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Bipolar transfer of the pectoralis major muscle for restoration of elbow flexion in 29 cases

Adeline Cambon-Binder, M.D.¹
Arnaud Walch²
Pierre-Sylvain Marcheix, M.D.³
Zoubir Belkheyar, M.D.⁴

¹ Saint-Antoine Hospital, Department of Orthopaedic, and Hand Surgery
184 Rue du Faubourg Saint-Antoine, 75012 Paris, France. APHP, Saint-Antoine Hospital,
Université Pierre et Marie Curie, Paris, France

² Hand and upper limb surgery department, Edouard Herriot hospital, Lyon, France

³ Orthopaedic and trauma department, CHU Dupuytren, 2 Avenue Martin Luther King, 87000
Limoges, France.

⁵ Clinique du Mont Louis, 8 Rue de la Folie-Regnault, 75011 Paris, France.

Corresponding author:

Adeline Cambon-Binder, M.D.
Saint-Antoine Hospital, Department of Orthopaedic, and Hand Surgery
184 Rue du Faubourg Saint-Antoine, 75012 Paris, France
Tel: +0033685573795
adeline_cambon@yahoo.fr

ABSTRACT

Backgrounds

The aim of this study was to evaluate the functional outcomes of bipolar pedicled pectoralis major (PM) transfer to restore elbow flexion.

Methods

We retrospectively reviewed 29 transfers in 28 patients who ranged from 5 to 65 years of age (mean age of 31.2 years.). The loss of elbow flexion was due to brachial plexus palsy for 24 patients, elbow flexors necrosis in four and poliomyelitis in one patient. The whole PM muscle was mobilized and fixed proximally to the coracoid process. Intraoperative positioning and post-operative immobilization of the shoulder and the elbow flexed at 60° and 120° respectively, allowed direct distal fixation of the muscle to the biceps brachii tendon.

Results

At the last follow-up (mean of 13 months, ranging from 4 to 37 months), 41% of the transfers (n=12) recovered grade-4 elbow flexion strength and were able to lift 2.2 kg on average (ranging from 0.5 to 5 kg). Fifty-two per cent of the patients (n=15) recovered grade-3 strength, and 7% (n=2) had a poor result (i.e. grade-2 elbow flexion). The mean active elbow flexion was 100° (ranging from 30 to 150°) and the patients had 0 to 10° elbow flexion contracture.

Discussion - Conclusion

Our results indicate that bipolar PM transfer is a reliable and effective procedure to restore elbow flexion. Flexion of the shoulder and elbow allowed the transfer to reach the elbow fold, and avoided having to resort to use of an interposition graft between the distal PM and the biceps brachii tendon.

Level of Evidence: Level IV

Key words:

Pectoralis major; elbow flexion; muscle transfer; brachial plexus; palliative surgery; upper limb palsy

INTRODUCTION

Restoration of elbow flexion remains a major goal in any paralytic arm reanimation program⁵⁻¹⁷.

Loss of active elbow flexion may arise from brachial plexus injury, destruction of the anterior arm compartment, or generalized muscle conditions such as arthrogryposis or poliomyelitis. Loss of elbow flexion leads to significant limitation of patient autonomy and their ability to work. The various options for flexion reanimation include nerve grafts, nerve transfers¹⁸, and muscle transfers³. The technique that is used depends on a variety of factors such as the palsy's etiology, the delay in performing the surgery, and the patient's surgical history. When elbow flexor muscles cannot be reinnervated due to an excessive preoperative delay or due to localized trauma, a regional pedicled muscle transfer or a vascularized free muscle transfer may be indicated²⁹.

Partial pectoralis major (PM) muscle transfer for elbow flexion restoration was first described by Clark in 1946¹³.

The PM muscle is comprised of two components: the superior clavicular part, which is innervated by lateral pectoral nerves (i.e. branches from the C5-C7 brachial plexus roots) and an inferior sternal portion innervated by the medial pectoral nerve (C8-T1). Its blood supply comes from the medial and the lateral thoracic arteries¹¹. The PM muscle contributes to arm flexion, arm adduction, and shoulder internal rotation.

A major technical concern is the length of the PM, as it is a thick fan-shaped muscle (Fig. 1a) that is too short to allow direct distal fixation on the biceps tendon. This hence forces surgeons to resort to using a variety of methods, for example by performing a rectus abdominis fascia graft²⁹, or by proximally²⁸ or distally⁷ suturing the PM to the biceps tendon.

A technical refinement of bipolar PM transfer was developed, allowing direct distal fixation on the biceps muscle and avoidance of a tendon graft. The aim of this study was to evaluate the functional outcomes of a series of 29 transfers to restore elbow flexion.

MATERIAL AND METHODS

Preoperative data

The principles outlined in the Declaration of Helsinki have been followed and consent was obtained from each patient. From 2006 to 2017, 33 patients underwent a bipolar PM transfer to restore elbow flexion. With the exception of five patients who were lost to follow-up, all of the patients were retrospectively reviewed. There were 29 transfers in total, as one patient was operated on both sides.

The reviewed patients comprised 23 males and 5 females. The right arm was affected in 19 patients and the left arm in ten. On average, they were 31.2 years of age at the time of the surgery (ranging from 5 to 65 years of age). The delay between the accident and the transfer was 57 months on average (ranging from 1 to 57 years).

Elbow flexion palsy was due to a complete brachial plexus palsy for eleven patients, a C5-C6 or C5-C6-C7 brachial plexus palsy for six patients, a brachial plexus palsy distal to the clavicle for six patients, and an obstetrical brachial plexus palsy for one patient. Two patients had ischemic necrosis of the elbow flexors secondary to arm replantation, and two others following a coma. One patient had suffered from poliomyelitis during childhood.

Fifteen of the patients with brachial plexus palsy had experienced a failure of a previous nerve transfer for elbow flexion restoration. For the others, the preoperative delay was too long to allow primary nerve surgery to be performed.

The preoperative clinical assessment included manual testing of the PM and elbow flexor strength according to the Medical Research Council (MRC) grading system. For all of the patients, the elbow flexors were rated M2 or lower, whereas the PM strength was at least M4.

Surgical procedure

The surgery was performed under general anesthesia with the patient in a supine position.

The incision was made along the seventh rib from the sternum to the anterior axillary line, and then extended to the axillary crease (Fig. 1a and 2a).

The humeral insertion of the PM tendon was located and the muscle dissected to its medial and upper sternoclavicular insertions. Care was taken to preserve the two neurovascular pedicles: neurostimulation helped to locate the nerves (Fig. 2b). The lateral pectoral nerve and the lateral thoracic artery were identified on the lateral edge of the muscle after the perforation of the pectoralis minor muscle. The medial pectoral nerve and the medial thoracic artery entered the sternocostal portion laterally to the middle of the clavicle.

Meticulous hemostasis of the deep layer was performed during the final muscle harvesting.

The PM tendon was not cut before the pedicles could be located and the entire dissection completed, since the PM retracts otherwise. The PM distal tendon was then cut and attached to the coracoid process with transosseous stitches. The muscle was prepared with sutures made at the sternal and clavicular insertions. When tension was applied on those sutures, the muscle assumed a fusiform shape (Fig. 2c). A longitudinal incision above the elbow crease allowed identification of the distal biceps tendon. The PM was then passed through a subcutaneous tunnel - at least four fingers wide - all the way to the distal arm incision. The shoulder was then flexed at 60° and the elbow at 120°, allowing the transfer to readily reach the elbow fold (Fig. 2d and 1c). The PM was fixed on the biceps tendon with a Pulvertaft-like suture. The muscle tension was adjusted so that the elbow spontaneously remained at 100° at the end of the fixation. The post-operative regimen included six weeks of immobilization in a splint with the shoulder flexed at 60° , in internal rotation, and the elbow flexed at 120° degrees, followed by an additional two

weeks using a splint with the elbow flexed at 90°. Active elbow flexion and extension started after the sixth week, increasing the extension by 10° each week.

In patients with shoulder palsy, shoulder arthrodesis was performed after the PM transfer as part of the program to restore function to the paralytic arm.

Outcome measurement

The active elbow flexion range of motion was measured for every patient. The elbow flexion strength was assessed according to the MRC grading system, with the elbow flexed at 90°. The maximum weight sustained at the level of the wrist was recorded for the patients who were able to flex their elbow against resistance. If the patient had a shoulder arthrodesis, the outcomes were measured at least four months later.

RESULTS

The mean follow-up was 13 months (ranging from 4 to 37 months). At the last examination, 59% of the transfers had recovered grade-4 elbow flexion strength (n=17), 34% had recovered grade-3 strength (n=10), and 7% had a poor result (n=2; MRC grade=2)(Table 1).

The mean active elbow flexion was 100° (ranging from 30 to 150°)(Fig. 3). All of the transfers recovered at least 90° of flexion, except for two patients with grade-2 strength, who only had 30° elbow flexion. One of them had co-contractions between the triceps brachii muscle and the PM. He later underwent a palliative transfer of the triceps muscle to the biceps that allowed for recovery of grade-4 elbow flexion strength, with 130° of active elbow flexion.

The M4-patients could lift an average of 2.2 kg (ranging from 0.5 to 5 kg).

Post-operatively, patients had 0 to 10° elbow flexion contracture.

There were no reported complications for any of the transfers during the post-operative period.

DISCUSSION

The first report of a unipolar transfer of the PM was by Clark in 1946¹³. He transferred the inferior part of the PM, innervated by the medial pectoral nerve on the biceps tendon. Since then, several studies have reported satisfactory results using this transfer method^{4,11,14,16,25,27} (Table 2). However, as the PM is often too short to reach the elbow fold, several solutions have been proposed to lengthen the transferred muscle. Seddon transferred the inferior part of the pectoralis major, including a section of the sheath of the rectus abdominis so as to serve as tendon²⁴. Brooks and Seddon harvested the long head of the biceps: it was passed through the PM tendon and then sutured to the distal biceps tendon⁷. Beaton et al. used a fascia lata graft⁴, with results similar to Steindler flexorplasty. The disadvantage of unipolar transfers is that the line of pull is not in direct line with the desired movement⁴. Schottstaedt et al. transferred both PM insertions on the coracoid process and the biceps tendon, respectively, but they harvested only the pectoralis externus (i.e. the proximal two-thirds of the PM, attached to the fourth, fifth, and sixth ribs)²³. In 1979, Carroll transferred the entire mass of the PM¹⁰. As the medial pectoral nerve innervates both the PM and pectoralis minor muscles, Tsai et al. transferred both of these muscles to protect their innervation²⁸. Tsai et al. also described a technique using the whole PM: suturing the PM proximally to the biceps tendon²⁸. Lastly, Wahegaonkar elongated the PM by using a wide strip of anterior rectus abdominis fascia to perform the suture on the biceps tendon²⁹.

The study indicates generally satisfactory results with bipolar PM transfers to restore elbow flexion, with direct distal fixation onto the biceps tendon in shoulder flexion. Flexing of the shoulder is an innovative surgical technique, allowing a direct suture of the PM with no tension and no need for a tendon graft. This allows for easier post-operative care and rehabilitation as there is no supplementary tendon donor site.

A preoperative requirement is that a muscle with a base line strength of at least grade-4 is needed²⁰⁻²¹. Both parts of the muscle are usually evaluated by manual testing. When in doubt, an electromyographic evaluation can be performed.

Incomplete lesions of the brachial plexus are good indications as the PM is innervated by nerve roots C5 to T1, and good functional outcomes have been obtained with such cases^{7,13}. Surprisingly, PM MRC grade-4 strengths have been observed in some cases of complete brachial plexus palsy, possibly due to some anatomical variations, which allowed the transfer to be performed. The contraindications of pectoralis major transfer are palsy of both clavicular and sternal portions of the muscle (which may occur when C7 is involved in the brachial plexus palsy), and agenesis of the muscle in some cases of arthrogryposis. In the latter situation, when elbow flexion restoration is considered, presence of the muscle should be checked clinically or with magnetic resonance imaging in overweight patients. A relative contraindication is the palsy of the sternal portion of the pectoralis major, as isolated transfer of clavicular part leads to weaker strength.

A bipolar transfer reproduces the flexor action of the biceps brachii for flexion and supination. Fixation of the PM to the coracoid process reduces the force needed for the hand to bear a weight, and the torque created when the PM is still attached to the chest^{4,6,10}. It aligns the transfer with the native position of the biceps and it enhances the transfer mechanism^{6,19}.

In theory, shoulder instability is a potential complication of bipolar PM transfer, due to the indirect line of pull and internal rotation force imparted on the shoulder²⁰. In our series, the 14

transfers without shoulder arthrodesis had no shoulder instability. Carroll did not observed any shoulder instability in their series either¹⁰.

Shoulder arthrodesis is a common procedure for arm stabilization in brachial plexus palsy. Associating the bipolar transfer of the PM with shoulder arthrodesis should stabilize the shoulder and transfer the entire working capacity of the transfer to elbow flexion, thereby avoiding loss of strength of the glenohumeral joint^{4,10,15}.

Many alternative surgical procedures to restore elbow flexion have been reported. Steindler's medial epicondylar transposition transposition was first described for elbow reanimation following poliomyelitis, and proposed afterwards in patients with residual weak elbow flexion^{1,2,22,26}. Disadvantages are the little gain in strength (more or less one point in the MRC grading system), and some residual elbow flexion contracture. Several free and reinnervated muscle transfers have been proposed, including gracilis, latissimus dorsi, and rectus femoris^{2,12}. These add microsurgery sutures for the nerve, artery, and veins. With a pedicled transfer of the latissimus dorsi, 85% of patients scored elbow flexion strengths of MRC 3-4, with little morbidity^{3,9,12}. This alternative does not require resorting to microsurgical neurovascular techniques. However, with brachial plexus palsy the latissimus dorsi is usually too weak to be transferred. Moreover, the muscle tends to be synergistic with elbow extension when the PM is synergistic with elbow flexion.

Transfer of the sternocleidomastoid muscle is biomechanically effective, but disfiguring⁸. The cosmetic consequences of PM harvesting on the anterior thorax are less noticeable in female patients - as the incision is located under the breast - than in fit male patients who will suffer post-operatively from chest asymmetry⁶.

Due to the rarity of indications, the main limitations of this study were its retrospective nature and the heterogeneous population in terms of the indications and the delay between the accident and the surgery.

CONCLUSIONS

This study indicates that a PM bipolar transfer provides satisfactory results in cases of elbow flexion palsy, even when there has been a long preoperative delay. Shoulder flexion allows for a direct distal suture with no tension, and facilitates the post-operative rehabilitation.

A PM transfer should be considered for elbow flexion restoration when palliative surgery is indicated – due to an excessive preoperative delay or failure of previous nerve surgery. In our experience, PM transfer supplanted latissimus dorsi transfer and Steindler's procedure to restore elbow flexion. This was especially so with brachial plexus palsy, as PM strength is usually strong in such cases.

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FIGURE AND TABLE LEGENDS

Figure 1. Anatomical view of pectoralis major (PM) muscle (pink), with its innervation (yellow) and vascularization (red) (a). Incision outline (red) (a). Bipolar fixation of the muscle onto the coracoid process proximally and the biceps tendon distally, with shoulder and elbow flexed (c).

Figure 2. Perioperative views of the surgical technique for the pectoralis major bipolar transfer. A long curvilinear incision is made from the sternum to the axillary crease, along the seventh rib under the nipple. A second incision is performed along the biceps distal tendon, without crossing the elbow crease (a). Electrostimulation helped identify the lateral pectoral nerve and the lateral

thoracic artery following their perforation of the pectoralis minor muscle (b). After complete harvesting, the PM tendon was attached proximally to the coracoid process, and “purse-like” sutures were made over the former proximal insertion to change the PM shape to a fusiform one (c). Lastly, the PM distal suture onto the biceps tendon was performed with the shoulder flexed at 60° and the elbow flexed at 120° (d).

Figure 3. Elbow flexion deficit due to a C5-C6 brachial plexus palsy in a 31-year old man. The preoperative elbow active range of motion was rated as M1. Four months after a bipolar PM transfer, the elbow flexion strength was rated as M4 and the patient recovered elbow active range of motion from 10 to 120°.

Pectoralis major transfer in 29 cases

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Pectoralis major transfer in 29 cases

435 Table 1: Clinical description and post-operative results from the pectoralis major transfer to
436 restore elbow flexion in our case series.

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Case	Age at surgery (years)	Etiology	Preoperative elbow flexion (MRC grade)	Preoperative PM strength (MRC grade)	Delay before transfer (months)	Follow-up (months)	Post-operative elbow flexion (MRC grade)	Post-operative active elbow flexion (°)	Shoulder arthrodesis after the PM transfer
1	27	Complete BPP	2	4	38	9	3	90	yes
2	31	Complete BPP	0	4	52	8	4	90	yes
3	6	Obstetrical BPP	0	5	75	9	3	90	no
4	5	Transbrachial replantation	0	5	6	4	4	90	no
5	61	Complete BPP	0	4	55	26	2	30	yes
6	31	C5-C6 BPP	1	4	NR	4	4	120	no
7	62	Poliomyelitis	0	5	689	4	4	150	no
8	65	Elbow flexor wound	0	4	25	8	3	90	no
9	22	C5-C6 BPP	1	4	20	4	4	120	yes
10	19	Arm compartment syndrome	0	5	7	5	3	90	no
11	26	Complete BPP	2	4	50	12	4	NR	yes
12	31	C5-C6-C7 BPP	0	5	33	24	4	100	yes
13	31	BPP, distal to the clavicle	2	5	34	4	4	120	no
14	37	brachial plexus, distal to the clavicle	0	4	15	4	4	100	no
15	23	Complete BPP	0	4	32	29	2	30	yes
16	33	Complete BPP	0	4	14	19	4	90	no
17	20	brachial plexus, distal to the clavicle	0	4	1	44	4	120	no
18	29	Arm compartment syndrome (coma)	0	5	21	17	4	110	no
19	49	BPP, distal to the clavicle	2	4	13	26	3	90	no
20	35	Complete BPP	0	4	23	6	4	NR	yes
21	30	Complete BPP	2	4	55	4	3	NR	yes
22	55	C5-C6 BBP	1	5	77	37	3	110	yes
23	31	BPP, distal to the clavicle	0	4	27	12	4	150	no
24	31	BPP, distal to the clavicle	0	4	24	13	4	NR	no
25	36	C5-C6 BPP	0	4	38	6	4	120	yes
26	28	Complete BPP	1	4	32	17	3	90	no
27	30	Complete BPP	2	4	27	11	3	NR	yes
28	22	Complete BPP	1	4	NR	8	3	90	yes
29	31	C5-C6 BPP	0	4	51	8	4	120	yes

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440 BPP: brachial plexus palsy; PM: pectoralis major; NR: not recorded

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445 Table 2: Review of the literature concerning pectoralis major transfer to restore elbow flexion.

Case Series	Number of cases	Etiology	Results	Active elbow range of motion
Dautry 1978	7 bipolar	Brachial plexus	7 M4	20 to 140°
Marshall 1988	11 bipolar	Brachial plexus	4 M4, 2 M3, 5 M2	Mean 34°, max. 120°
Botte 1989	5 bipolar	4 brachial plexus + one distal humerus amputation	2 M3, 3 M4	91° mean
Ghahremani 1996	7 bipolar + latissimus dorsi for external rotation	6 brachial plexus and one biceps brachii muscle loss	5 M4, one M3, one lost to follow-up	5 > 120°, one 50°, one lost to follow-up
Lahoti 2005	10 bipolar	arthrogryposis	9 M3 or M4	No data
Terzis 2010	3 bipolar	Obstetrical brachial plexus palsy	3 M3	35 to 80°

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