PECTORAL TRANSPLANTATION FOR PARALYSIS OF THE FLEXORS OF THE ELBOW

A New Technique

D. M. BROOKS and H. J. SEDDON, LONDON, ENGLAND

From the Institute of Orthopaedics, Royal National Orthopaedic Hospital, London and Stanmore

Restoration of elbow flexion in paralytic disorders has taxed the ingenuity of surgeons for half a century. Four types of operation have emerged: 1) proximal transplantation of the flexor or extensor origins of the forearm muscles, or both; 2) transplantation of triceps to biceps; 3) transplantation of pectoralis major to biceps; and 4) transplantation of sternomastoid to biceps.

This communication is concerned solely with pectoral transplantation. The first such operation was described in 1917; Schulze-Berge transplanted the tendon of insertion of pectoralis major direct into the belly of biceps. Various modifications of this technique were later employed by Hohmann (1918), Rivarola (1928), Fritz Lange (1930) and Max Lange (1951). These authors were dissatisfied with the original method of insertion of pectoralis major into biceps and used fascia lata or strands of silk to form tendons of insertion either into the biceps tendon or into the ulna. It was not until after 1946 that the ingenious pectoral transplantation described by Clark came into general use. Clark's operation differs fundamentally from those previously described. The lower fibres, comprising the sternal origin of the muscle, are detached from the chest wall and mobilised towards the axilla as far as the nerve and blood supply will allow. The muscle mass is then passed down the arm and attached to the biceps tendon. This operation is particularly useful for patients who have suffered a traction lesion of the upper trunk of the brachial plexus because the sternal head of pectoralis major is not paralysed.

In 1952 one of us (D. M. B.) was confronted with an awkward problem. A girl of ten years was left with extensive paralysis of the upper limb after an attack of poliomyelitis. The distribution of the paralysis was such that neither Steindler's operation nor a triceps transplantation was possible. The clavicular head of pectoralis major, however, contracted strongly and caused the head of the humerus to luxate anteriorly; the sternal head was completely paralysed. At first sight it appeared a good opportunity to carry out one of the earlier techniques of pectoral transplantation. Unfortunately, the fascia lata had been removed previously for a reconstructive procedure on the shoulder. To overcome this difficulty the long head of biceps was converted into a "tendon" by the technique to be described.

THE CONVERSION OF DENERVATED MUSCLE INTO TENDON

At this time we were interested in the changes occurring in muscle as a consequence of ischaemia. One of these changes, due to subtotal ischaemia, is an intense fibrosis which converts muscle into something resembling tendon. We wondered whether this usually noxious change could be put to good use where, as in the transplantation under consideration, a completely fibrotic biceps was likely to be more useful mechanically than a denervated muscle that might stretch under the action of the pectoral transplant. It was surgically feasible to devascularise the long head of biceps; but would denervated muscle respond in the same way as normal muscle? Denervated muscle always becomes more or less fibrous and it therefore seemed reasonable to attempt to hasten the process by deliberately reducing its blood supply.
FIG. 1
Denervated muscle two months after surgical devascularisation. (× 130.)

FIG. 2
Denervated muscle fifteen months after surgical devascularisation. (× 205.)
If the long head of the biceps is detached from its origin and completely mobilised, it must depend for its blood supply on vessels in its tendon of insertion, although later it may be partly revascularised from its tissue bed. We have found that this blood supply is sufficient to prevent necrosis of the muscle but induces its conversion into what amounts to tendon. It has twice been possible to examine the devascularised long head of biceps, at two and fifteen months from the time of operation. In the tissue removed at two months, Dr H. A. Sissons found no muscle fibres that were necrotic, but most showed advanced atrophy and there was pronounced fibrosis of the muscle; a few muscle fibres of normal size remained. The biopsy material removed at fifteen months consisted of a single piece of white tough fibrous tissue which proved on microscopy to be dense collagenous tissue indistinguishable from normal tendon without any clear evidence that it derived from muscle (Figs. 2 and 3). The practical significance of this treatment of the biceps muscle is obvious. It provides a useful means of bridging the gap between the detached tendon of pectoralis major and the tuberosity of the radius.

THE OPERATION

Incisions—Two incisions are made (Fig. 4): one extends from the lower end of the deltopectoral groove down to the junction of the uppermost and middle thirds of the arm; the second incision is L-shaped and situated over the antero-medial aspect of the elbow.

Technique—Through the first incision the insertion of pectoralis major is detached as close to the bone as possible (Fig. 5). The muscle is mobilised from the chest wall by blunt dissection towards the clavicle. The deltoid is then retracted laterally and upwards to allow exposure of the tendon of the long head of biceps running upwards into the shoulder joint. This tendon is severed at the upper end of the bicipital groove and withdrawn into the wound (Fig. 6). The belly of the long head of biceps is freed from the short head by blunt and sharp dissection and all vessels entering the muscle belly are ligated and divided. By retraction it is possible to mobilise the muscle belly to the lowest third of the arm. The remaining neurovascular connections are divided so that the tendon and muscle are completely free down to the tuberosity of the radius. The whole of the long head is then withdrawn through the lower incision (Fig. 7). It will often be found that in long-standing paralysis the muscle belly is adherent to the overlying fascia and sharp dissection is required to free it. Until this has been done it may not be possible to flex the elbow by traction on the proximal tendon of the long head. The long head of biceps is then replaced and its tendon, now visible through the upper incision, is passed through two slits in the tendon of pectoralis major and looped on itself so that the proximal tendon can be brought down again into the distal incision (Fig. 8). The proximal tendon is then buttonholed into the distal tendon with the elbow acutely flexed. Silk stitches are inserted.
FIG. 4
The skin incisions.

FIG. 5
Detachment of the insertion of pectoralis major.

FIG. 6
Exposure of the long head of biceps which is severed proximally.
at the level of the tendon of pectoralis major and at the distal junction of the tendons. The incisions are then closed.

**Post-operative treatment**—A plaster back slab is retained for three weeks. At the end of this time re-education is started, but care should be taken to extend the elbow gradually so that active flexion above the right-angle position is maintained. It may be two to three months before full extension of the elbow is possible.

**RESULTS**

This technique has been employed on eight occasions and in two further cases a slight modification has been used: the tendon of pectoralis major was sutured directly to the long head of biceps after it had been mobilised, the practical difference being that the tension under

* These results differ from those reported by Segal, Seddon and Brooks (1959). Two additional cases are included here, one of arthrogryposis, and the assessment of results was made at a later date. Two of the failures reported by Segal et al. were due to simultaneous action of the transplant and the triceps; these were converted into good results (Cases 5 and 9) by transplantation of the triceps into the biceps tendon.
which the transplantation was done was probably less than in the technique described. The results in the ten cases are summarised in Table I. Five patients had suffered a traction lesion of the brachial plexus; there were four cases of poliomyelitis and one of arthrogryposis multiplex. Re-education sometimes included faradic stimulation of the transplant. The

average duration of post-operative observation was about two and a half years. There have been three excellent results—that is, with active flexion against resistance through a useful range of movement. There were three good and two fair results; in the good and fair results either the range of active flexion did not equal that of passive flexion or the power of flexion was against gravity but not resistance. There were two complete failures, both due to the pectoralis

\[\text{TABLE I}\]

CLINICAL DETAILS AND RESULTS IN TEN CASES

<table>
<thead>
<tr>
<th>Case number</th>
<th>Sex</th>
<th>Age (years)</th>
<th>Disease</th>
<th>Arthrodesis of shoulder</th>
<th>Duration of paralysis (years)</th>
<th>Duration of post-operative observation (years)</th>
<th>Range of flexion</th>
<th>Power of flexion (M.R.C. grading)</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F</td>
<td>15</td>
<td>Poliomyelitis</td>
<td>No</td>
<td>7</td>
<td>5</td>
<td>30–full to 30–135</td>
<td>4</td>
<td>Excellent</td>
</tr>
<tr>
<td>2</td>
<td>F</td>
<td>18</td>
<td>Poliomyelitis</td>
<td>Yes (before)</td>
<td>7</td>
<td>3</td>
<td>20–120 to 20–100</td>
<td>3</td>
<td>Good</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>30</td>
<td>Poliomyelitis</td>
<td>No</td>
<td>1</td>
<td>2</td>
<td>30–140 to 30–90</td>
<td>2</td>
<td>Failure</td>
</tr>
<tr>
<td>4</td>
<td>F</td>
<td>15</td>
<td>Poliomyelitis</td>
<td>Yes (after)</td>
<td>15</td>
<td>1</td>
<td>45–full to 45–135</td>
<td>3½</td>
<td>Excellent</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>24</td>
<td>Brachial plexus injury</td>
<td>Yes (after)</td>
<td>2</td>
<td>4</td>
<td>20–120 to 20–90</td>
<td>4</td>
<td>Good* (combined)</td>
</tr>
<tr>
<td>6</td>
<td>M</td>
<td>26</td>
<td>Brachial plexus injury</td>
<td>No</td>
<td>2</td>
<td>3</td>
<td>30–130 to 30–90</td>
<td>3</td>
<td>Fair</td>
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<tr>
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<td>F</td>
<td>16</td>
<td>Brachial plexus injury</td>
<td>No</td>
<td>1</td>
<td>3</td>
<td>30–full to 30–full</td>
<td>4½</td>
<td>Excellent</td>
</tr>
<tr>
<td>8</td>
<td>M</td>
<td>21</td>
<td>Brachial plexus injury</td>
<td>No</td>
<td>2</td>
<td>3</td>
<td>30–130 to 30–90</td>
<td>3</td>
<td>Fair</td>
</tr>
<tr>
<td>9</td>
<td>M</td>
<td>22</td>
<td>Brachial plexus injury</td>
<td>Yes (after)</td>
<td>2</td>
<td>1</td>
<td>45–135 to 45–90</td>
<td>4</td>
<td>Good* (combined)</td>
</tr>
<tr>
<td>10</td>
<td>M</td>
<td>9</td>
<td>Arthrogryposis multiplex</td>
<td>No</td>
<td>9</td>
<td>3</td>
<td>35–full to 35–60</td>
<td>3</td>
<td>Failure</td>
</tr>
</tbody>
</table>

* Triceps transplantation performed subsequently.
Fig. 11
Result of transplantation of the clavicular portion of pectoralis major by
the method described.

Fig. 12
The girl can lift a weight of 4 lb. 11 oz. Control of the shoulder is normal.
major's being too weak. In one, a child with arthrogryposis, the pectoralis muscle was seen to be very flimsy at operation, and in the other, a patient with poliomyelitis, the strength of the muscle was over-estimated.

If the shoulder can be stabilised, either by muscular control or by arthrodesis, the power of a pectoral transplant is greatly enhanced because it acts only on the elbow (Figs. 9 and 10). In the case illustrated in Figures 11 and 12 there was an irreparable lesion of the musculocutaneous nerve and paralysis of the lower part of pectoralis major; all other shoulder muscles were normal and the result of the transplantation was probably the best in the series. In cases 4, 5 and 9 an arthrodesis of the shoulder was subsequently performed with good effect. In Case 1, however, the result was excellent in spite of a flail shoulder. In Cases 5 and 9 a triceps to "biceps" transplantation was subsequently necessary owing to simultaneous action of the pectoralis major and the triceps—a phenomenon frequently encountered in brachial plexus lesions and due to axonal confusion during regeneration.

CONCLUSION

We believe that this technique has several advantages. After poliomyelitis recovery in the clavicular head of pectoralis major may exceed that in the sternal head; there may be considerable but incomplete recovery in both heads and it is then desirable to use all the active muscle available. Girls and women dislike conspicuous scars; the incisions used in this technique are unobtrusive when the arm is by the side.

REFERENCES


