Transfer of flexor carpi ulnaris combined with selective release of the flexor pronator origin was undertaken in 35 patients with hemiplegic cerebral palsy for a pronation flexion deformity of the forearm, hand and wrist. The patients were divided into four groups depending on the severity of the deformity, the surgical procedure recommended, potential hand function and prognosis.

The procedure reduces the power of wrist and finger flexion by release of the flexor pronator origin, and reinforces the strength of extension and supination of the wrist by transfer of flexor carpi ulnaris. After a mean follow-up of four years the appearance of the hand and forearm improved in all patients. None lost movement and all gained improved mobility of the forearm, wrist and hand. There was no overcorrection.

In children with cerebral palsy parents, therapists and orthopaedic surgeons are primarily concerned with the inability to stand and walk; the upper limb is often ignored.1 A pronation contracture of the forearm, in association with a flexion contracture of the wrist, is a common deformity in the upper limb in patients with spastic cerebral palsy.2 As a result of this deformed posture hand function is poor. Any attempt to use the hand is hindered by the overpowering flexor mechanism. The contracted flexor muscles not only prevent extension of the wrist, but are rendered ineffective for grasping because of tension in the stretched extensor muscles and their reduced excursion.3 Many attempts to correct this deformity have been described including denervation, myotomy, tenotomy, tendon lengthening, tendon transfer, tenodesis, capsulotomy, excisional arthroplasty, and arthrodesis.4 5 Release of tendons or muscles combined with tendon transfer, is always prefer-

able.6 Transfer of flexor carpi ulnaris (FCU) as described by Green7 is an excellent procedure for improving dorsiflexion of the wrist or fingers, but the effect on supination when accompanied by a pre-existing pronation contracture is small. When there are severe contractures of the wrist and fingers, tendon transfers are unsuccessful.7 Release of the flexor pronator origin (FPO) is effective for correction of the flexion contracture of the wrist and fingers but does not restore the ability to supinate the forearm actively or to dorsiflex the wrist and fingers.8

The aim of this article is to discuss the merits of a procedure which combines selective release of the FPO with transfer of FCU. A similar operation was described by Braun, Mooney and Nikel9 in a preliminary report of three patients suffering from hemiplegia after a stroke.

**Patients and Methods**

Combined transfer of FCU and selective release of the FPO was carried out in 35 hemiplegic patients with flexion pronation deformity of the hand and forearm. The right hand was affected in 13 and the left in 22. There were 18 girls and 17 boys. Their mean age at operation was 12 years (6 to 19); 19 were high-school students. Five patients had an associated severe flexion contracture of the elbow and 14 had a deformity of the thumb, usually of the 'thumb-in-palm' type. All the patients had a variable amount of spasm of pronator teres.

They all had some degree of sensory deficit, the most common being astereognosis; pain and touch were normal. The intelligence of the patient and the ability to communicate are important. In the infant and young child, intelligence testing is difficult, but an overall impression can be gained. Most patients had an intelligence quotient (IQ) of 80 or more.

The ability to grasp, release, reach for objects and pass them from one hand to the other was noted.

We modified the two-pattern classification system of Zancolli and Zancolli10 to assess the severity of the flexion deformity of the wrist and fingers and the indications for surgery, adding two further divisions, giving the following four groups:

A) Active finger extension was possible with the wrist extended at least to the neutral position (six patients).
B) Finger extension was possible with the wrist flexed less than 50° (15 patients).
C) Finger extension was only possible with the wrist flexed more than 50° (nine patients).
D) There was severe flexion deformity of the wrist and fingers with little or no ability to extend them (five patients).

In all patients, transfer of FCU was combined with selective release of the FPO. The suitability of the FCU for transfer was evaluated before operation:
1) voluntary action of FCU was determined by palpation and observation of the muscle tendon during active wrist flexion;
2) co-ordinated activity was assessed by observation of the contracting FCU as the fingers were flexed; and
3) excessive response to the stretch reflex was evaluated by rapid passive extension of the wrist against the FCU with the wrist in maximum extension, in neutral and in flexion.

Operative technique. The operation is carried out under general anaesthesia with the patient supine, the upper limb on a hand table and a tourniquet applied to the upper arm.

A longitudinal incision, approximately 5 cm long, is made, starting from the pisiform bone and extending proximally. After exposure of the insertion of FCU into the pisiform bone the ulnar nerve is identified and protected. The tendon is then detached from the pisiform bone and dissected proximally from the ulna. A suture is passed through the end of FCU and the muscle pulled to delineate its course up to the forearm.

A second skin incision is made from a point 2.5 cm above the medial epicondyle extending distally about 10 cm over the muscle belly of FCU which is defined and dissected from the ulna and deep fascia working from distal to proximal. The tendon is then delivered into the proximal incision (Fig. 1) and the muscle released until it passes through the end of FCU and the muscle pulled to delineate its course up to the forearm.

A third skin incision, made on the dorsal aspect of the wrist extending from the crease of the wrist joint proximally for about 3 cm, exposes the tendons of extensor carpi radialis longus and brevis. Either can be chosen for the insertion of the transferred FCU tendon. That of brevis gives more extension of the wrist and this procedure was carried out in 22 patients. Use of longus gives more power for supination and this was undertaken in 13. A slit is made in the chosen extensor tendon and the tendon of FCU is passed through it. With the forearm in full supination and the wrist in 45° of dorsiflexion the two tendons are sutured under tension with a non-absorbable suture.

The tourniquet is released and haemostasis obtained before the wound is closed with suction drainage. An above-elbow plaster cast is applied with the wrist in 45° of dorsiflexion and the forearm in supination. The cast is bivalved to allow for swelling.

Postoperative management. The limb is elevated for 48 hours and finger movements encouraged. If swelling of the fingers occurs, the bivalved cast is opened slightly. On the fifth postoperative day, the wounds are inspected and dressings changed. An exercise programme, consisting of active assisted movements of the elbow, forearm and hand, is begun. Three weeks later, more active, vigorous exercises are started. The bivalved cast is retained, except for exercise periods, for two months and used at night for at least four months.

Results

Our aim was to enhance function and appearance in the first three groups (A, B and C) and to improve appearance in the fourth (D). The mean follow-up was for four years (2.5 to 5). For the six patients in group A, the functional improvement was very dramatic, with hand control being the most
impressive gain. Active supination, grasp and release of the hand were restored. The 15 patients in group B showed good extension of the wrist and flexion of the fingers, but weak active extension of the fingers, resulting in good hand grasp but weak release. Group C patients showed weak grasp and extension of the fingers which was aggravated by a ‘thumb-in-palm’ deformity. This was present in all nine patients in this group, but was subsequently corrected. In the five patients in group D, some active finger flexion was seen, but these movements were not functionally effective. In this group our objective was to improve appearance since surgery could not be expected to enhance function or range of movement (Table I).

The patient and parents must have a clear understanding that the operation will not produce a normal hand or arm. All were pleased with the cosmetic results of the procedure, particularly the five patients in group D in whom the cosmetic disability had been the primary indication for surgery. At follow-up, the limbs remained in an almost normal position by the side during gait. With excitement, an attitude of slight flexion was assumed, but did not appear to embarrass the patients. None lost movement and all gained some increase in mobility of the wrist and hand. The flexion deformity of the elbow was improved in all cases. Overcorrection of the flexion deformity of the wrist or fingers did not occur, but in five patients there was some undercorrection of the deformity, which is preferable to the former.\(^4\) The pronation contracture was corrected and active supination improved in all cases. A marked increase in movement of the wrist and fingers was observed at follow-up, except in the five patients with in group D.

### Discussion

The aims of operation in a child with cerebral palsy must be very specific. Pessimism concerning the results of operation on the upper limb in patients with spasticity due to cerebral palsy has generally been justified.\(^1,2\) It must be recognised that, although some improvement in function and appearance may be a realistic goal for carefully selected patients, normality cannot be achieved.\(^13\) As a general rule, the patient with spastic hemiplegia is much more suited to surgical intervention than one with spastic quadriplegia. In the hemiplegic patient, the aim of surgery is to modify the involved limb so that overall function when combined with the opposite normal side is better. Grasp, release and reach can all be improved.\(^3\) All the patients selected for this study suffered from hemiplegia.

Of the surgical procedures previously proposed for correction of flexion deformities of the fingers and wrist only two, wrist fusion and tendon lengthening, have proved useful. Each has its own problems.\(^3\) Arthrodesis of the wrist is primarily used to control position and improve hygiene in a hand with poor motor control and sensitivity. It should not be undertaken when the patient requires wrist flexion to obtain extension of the fingers and wrist extension for closure of the fingers. Goldner\(^11\) considered arthrodesis to be a last resort and to be avoided if possible. Lengthening of the tendon can be helpful when the flexion contracture is limited to one or two muscles, and if it is done at the musculotendinous junction.\(^3\) Combined lengthening of several tendons in the lower forearm has resulted in their becoming bound in scar tissue with loss of function.

Release of the FPO from the medial part of the humeral epicondyle and the proximal third of the forearm is effective for the correction of a flexion contracture of the wrist and fingers. It can also relieve a flexion contracture of the elbow and a pronation contracture. Release allows the hand and fingers to function in a more satisfactory attitude, but not to attain normal control or power.\(^3\) It is not indicated in hands which can be corrected passively but assume a flexed position during grasp.\(^4\)

The extent of release of the FPO in this study was determined by the severity of the deformity. When this was very mild only the origin of pronator teres was released, but in the most severe cases the entire FPO was freed from the medial epicondyle and the upper third of the forearm.

Transfer of FCU dorsally to a radial extensor of the wrist removes a deforming factor which pulls the hand into ulnar deviation and flexion, and provides a force which promotes supination of the forearm and extension of the wrist. In this study FCU was always transferred and combined with a selective release of the FPO. Transfer of the tendon of FCU into the extensor carpi radialis allowed patients to extend the wrist while release of the FPO prevented the fingers from flexing tightly into the palm during such extension.

<table>
<thead>
<tr>
<th>Pattern</th>
<th>Deformity of hand and wrist</th>
<th>Surgical recommendation</th>
<th>Results Function</th>
<th>Appearance</th>
<th>Number of patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Very mild</td>
<td>FCU transfer and pronator teres release</td>
<td>Good grasp and release</td>
<td>Improved 6</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Mild</td>
<td>FCU and FPO from medial epicondyle</td>
<td>Good grasp and weak release</td>
<td>Improved 15</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Moderate</td>
<td>FCU and entire release of FPO</td>
<td>Weak grasp and release</td>
<td>Improved 9</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>Severe</td>
<td>FCU and entire release of FPO</td>
<td>Ineffective movements</td>
<td>Improved 5</td>
<td></td>
</tr>
</tbody>
</table>

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The procedure improved function and cosmesis in groups A, B and C, but was of cosmetic benefit only in severe cases (group D).

Hoffer, Leham and Mitani emphasized that transfer of FCU should not be carried out in conjunction with release or lengthening of flexor carpi radialis, because it may cause a hyperextension deformity of the wrist. The child would be unable to release objects when there was primary weakness of the finger extensors.

A pronation contracture is a common problem in patients with spasticity, the offending muscle usually being the pronator teres. Treatment by distal release through a longitudinal mid-lateral incision or by redirectional transfer to act as a supinator often produces a fixed supination deformity. This did not occur with the proximal release of pronator teres origin as used in this study.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References


