

The Orthopaedic Hospital of the Invalid Foundation, Helsinki, Finland.

FLEXORPLASTY OF PARALYTIC ELBOWS

Analysis of Late Functional Results

T. SAM LINDHOLM & SAKARI EINOLA

Accepted 9.x.72

A method for surgical management of flexion paresis of the elbow joint was published by Arthur Steindler in 1918. He transposed the insertion of the flexor group of the wrist and fingers from the median epicondyle of the humerus proximally to the diaphysis of the humerus, and thus increased the leverage of these muscles on the elbow joint without impairing their original function. Modifications of the method have been presented by e.g. Bunnell (1951), who used a fascial transplant as continuation to the muscle group, and Mayer & Green (1954) who attached the epicondyle to the volar aspect of the humerus. Both these methods seek to move the insertion from the median surface of the humerus more laterally in order to prevent pronation contracture. Mayer & Green (1954) tried to reinforce the result of flexorplasty by also moving the extensor group proximally, but abandoned this method because of the risk of nerve damage that it involved.

Other alternatives have been suggested for the restoration or improvement of the flexion of the elbow joint. The transposition of pectoralis major to biceps introduced by Clark (1946) and modified by Brooks & Seddon (1959), of sternocleidomastoideus to biceps by Bunnell (1951) and of triceps by Carroll (1952), which are mentioned as the main alternatives to Steindler's method, are not discussed here. The present material consists of cases in which transposition of Steindler's flexor group was the basic procedure used in the treatment of flexion paresis of the elbow joint.

METHOD

The ulnar nerve was freed and protected during the operation. The median epicondyle or part of it was detached by chisel and the flexor group was dissected. Detachment from the epicondyle was done subperiosteally in children. The freed muscle bundle was fixed to the medial or mediovolar surface of the humerus 2-6

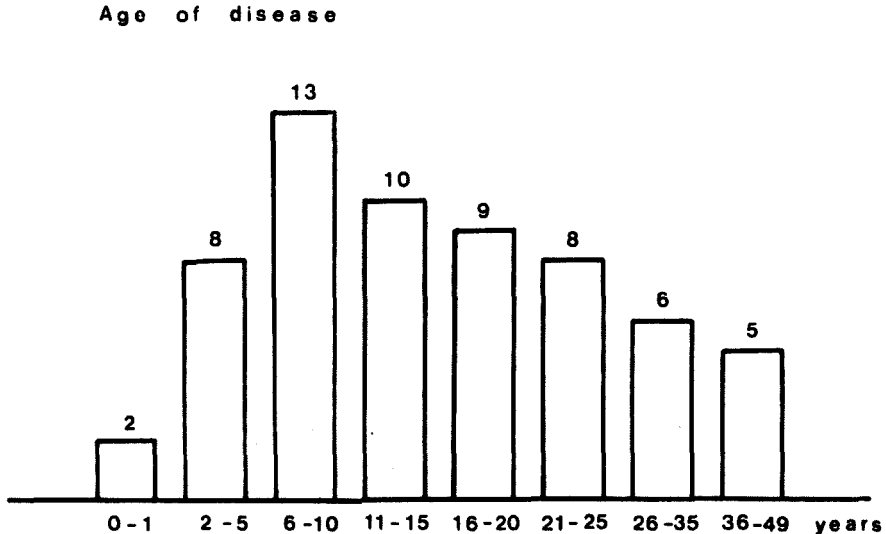


Figure 1. Age distribution at the onset of poliomyelitis or time of lesion. More than half of the patients were diseased between 0 and 15 years.

cm proximally, mostly into a periosteal pocket and septum intermusculare. In 7 cases the fixing wire was pulled through a hole drilled in the bone. The epicondyle fragment was fixed by screw in 2 cases. The lateral extensor group was also transposed 3-7 cm proximally in 6 cases, in 2 of them at a separate operation. Bunnell's fascial transplant was used in one case. After the operation the limb was immobilized in plaster of Paris, flexed 90° or less and with the forearm in maximal supination for six weeks. Physiotherapy was started after removal of the cast.

Four patients underwent humeroscapular arthrodesis, 2 carpal arthrodesis and in another 2 cases transposition of the flexor carpi ulnaris was performed.

MATERIAL

The series comprised 61 cases; 59 with a post-poliomyelitis status, one obstetric and one postoperative upper limb paresis. The patients had been operated on at the Orthopaedic Hospital of the Invalid Foundation in 1946-1966 and given a follow-up examination in 1960 and 1971. Two-thirds of the patients were followed up 6-15 years after the operation: 34 were women and 27 men. The operation was performed 29 times on the left and 32 on the right side. The ages of the patients at the onset of the illness, at the operation and interval between onset and surgery are presented in Figures 1-3.

In 33 cases one upper limb was affected, whereas the pareses were more extensive in the remaining 28 cases. Six patients had pareses of the digital flexors, 4 of the extensors, 15 on the flexor side of the wrist and 6 on its extensor side, involving

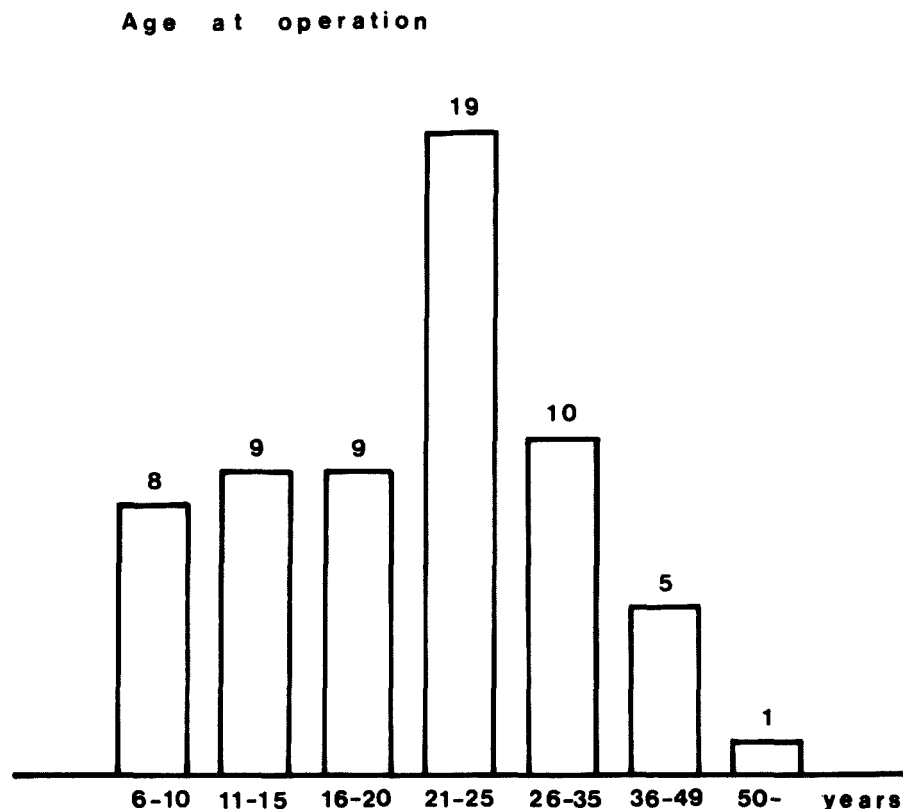


Figure 2. Age distribution at the time of operation. About three-fourths of the patients were operated between 6 and 25 years, with the maximum rate at 21-25 years.

one or some of the muscles in question. Paresis of both the finger and wrist muscles was observed in 11 cases. Complete flexion paresis in the elbow joint was present in 26 cases, combined with totally paretic triceps in 20 cases. The ipsilateral humeroscapular muscles of 40 patients were either completely or largely paretic, causing subluxation of the humerus.

FOLLOW-UP

Elbow Flexion

Forty-six of the patients considered subjectively that they had derived distinct benefit from the operation. All but 5 of the patients were able to make a flexion-extension movement of the operated elbow (Figure 4). One patient was able to lift 2 kg, and 10 could lift 1 kg at right angles. Eighteen patients were able to handle light objects and

Period from disease to operation

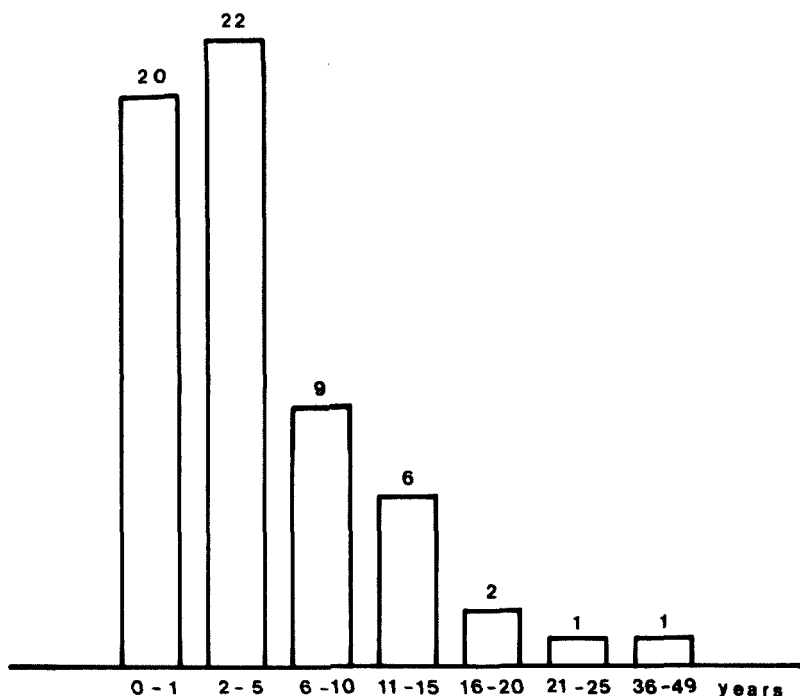


Figure 3. The periods up to the time of operation. Two-thirds of the patients were operated 0-5 years after the occurrence of the disease.

to lift 200 g within the full range of movement. The strength of the active flexion was consequently equal to or slightly greater than the gravitational force in 27 cases.

Evaluation of the *strength of flexion* in the 11 patients who were able to lift a weight of over 1 kg at right angles revealed that they all had normal or only slightly reduced strength in the hand and wrist. In 7 cases the preoperative limitation of extension was over 30° and in the patient with the best flexion rating it was 55° . In the other cases some degree of flexion function was preserved in the natural elbow flexores before the operation.

Maximal strength of flexion was achieved in one of the patients where combined transposition of the median flexor group and the lateral extensor group was performed, but the same case displayed the maximum extension limitation. No clear evidence of increased exten-

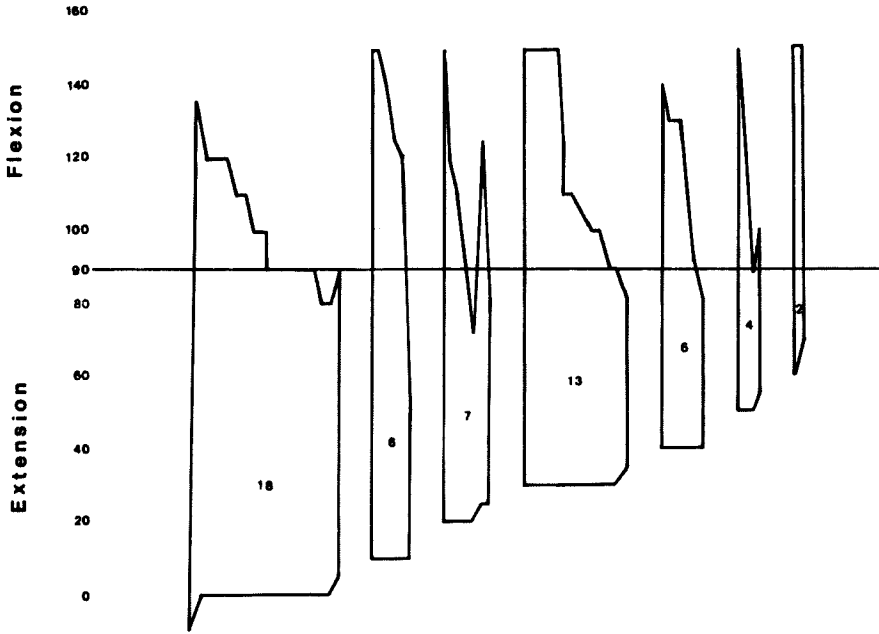


Figure 4. The range of movement achieved in 56 patients with flexorplasty of the elbow. 5 patients had no active movement at the follow-up examination. The active movement is arranged according to the limitation of extension and the degree of flexion. Preoperatively three-fourths of the patients had no active function of biceps, two-fifths no active triceps. The major part of the patients hold the elbow in a straight position, in 7 cases there was a limitation of extension over 30°, in one case about 55°.

sion contracture or flexion strength by this method could be found in the other cases.

The patients with a paretic shoulder said that they often supported the elbow joint against the table, which enabled them to increase the flexion strength of the joint. This was confirmed in these cases by supporting the paretic shoulder when the strength of flexion was studied.

Degree of elbow flexion. The range of movement achieved in the elbow joint can be seen in Figure 4. Many of the patients preferred to flex the elbow with a clenched hand. There were 3 cases in which the forearm was pronated, 4 in which the wrist was in volar flexion and one in which it was in supination when the movement was performed. The fingers and wrist of 7 patients were in pronounced hyperflexion on performing the movement; the extension strength rat-

ing of the fingers and wrist of these patients was nil. The patients with loosening of the transposed median epicondyle retained some biceps and brachial function, which obviously helped to increase flexion strength. One patient had such a poor muscular strength rating in the limb that he felt the operation had been of no benefit although he was able to flex the limb. Fixation had been done 2-2½ cm proximally in another 2 cases and was probably a major reason for the poor flexion strength. One of these 2 patients had moreover undergone transposition of the extensor group 7 cm proximally, but it obviously did not affect the strength of flexion. It was impossible to decide with certainty in 2 cases why the result was poorer than expected. Both of these patients, however, considered that surgery had been of considerable benefit; one was capable of lifting 200 g with the hand clenched.

Elbow Extension

No *limitation of extension* was observed in 18 patients. The pre-operative flexion strength of the forearm had been nil in all these cases; 4 were capable of flexing it under 120° at the follow-up examination, and all of them had good muscle strength in the wrist and fingers. The extension strength of the elbow joint was rated 0 in 7 cases. An increased limitation in extension postoperatively is a fact in many cases.

Supination and Pronation

Pronation contracture of varying degree was established in 17 patients at the follow-up. In 14 of them the strength of supination pre-operatively had been rated 0 and the degree of pronation good. The strength ratio was distinctly in favour of pronation in the remaining 3 cases. Six of these 17 patients had a contracture in pronation pre-operatively. Slight limitation of supination was seen in 14 cases; in these cases, too, the strength of pronation was distinctly greater than the degree of supination or both were nil.

The strength of pronation-supination was equal in the remaining 30 cases or supination was stronger than pronation. The supination rating had increased during the six follow-up years in 9 cases. One patient's forearm turned to supination on bending; the epiphyseal transplant had worked loose.



Figure 5. *A series of roentgenograms of the state of the transposed medial epicondyle ad modum Steindler at follow-up. In the last example the epicondyle has broken loose from its attachment to the bone.*

Complications

There were symptoms in 2 cases of damage to the ulnar nerve. The paresthesia disappeared in one case in a few months, but the other patient still complained of that at the follow-up examination. The roentgenograms taken at the follow-up showed that the transposed median epicondyle had worked loose from its periosteal attachment in three cases and the lateral epicondyle had loosened in one case. Not a single transplant fixed to bone had worked loose (Figure 5).

DISCUSSION

The primary object of Steindler's flexorplasty is to reactivate or increase the range of elbow flexion so that the patient can raise his working hand to the right level. The importance of this simple movement in, e.g., desk work or even just raising the hat is obvious. Fifty of the 61 cases of this series achieved a range of flexion of at least 90°. Some of these patients did not meet the other important criterion of flexorplasty, that is, a hand functioning sufficiently well for the patient to benefit from the intervention.

The main requirement for achievement of good flexion mobility and strength with Steindler's method is the condition of the muscle group to be transposed, provided that the procedure has been correctly performed technically. This has been stressed not only by the creator of the method but also by all other investigators. In the present material, the function of both the flexors and extensors of the fingers and the wrist was either not or only slightly impaired in the groups with the best range of motion and in the best cases as regards strength of flexion. In contrast, absence of function in the extensor group made the hand useless in the two cases in which flexing of the elbow joint caused maximal flexion in both the fingers and the wrist.

An ideal end result is good flexion strength and good range of motion, which are to some extent parallel requirements. In this series the best "lifters" of each group were the patients who achieved a fairly good range of mobility. The best result achieved, that is 2 kg, matches the best in Nyholm's (1963) series. The best strength of flexion achieved by Kettelkamp & Larson (1963) was 3 kg.

The recommended distance of transposition for the medial epicondyle is approx. 5 cm, sometimes a little more. In most of the present cases the epicondyle was transposed some 3–4 cm proximally, judging by the control roentgenograms. The poor flexion strength in some

cases was attributed at least partly to the short (about 2 cm) distance of transposition. Indeed, it seems natural that if the strength of the transposed flexor group is reduced a better flexing strength might be achieved with a longer transposition distance, though an increase in the extension limitation would then have to be expected. Bunnell's (1951) method of using a fascial transplantate as a continuation for the muscle group gives a longer lever arm for weak muscles and possibly reduces the limitation of extension.

Limitation of extension in the elbow joint often follows flexorplasty. It was an average of 15–20° in Nyholm's (1963) material, 30 in that of Mayer & Green (1954), 40 in Carroll's (1952) series and 60 in the material reported by Segal et al. (1959). In the present material the average extension limitation was 25°.

The strength of the triceps has been considered to be correlated with the limitation of extension (Mayer & Green 1954). In the first two groups of this series in which the extension limitation was not over 10° at most, the triceps were in good condition and the muscle group to be transposed was practically normal in the majority of the cases. The range of mobility achieved in these cases was good. This suggests that a new antagonist muscle in good condition would seem to have a favourable effect on the function of the transposed muscle group. On the other hand, a severely paretic triceps appears to increase the limitation of extension, as evidenced by the distribution of the triceps-0 patients in the material.

The cases in which both the extension and flexion strength was completely paretic because of paralysis were among the poorest because of the concurrent weakness of the muscle group to be transposed. This paretic combination also appears to be reflected in the degree of impairment of the other muscle of the limb. The pronounced extension limitation of one patient was obviously a part factor in the achievement of good strength of flexion with unimpaired muscles of the forearm, a finding in agreement with earlier observations (Segal et al. 1959, Nyholm 1963). It should be noted that this patient had also undergone transposition of the extensor group, which has been considered to be of significance for the magnitude of the limitation of extension. Incidentally, transposition of the extensor group was not found to have any definite effect on the flexion strength achieved.

One of the major drawbacks of Steindler's method is the tendency to pronation contracture. It was observed in almost one-third of the cases at the follow-up examination. This must be regarded as the

combined result of the serious disproportion between the pronation-supination strengths before the intervention and the effect of the operation in these cases. This contracture did not ensue in a single case in which the muscle power of the functioning pronators and supinators was fairly balanced. Bunnell (1951) and Mayer & Green (1954) developed their modification of the fixation of the flexor group laterally in order to prevent contracture from originating. Bunnell's (1951) proposal to transpose the flexor carpi ulnaris to the radius to serve as a supinator had the same aim.

The duration of postoperative immobilisation in this series was six weeks. Several authors consider an immobilisation period of three weeks to be sufficient. However, Carroll & Gartland (1953) say that this has no effect on the end result.

One of the objects of Steindler's flexorplasty was to restore the function of the elbow joint enough to enable the patient to raise his hand to his face. Paresis in the muscles of the shoulder region, however, makes even a successful flexorplasty fail in this respect. The role of humeroscapular arthrodesis as a stabilising supplementary procedure is in fact unchallenged; yet, full benefit is derived from it only if the scapular muscles are functioning. This operation was performed on four patients of the present material and it was beneficial in all of them.

SUMMARY

Flexorplasty of the elbow joint *ad modum* Steindler was performed on 61 cases, and on six of them transposition of the extensor group as well. The range of mobility achieved was 30–120° or more in 18 cases. The flexion strength achieved equaled the gravitational force in 27 cases, it was equal to or greater than 200 g in 18 cases, and equal to or greater than 1 kg in 11 cases. The flexion strength was less than the gravitational force in 5 cases. The dependence of the results on various factors is discussed.

REFERENCES

- Brooks, D. M. & Seddon, H. J. (1959) Pectoral transplantation for paralysis of the flexors of the elbow; a new technique. *J. Bone Jt Surg.* 41-B, 36–43.
Bunnell, S. (1951) Restoring flexion to paralytic elbow. *J. Bone Jt Surg.* 33-A, 566–571.
Carroll, R. E. (1952) Restoration of flexor power to flail elbow by transplantation of triceps tendon. *Surg. Gynec. Obstet.* 95, 685–688.

- Carroll, R. E. & Gartland, J. J. (1953) Flexorplasty of elbow; evaluation of method. *J. Bone Jt Surg.* **35-A**, 706-710.
- Clark, J. M. P. (1946) Reconstruction of biceps brachii by pectoral muscle transplantation. *Brit. J. Surg.* **34**, 180-181.
- Kettelkamp, D. B. & Larson, C. B. (1963) Evaluation of the Steindler flexorplasty. *J. Bone Jt Surg.* **45-A**, 513-518.
- Mayer, L. & Green, W. (1954) Experiences with Steindler flexorplasty at elbow. *J. Bone Jt Surg.* **36-A**, 775-789; 858; 862.
- Nyholm, K. (1963) Elbow flexor plasty in trendon transposition. (An analysis of the functional result in 26 patients.) *Acta orthop. scand.* **33**, 30-42.
- Segal, A., Seddon, H. J. & Brooks, D. M. (1959) Treatment of paralysis of the flexors of the elbow. *J. Bone Jt Surg.* **41-B**, 44-50.
- Steindler, A. (1918) Orthopedic reconstruction work on hand and forearm. *N. Y. med. J.* **108**, 1117-1119.

Correspondence to:

T. Sam Lindholm
The Orthopaedic Hospital of the Invalid Foundation
Helsinki
Finland