Immediate Thumb Extension following Extensor Indicis Proprius–to–Extensor Pollicis Longus Tendon Transfer Using the Wide-Awake Approach

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Background: The elective use of low-dose epinephrine in hand surgery has allowed for the performance of simple operative procedures with tourniquet-free pure local anesthesia (the wide-awake approach). The absence of general anesthesia or sedation has, in turn, allowed for the observation of how quickly the sensorimotor cortex adapts following procedures such as tendon transfer.
Methods: Seven patients underwent a wide-awake transfer of the extensor indicis proprius to the extensor pollicis longus between February of 2002 and May of 2005 for restoration of thumb extension using local lidocaine with epinephrine alone. One of the seven patients experienced rupture of the initial transfer, necessitating transfer of the extensor carpi radialis longus to the extensor pollicis longus using the wide-awake approach.
Results: All seven patients were able to extend their thumbs fully by means of extensor indicis proprius intraoperatively immediately following transfer suture placement. Restoration of function was not ablated by loss of proprioception or visual feedback. At a mean follow-up of 15 months, thumb extension was restored to within normal limits in the affected thumb, with a slight decrease in grip and tripod pinch strength.
Conclusions: The wide-awake approach has allowed the authors to adjust tendon transfer tension with active movement before skin closure without the risks associated with general or regional anesthesia. In addition, it has allowed them to observe immediate cortical adaptation in the context of a simple tendon transfer. The authors hypothesize that the brain's ability to immediately use extensor indicis proprius for thumb extension stems from the activation of preexisting synergistic cortical finger movement programs. (*Plast. Reconstr. Surg.* 119: 1507, 2007.)

The hand represents one of the most elegant and complex biological motor systems. The coordinated movement of its five digits alternately allows for grasping with the entire fist and pointing with individual fingers. How the motor cortex of the brain controls these various actions remains an area of intense interest.

Although the cerebral cortex clearly controls the musculature of the hand, changes in the hand's muscles and tendons have an equally profound effect on the brain. This has been demonstrated in a number of settings, ranging from dynamic immobilization to toe-to-thumb transfer.[1,2] No studies have examined the cortical changes associated with tendon transfers.

In this article, we examine how the wide-awake approach to hand surgery has allowed us to perform simple tendon transfers—namely, extensor indicis proprius to extensor pollicis longus, and extensor carpi radialis longus to extensor pollicis longus—with pure local anesthesia and without

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a tourniquet. As these patients are awake and comfortable without a tourniquet and with full motor control of the hand, they have allowed us to make interesting initial clinical observations on how quickly the brain "learns" the new function of a muscle following its transfer to a different tendinous insertion. The wide-awake approach also allows us to adjust tendon transfer tension with active movement to make sure the transfer is not too tight or too loose before the skin is closed.

PATIENTS AND METHODS

Ethics approval was obtained from each center involved in the study. Seven patients were included in this study. In each case, extensor pollicis longus rupture was diagnosed on the basis of history and the absence of tension through the extensor pollicis longus tendon with active attempted thumb extension, and was confirmed intraoperatively. The first subject, a 66-year-old man, underwent extensor indicis proprius–to–extensor pollicis longus tendon transfer in February of 2002 following a fall on his right thumb. The second subject was a 15-year-old girl who ruptured her extensor pollicis longus after cast immobilization of a right distal radius fracture sustained in February of 2003; her extensor indicis proprius–to–extensor pollicis longus tendon transfer was performed in July of 2003. This second case was complicated by the fact that the patient suffered an undetected rupture of her initial tendon transfer, necessitating a second tendon transfer of the extensor carpi radialis longus to the extensor pollicis longus in November of 2003 performed under pure local anesthesia with epinephrine and without a tourniquet (the wide-awake approach). The third patient, a 64-year-old woman with rheumatoid arthritis, sustained a rupture of her right extensor pollicis longus tendon secondary to a displaced distal radius fracture in 2003. Her extensor indicis proprius–to–extensor pollicis longus tendon transfer was performed in October of 2003. The fourth patient, a 35-year-old woman, ruptured her right extensor pollicis longus in February of 2005 secondary to a comminuted distal radius suffered in September of 2004. The fifth patient, a 59-year-old woman, suffered a spontaneous extensor pollicis longus rupture in January of 2005. Both the fourth and fifth patients underwent their extensor indicis proprius–to–extensor pollicis longus transfers in May of 2005. The sixth patient was a 64-year-old woman who ruptured her right extensor pollicis longus in January of 2005, undergoing a repair in February of 2005. The seventh patient, a 36-year-old man, ruptured his extensor pollicis longus and had his repair in October of 2005.

The same operative method was used in all patients. Each patient was injected with 20 cc of 1% lidocaine with 1:200,000 epinephrine in the area shown in yellow in Figure 1. The local anesthetic was injected in the patient waiting area at least 30 minutes before the patient entered the operating room to allow the epinephrine to take effect and provide an adequately dry working field. Extensor indicis proprius–to–extensor pollicis longus tendon transfers were performed as previously described.[3] In the third subject, extensor carpi radialis longus–to– extensor pollicis longus transfer was performed as described elsewhere[4] (Fig. 2).

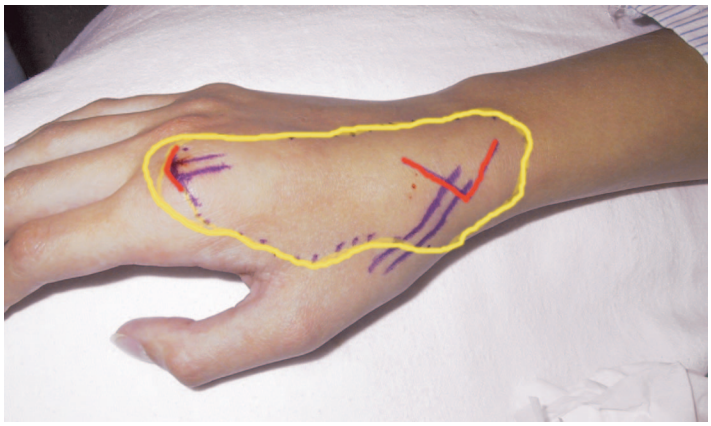

Fig. 1. The circled area was injected with 20 cc of 1% lidocaine with 1:200,000 epinephrine 30 minutes before the operative procedure. *Red lines* indicate incisions. *Purple lines* outline the extensor indicis proprius and extensor pollicis longus tendons.

Fig. 2. A 66-year-old man 3 years after right extensor indicis proprius–to–extensor pollicis longus tendon transfer using the wide-awake approach. Both thumbs are held in full active extension. Note the excellent symmetry between the two sides.

RESULTS

After the initial temporary suture of the extensor indicis proprius–to–extensor pollicis longus transfer was placed, each patient was asked to actively extend his or her thumb. In the first three cases, the patients were asked to perform this action while looking at their affected hand. To block joint proprioception through the affected thumb, the next two patients in the series underwent a metacarpal block with 5 cc of 1% lidocaine with 1:200,000 epinephrine before attempting the movement; in addition, these two patients were prevented from looking at the hand during the attempted movement using a screen. In the final two cases, the patients were prevented from looking at the hand during the attempted movement in the absence of a metacarpal block.

In all eight operations, the response was the same. Each patient extended the thumb without hesitation in the operating room. Each of the seven patients was also able to independently extend the thumb and index finger on the first attempt, without having to practice the movement. Interestingly, in each patient, a concomitant flicker of flexion was noted in the neighboring index finger with the first attempt at thumb extension; this movement was not sustained with further attempts at thumb extension. Please visit the online version of the *Journal* at www.PRSJournal.com to access video footage of the second patient in the study taken intraoperatively during both initial extensor indicis proprius–to–extensor pollicis longus transfer and subsequent extensor carpi radialis longus–to–extensor pollicis longus transfer.

Further observations were made before placement of the temporary transfer suture in the case of the two patients who were both screened from seeing the affected hand and in whom the digital block of the thumb was performed. Immediately after division of the extensor indicis proprius tendon, the patients were asked to extend their thumbs; it is noteworthy that both patients displayed vigorous retraction of the extensor indicis proprius tendon's proximal end into the forearm before any observable movement through the thumb.

In the absence of a tourniquet, the patients were awake and comfortable at the time of surgery. Good operative site anesthesia and hemostasis were obtained with the initial infiltration; indeed, no supplementary local anesthetic was required during any of the procedures.

Follow-up measurements, including range of motion, pinch strength, and grip strength, were taken of both the affected dominant right and unaffected contralateral thumbs in the first five patients (Table 1). A mean follow-up of 16 months was obtained. Mean increases in extension of 1.0 degree and 0.6 degree were noted in the affected thumb at the interphalangeal and metacarpophalangeal joints, respectively, when compared with the unaffected thumb. With the gain in extension, however, there was a concomitant mean loss of flexion of 1.6 degrees and 1.0 degree at the interphalangeal and metacarpophalangeal joints, respectively. Mean tripod pinch strength was greater than in the unaffected hand by 0.9 kg, whereas mean grip strength was weaker by 0.2 kg. Lateral pinch strength was, on average, greater in the affected hand by 0.6 kg.

DISCUSSION

In this article, the authors report on seven patients in whom extensor indicis proprius–to–extensor pollicis longus tendon transfer was performed using the wide-awake approach with pure local anesthesia of lidocaine with 1:200,000 epinephrine and no tourniquet. This technique permits the surgeon to observe the patient perform a full comfortable active range of motion of the digit and make necessary adjustments before the skin is closed. The movement of the affected thumb can be compared with the normal thumb while a temporary suture is still in place, thereby allowing for a more accurate setting of tension at the site of tendon repair. Because a full range of active flexion and extension can be observed before the skin is closed, transfer tension can be adjusted to make sure that it is not too tight or too loose.

Table 1. Patients Who Underwent Extensor Indicis Proprius–to–Extensor Pollicis Longus Transfer Using the Wide-Awake Approach*

Case No.	1	2	3	4	5
Age at diagnosis, years	66	15	64	36	59
Date of diagnosis	February 26, 2002	April 14, 2003	August 8, 2003	October of 2004	April of 2005
Date of tendon transfer(s)	February 26, 2002, EIP to EPL	July 3, 2003, EIP to EPL (ruptured); November 5, 2003, ECRL to EPL	October 22, 2003, EIP to EPL	May 18, 2005, EIP to EPL	May 18, 2005, EIP to EPL
Date of follow-up measurements	36 mo	16 mo after ECRL to EPL	17 mo	6 mo	6 mo
Operated thumb IPJ flexion/extension, degrees	55/−10	94/−10	40/0	64/0	60/0
Unoperated thumb IPJ flexion/extension, degrees	64/−15	85/0	55/0	62/0	55/0
Operated thumb MPJ flexion/extension, degrees	50/−10	66/−10	50/−14	60/0	64/0
Unoperated thumb MPJ flexion/extension, degrees	43/0	67/−20	66/−11	60/0	59/0
Operated thumb tripod pinch strength, kg	7.3	5.5	5.5	6.8	4.0
Unoperated thumb tripod pinch strength, kg	7.0	4.5	4.5	5.0	3.5
Operated thumb lateral pinch strength, kg	8.3	5.5	6.5	8.0	4.5
Unoperated thumb lateral pinch strength, kg	7.5	4.5	5.5	7.5	5.0
Operated thumb grip strength, kg	28	21	20	28	22
Unoperated thumb grip strength, kg	33	21	21	25	20

EIP, extensor indicis proprius; EPL, extensor pollicis longus; ECRL, extensor carpi radialis longus; IPJ, interphalangeal joint; MCJ, metacarpophalangeal joint.
*Donald H. Lalonde, M.D., performed all of the operations presented in this table.

Although extensor indicis proprius–to–extensor pollicis longus tendon transfer has historically been performed with good results using general and regional anesthesia, local anesthesia without a tourniquet avoids the risks to the patient associated with these approaches. At a time of increasing fiscal restraint in many health care systems, it also allows the surgeon to take what was once a procedure for the main operating room safely into the minor procedures area with a concomitant savings in time and cost.

Although the number of patients treated with this novel approach to date is small relative to earlier retrospective studies using a standard non–wide-awake approach under general anesthesia, the final functional outcomes are nevertheless comparable.[5–7] The presented study is also comparable in that outcomes are compared with the unaffected contralateral hand. In many instances, the current work shows more favorable initial results as compared with the standard approach, in terms of both flexion at the interphalangeal joint and grip strength of the affected hand.[3,7]

Classic teaching has held that low-dose (1:100,000 or less) epinephrine use in the hand, particularly as part of a digital block, carries with it the significant risk of vascular compromise. An increasing body of evidence shows that this concern is not valid.[8–14] As this article illustrates, the use of local anesthesia with epinephrine alone has also allowed for some fascinating clinical observations.

In our seven cases, the patients were each able to extend the thumb using the extensor indicis proprius without appearing to have the brain learn this new function. The patients were each able to extend the thumb easily on the first attempt. When we asked the patients what they were thinking when they used the transfer the first time, they each said that they were trying to lift their thumb, not their index finger. It would appear that the brain is able to learn this new

function instantly rather than after months of intensive hand therapy, as is commonly thought for tendon transfers.

Given the rapidity with which the brain is able to make use of the transferred extensor indicis proprius muscle, we postulate that this phenomenon occurs through the activation of a preexisting neuronal network. An increasing body of evidence indicates that different hand movements are controlled not by functionally and spatially discrete groups of neurons, but by a highly distributed network where the balance of activation and inhibition of individual neurons produces various individuated finger movements.[12–15] After extensor indicis proprius–to–extensor pollicis longus tendon transfer, the single individuated movement of thumb interphalangeal joint extension not only activates the extensor pollicis longus to the thumb but similarly activates muscles acting on neighboring digits.[16,17] With no proprioceptive feedback from the tendon organ of the extensor pollicis longus, the balance of neuronal activity shifts to these nearby muscles, such as the extensor indicis proprius, unintentionally activated through a phenomenon known as "force enslaving."[18–21] The fact that the transfer of the extensor indicis proprius to the extensor pollicis longus affects more than just these two tendons is evinced by the flicker of movement consistently observed in the index finger with thumb extension. With the transfer of the extensor indicis proprius, we postulate that the antagonist muscle (flexor digitorum profundus) is still activated to prevent overshoot, as though the index finger were being asked to extend. This index movement is not sustained with further thumb extension. As we have seen in our fourth and fifth subjects, thumb extension through the extensor indicis proprius was not ablated through loss of visual or thumb joint proprioceptive feedback as we also blocked joint proprioceptors with local anesthesia in these cases.

CONCLUSIONS

The fact that all patients were able to extend their thumb immediately after transfer of the extensor indicis to the extensor pollicis longus (without a learning period) may shed light on the brain's inherent ability to adapt to changes in the body's peripheral apparatus. One area of investigation would be to measure cortical activity before and immediately after tendon transfer using either positron emission tomography or functional magnetic resonance imaging. Unfortunately, these imaging modalities lack sufficient spatial resolution at this time to be able to distinguish cortical activity attributable to extensor indicis proprius versus extensor pollicis longus firing.[22,23] Regardless of what direction is taken, the use of the wide-awake approach has clearly opened new directions of research and has called into question the popular thinking that restoration of function following tendon transfer requires formal retraining.

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DISCLOSURE

None of the authors has any commercial association that might pose or create a conflict of interest with information presented in this article.

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