Treatment of Established Volkmann's Contracture*

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The disease first described by Volkmann in 1881 is generally considered to result from spasm of the main arteries of the forearm and their branches as a consequence of trauma to the elbow or forearm. The severe and prolonged but incomplete interruption of arterial blood supply, together with venostasis, produces acute ischemic necrosis of the flexor muscles. The most marked ischemia occurs in the deeply situated muscles such as the flexor pollicis longus and flexor digitorum profundus, but severe ischemia is evident in the pronator teres and flexor digitorum superficialis muscles, and comparatively mild ischemia occurs in the superficially located muscles such as the wrist flexors. The muscle degeneration which follows is most marked in the middle of the forearm and its extent decreases peripherally, so that a so-called ellipsoid-shaped infarct, as described by Seddon, may be the end result.

The causes of nerve paralysis occurring during the early phase of the disease are ischemia and mechanical compression of the nerve by edema, while during the later phases compression is caused by a constricting cicatrix. The median nerve which lies near the center of the necrotic muscles is usually more severely involved than the ulnar nerve, which is peripheral to those muscles.

Some areas of the necrotic muscles regenerate but others heal by fibrosis, which gradually causes a contracture. This contracture, due to scarring, may be superimposed on paralysis of the intrinsic muscles resulting from nerve paralysis, and a deformity of varying degree is the result.

The treatment of Volkmann's contracture in its late stages has variably included one or more of the following: lengthening of the flexor tendons, shortening of the bones of the forearm, arthrodesis of the wrist, excision of the carpal bones, reconstruction of lost function by tendon transfer with excision of all irreparably damaged muscles, and the muscle-sliding operation.

Clinical Material

During the past eighteen years, I have treated sixty-nine cases of contracture of the forearm muscles and two of contractures of both forearm and hand muscles, totaling seventy-one cases. Interval from injury to being seen at our institution ranged from thirty-three days to twenty years.

The cases are divided into three groups according to the extent of the disease: mild, moderate, and severe. In the *mild* type, also called the localized type, there was degeneration of part of the flexor digitorum profundus muscle, causing contractures in only two or three fingers. There were hardly any neurological signs, and when present they were minimum. In the *moderate* type, the muscle degeneration involved all or nearly all of the flexor digitorum profundus and flexor pollicis longus, with partial degeneration of the superficial muscles as well. The neurological signs were invariably present and generally the median nerve was more severely affected than the ulnar nerve. In the *severe* type, there was degeneration of all the flexor muscles with necrosis in the center and also varying degrees of degeneration of the extensor muscles. The neurological signs were severe. In this group are included old cases with marked joint contractures, cicatrization of the skin, and deformities of bone. The unsuccessful surgical cases are also included in this group. The breakdown of the seventy-one cases of contracture of the forearm muscles show that twenty-seven were mild, twenty-one were moderate, and twenty-three were severe.

Mild Type

The mild cases can be further classified into three groups: (1) twenty-two in which the affected site was in the middle one-third of the forearm — the common type; (2) three in which the proximal one-third of the forearm was involved — the proximal type; and (3) two in which the distal one-third was involved — the distal type. The common-type subgroup contained cases with varying degrees of contracture. When the muscle degeneration was limited to part of the flexor digitorum profundus, there was contracture of the long or ring finger, or both, whereas when the area of degeneration was more extensive contractures of the long, ring, and little fingers also developed. The thumb was the last digit to be affected. Even in cases in which there was contracture of the fingers, extension was possible when the wrist was in the flexed position.

The classification according to the fingers affected in the mild group was: ring finger — two cases; long and ring fingers — ten; long, ring, and little fingers — five; and index, long, ring, and little fingers — five.

Classification of the mild cases according to the injury received (Table I) showed that about half of the cases were due to contusion and crush injury of the forearm, while only four were due to supracondylar fracture. Another point of interest was that the largest number of

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TABLE I

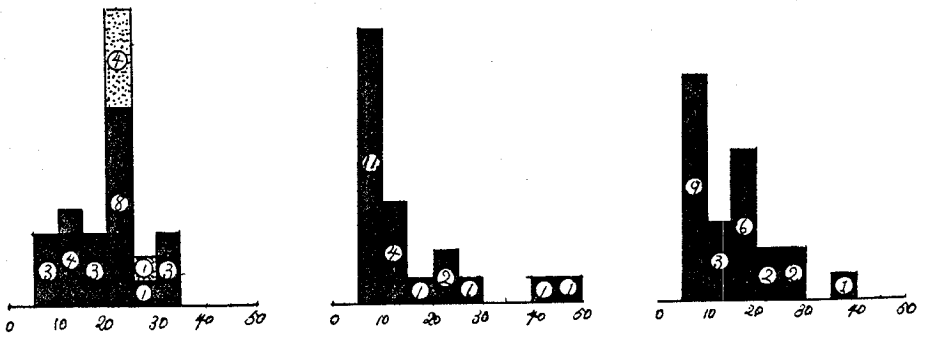
	Fractures and Dislocations				Soft-Tissue Injury			
	Supracondylar	Lateral Condyle	Forearm	Elbow	Crush Injury	Abscess	Injections	Misc.
Mild	4	1	3		14	2	2	1 (overdose of sleeping pills)
Moderate	13*	1	3	2†	2			
Severe	13*		4	1	2			3 (overdose, cardiac surgery)

* Includes supracondylar fractures with concomitant forearm fracture.
† Elbow dislocations with forearm fracture.

cases was found in the twenty to twenty-five-year-old age group (Fig. 1). These findings differ greatly from those of the moderate and severe types. In those cases, the commonest injury was supracondylar fracture of the humerus and the age group most affected was under ten years. The listing of intervals between injury and treatment (Table II) showed that in some cases (mostly mild ones) consultation was delayed until several years after injury because the patient sustained the injury during childhood and only with skeletal development did deformity become pronounced.

The treatment of the mild type of contracture when the time interval after injury is less than a month is a combination of dynamic splinting, physical therapy, and functional training, and good results can be expected. In older injuries surgery is usually indicated. When the contracture involves only one or two fingers and the extent of muscle degeneration is comparatively limited, dissection or excision of the affected area will suffice. When, however, degeneration is extensive and there is contracture of three or four fingers, a muscle-sliding operation is indicated. Excision of cicatricial contracture was performed in four of our cases, while a flexor muscle-sliding operation [1,2] was performed on the rest.

The sliding operation is performed by releasing the flexor muscles from their origins. The flexor muscles attached to the interosseous membrane also are released. The release is performed while the fingers are extended from time to time to determine the degree of improvement, but care must be exercised to avoid injuring the anterior interosseous artery, vein, and nerve during these procedures. Particular attention must also be paid to avoid traumatizing the dorsal interosseous artery and vein which pass between the two bones at the central terminal of the interosseous membrane and run to the dorsal aspect. If the median and ulnar nerves pass through the scarred portion of the muscles, neurolysis should be combined with the procedure. The contractures of the hand and fingers should be almost completely alleviated. The ulnar nerve must be translocated to the anteromedial side of the elbow joint. After surgery the forearm is kept in supination, the wrist is immobilized in dorsiflexion, and the metacarpophalangeal joints are kept in slight flexion with the fingers extended for two or three weeks, after which time exercise is begun. Subsequently, the patient is instructed to use a dynamic splint. This is also effective in preventing recurrence of contracture. The results in the mild cases with the sliding operation were good (Figs. 2-A through 2-D) and there was hardly any recurrence. If there is a recurrence, it is either because the sliding operation was technically inadequate or too traumatic, or because degeneration was so extensive that the case should have been classified as moderate or severe.



Mild type (27 cases) Moderate type (21 cases) Severe type (23 cases)

Age distribution by type

Proximal and distal type

FIG. 1

The comparatively rare case of proximal and distal involvement requires a brief separate discussion. Three instances of the proximal type, in which degeneration develops chiefly in the pronator teres, were seen. The causes were crush injury in two instances and infiltration of intravenous transfusion in one. All three patients were in their twenties. The symptoms noted in all were pronation contracture of the forearm and sensory disturbance in the median-nerve distribution. The diagnosis could readily be made by palpation of localized induration. Good results were obtained by dissection of the pronator teres and neurolysis. The distal type, in which muscle degeneration occurred in the distal part of the forearm, was seen in two patients. Both patients were in their twenties, and the lesions were caused by crush injury in one and an overdose of sleeping pills in the other. The symptoms noted were contracture of the pronator quadratus and flexion contracture of the wrist. The diagnosis could be readily established by palpation of the local induration. The treatment procedures in both cases were tenolysis, neurolysis, and dissection of the pronator quadratus. Good results were achieved.

Generally, the prognosis is favorable in mild cases, including the proximal, distal, and middle types.

Moderate Type

Twenty-one cases in this group were seen. The symptoms were an intrinsic-minus claw hand with flexion contracture of all digits, sensory disturbance in the median and ulnar-nerve distributions, and intrinsic-muscle paralysis. The injury causing the Volkmann's contracture in these cases was supracondylar fracture (eleven cases), but other fractures or dislocations of the elbow also occurred in all but one case. The age at injury in most cases was between five and ten years. The majority of the patients were treated within one year of injury. The methods of treatment we used in lesions of the moderate type were: the muscle-sliding operation (fourteen cases), tendon transfer (seven), and sliding operation followed by tendon transfer (one).

Because muscle degeneration is more extensive in the moderate case than in the mild one, it affects not only the deeply situated muscles such as the flexor pollicis longus, but also such superficial muscles as the wrist flexors. Therefore, the area requiring muscle release has to be more extensive: it is also necessary to detach the flexor pollicis longus and the pronator teres from the radius. It is difficult to release these muscles from the radius by approaching them from the ulnar side and reaching beyond the interosseous membrane with a periosteal elevator, and there is a high risk of crushing the tissue and also injuring the anterior interosseous artery, vein, and nerve. It is therefore desirable to strip the flexor pollicis longus and the pronator teres through an additional periosteal incision between the brachioradialis and the flexor pollicis longus and pronator teres. The interphalangeal joint of the thumb should be extended from time to time during the procedure, thus ensuring that the thumb extends fully. It should be possible to advance all of the flexor muscles three to four centimeters by this procedure, and then neurolysis and dissection of scar tissue can be performed to release the median nerve. Release of the ulnar nerve is performed through the first incision made on the ulnar side. The postoperative treatment is as described earlier for the mild type. The merits of the muscle-sliding operation are as follows: (1) the procedure is comparatively simple, (2) the

TABLE II

INTERVAL BETWEEN INJURY AND TREATMENT

	<3 Mos.	3-6 Mos.	7-12 Mos.	1-2 Yrs.	3-5 Yrs.	5-10 Yrs.	>10 Yrs.
Mild	8	4	4	3	1	2	5
Moderate	5	4	6	2	1	3	0
Severe	2	9	4	5	1	0	2

FIG. 2-A

FIG. 2-B

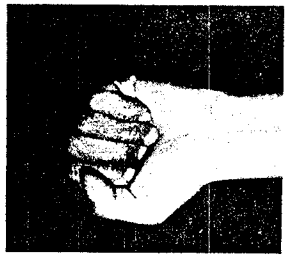


FIG. 2-C

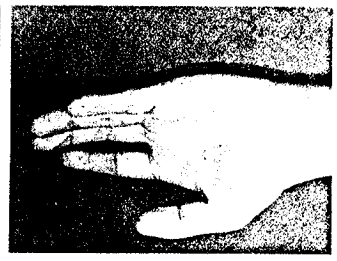


FIG. 2-D

Figs. 2-A through 2-D: Twenty-two-year-old man. Gradual flexion contracture of the long, ring, and little fingers developed after contusion on the volar aspect of the forearm six months prior to the patient's initial visit. There is slight sensory disturbance in the ulnar area.
Fig. 2-A: Preoperative photograph.
Fig. 2-B: When the wrist is in the flexed position, extension of the fingers is possible.
Figs. 2-C and 2-D: Finger extension and flexion one year after muscle-sliding operation.

FIG. 3-A FIG. 3-B FIG. 3-C FIG. 3-D

Figs. 3-A through 3-D: Five-year-old girl, five months after supracondylar fracture. Chief complaints were marked flexion contracture of all fingers, complete loss of sensation, and total paralysis of intrinsic muscles. First operation consisted of excision of all flexor muscles and neurolysis of the median and ulnar nerves. With restoration of extensor-muscle power, sensation of hand, and function of intrinsic muscles, transfers of the brachioradialis to the flexor pollicis longus and of the extensor carpi radialis longus to all profundus tendons through the interosseous membrane were performed as a secondary operation seven months later.

Fig. 3-A: Preoperative photograph.

Fig. 3-B: Findings seven months after first operation. Function of intrinsic muscles has been well restored.

Figs. 3-C and 3-D: Finger extension and flexion two years after secondary operation.

total procedure can be completed in one operation, and (3) it is possible to perform tendon transfer as a secondary procedure. Recently we have used this procedure for a wider range of indications. However, there are disadvantages, such as: (1) some scar tissue is left; (2) there is a risk of recurrence of contracture with growth of the bone, and (3) there is a decrease in strength of grip, in particular in flexion of the distal interphalangeal joint. However, if the muscle-sliding operation has been performed adequately and postoperative procedures such as dynamic splints are used correctly, the risk of recurrence of the contracture is not great and good recovery of sensation and intrinsic-muscle function are usually attained, particularly in young patients.

However, when the extent of muscle degeneration is severe, even though the deformity can be corrected by the sliding operation the grip strength will be markedly decreased and in particular the power in flexion of the distal interphalangeal joint will suffer. In such cases, therefore, tendon transfer should be considered as a simultaneous procedure with excision of the degenerated muscle and neurolysis or as a secondary procedure.

The decision as to whether tendon transfer should be performed immediately after excision of necrotic muscle or as a separate procedure should be made on the merits of each case. If transfer sources are readily available, however, and there is minimum joint contracture, transfers should be done to the flexor pollicis longus and the four flexor digitorum profundus tendons immediately, and the flexor digitorum superficialis tendons from the wrist distally should be excised. However, in old cases with severe contracture or when the extensors have to be used as the motor for the transfer, the primary procedure should be limited to excision of the necrotic muscles and neurolysis. Five or six months after the joint contractures have been eliminated, the tendon transfer should be performed. Maximum recovery of strength of the extensors at their altered length will then have been attained. Excision of the flexor digitorum superficialis tendons distal to the wrist normally is performed not at the time of the primary surgery but at the time of tendon transfer, because then partial tenolysis of the profundus tendons can also be done and less adhesion of the profundus tendons will occur than if the superficialis had been excised initially.

Using these procedures for the moderate cases, as described, it was possible to obtain satisfactory results in recovery of sensation and function.

Severe Type

The most common cause of the severe type of Volkmann's contracture was supracondylar fracture (Table I), followed in frequency by fracture and crush injury of the forearm. The age distribution (Fig. 1) shows that this type of case is most frequent in the younger age group. The majority of our cases were seen within one year after injury. These findings correspond to those in patients with moderate involvement.

The treatment of severe contracture with extensive muscle degeneration in a child seen within a few months of injury, early excision of the degenerated muscles and

FIG. 4-A FIG. 4-B FIG. 4-C

Figs. 4-A, 4-B, and 4-C: Thirty-eight-year-old man. Volkmann's contracture is believed to have developed after prolonged pressure on the hand following an overdose of sleeping pills one year and four months prior to being seen at this institution. Lengthening of the flexor tendons had been performed elsewhere with poor results. Flexor tenodesis and intermetacarpal fusion in thumb opposition were performed after excision of the necrotic muscles.

Fig. 4-A: Findings at time of initial visit.

Figs. 4-B and 4-C: The state of automatic finger extension and flexion three years after surgery.

neurolysis should be performed to restore sensation and function of the intrinsic and extensor muscles. Restoration of function should be performed by tendon transfer as a secondary procedure. The time for the primary procedure is difficult to determine but it probably should be done when bone union of any fracture is almost complete and when vesicle formation in the skin has resolved. Usually the necrosis is extensive in such cases and a yellowish, pulpy mass can be seen in the center of all of the flexor muscles. As much as possible of this is excised, but special care should be taken to spare the nerves and vessels. In particular, it is better to leave some scar in the periphery of the muscles than to disturb the circulation in an attempt to make removal complete.

The median and ulnar nerves released by this procedure should be placed where good blood circulation is available. If there is severe scarring of the skin on the volar aspect of the forearm, a pedicle skin graft may be performed immediately. The decision of when to perform the secondary operation should depend on the recovery of sensation in the hand and the function of the intrinsic and extensor muscles. In many cases the secondary procedure will be performed six months or more after the primary operation.

The brachioradialis or wrist extensors are frequently selected as the motors and are transferred to the flexor pollicis longus and the profundus of the four fingers. The superficialis tendons are excised at this time.

However, in old cases in which there is severe joint contracture, no hope for nerve regeneration, and the nerves are totally degenerated and present a cord-like appearance, or when a motor is not available because of degeneration or marked atrophy of the extensors, consideration should be given to a combined procedure of flexor tenodesis and intermetacarpal fusion with the thumb in opposition.

When the patient has a severe crush injury with damage to the median and ulnar nerves, intrinsic-minus deformity due to nerve paralysis and flexion contracture of the fingers may occur, and the patient will have a Volkmann-like contracture. Although this type of case is slightly different from Volkmann's ischemic contracture in the true sense, there were a few patients in our series with these findings. In such cases, correction of the deformity by excision of the scar and pedicle graft must be considered, while for treatment of the nerves, nerve grafts or nerve-pedicle grafts should be considered as a secondary procedure, but good results cannot be considered likely.

Generally, in patients with severe contractures, even when nerve grafts are substituted for nerves which have developed a cord-like appearance there is so much scarring, the circulation is so poor, and the likelihood of success is so small that the procedure cannot be recommended.

The surgical procedures performed in the twenty-three severe cases were: pedicle graft (nine cases), tendon transfer (seven), tenodesis (four), intermetacarpal fusion in thumb opposition (three), arthrodesis of the wrist (two), resection of the scarred muscle (two), nerve-pedicle graft (two), and osteotomy (one).

Treatment of the severe case is very difficult. If the conditions are comparatively good, tendon transfer should be considered after early excision of the necrotic muscle and when there has been some recovery of the nerves and extensor motor power. However, there were a few old cases in which we had to be satisfied with mere correction of the deformity.

Conclusion

Volkmann's contracture can be classified into three types on the basis of clinical findings relating to the severity of the process. For the mild type, dissection of the scarred muscle and a flexor muscle-sliding operation produces favorable results. For the moderate type, treatment with a flexor muscle-sliding operation is a good procedure in most cases, but when the neurological deficit is severe and muscle degeneration is marked, tendon transfer should be performed after dissection of the necrotic muscles and neurolysis. Even in the severe type, if the conditions are comparatively good tendon transfer can be considered, but there are also quite a number of patients who will have to be satisfied with such procedures as tenodesis and mere correction of the deformity. In general, the more severe the contracture the earlier surgery should be performed.

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