	High (elbow): FCR, PL, FDS M^{II-V}, FPL, FDP^{II-III} Low (wrist): Opp, CF, Lb	FCR, PL, FDS M^{II-V}
Ulnar	High: FCU, $FDP^{II-IV-V}$ Low: Add, IO	FCU