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Electrophysiological and histological changes in extrinsic muscles proximal to post burn contractures of hand

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ABSTRACT

Burn scar hand contractures of variable degree are frequently encountered. Although the forearm is apparently spared, it was clinically observed that there was disuse atrophy in the unburnt extrinsic forearm muscles. Usually the clinicians do not give much importance to this fact. The girth at the midforearm was significantly reduced as compared to normal side. The flexion of the hand joints are governed by two components (a) intrinsic and (b) extrinsic muscles. The intrinsic muscles are directly involved in the contracted tissue. Therefore it was thought essential to evaluate the extrinsic group of muscles for their contribution in the final functional recovery following corrective surgery. Thirty patients having unilateral post thermal burn contracture sparing forearm were studied.

A detailed clinical evaluation was made including grade of contracture and reduction in the forearm girth. The forearm unburnt muscles were evaluated by preoperative electrophysiological studies. Intraoperative biopsies were taken from these muscles for histopathological examination.

On histopathological examination, there were significant abnormal changes in the form of muscle fiber atrophy, fibrolipomatous tissue replacement of atrophic muscle fibers and sarcolemmal changes. These changes were directly proportional to the severity of contractures. The electrophysiological studies showed proportionate changes in the form of reduction in amplitude, duration and interference. This study suggests that if these changes are mild and in reversible stage, they will favourably affect the functional recovery following surgery. However if these changes are of severe grade and irreversible, in spite of adequate surgery, splinting and physiotherapy, the functional recovery may not be complete.

1. Introduction

Burn scar contractures of hand are frequently encountered in plastic surgery. It was clinically observed that extrinsic muscles in the forearm proximal to the contracture undergo variable degree of atrophy depending upon the severity of contracture. Since the dynamic status of these extrinsic proximal muscles have significant role in various movements of the hand, this may proportionately affect the functional recovery following release of contracture, resurfacing and postoperative physiotherapy.

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2. Aims

The aim of this study was to find out the adverse changes in the muscles proximal to the post burn contracture of the hand. They have significant role in maintaining the functional status. The clinical parameters were age, gender, severity of contracture and atrophy of the forearm muscles. The investigative procedures were histopathology and electrophysiological studies of the muscles. The correlation of these parameters was significant to evaluate the magnitude of damage to these muscles due to prolonged disuse.

3. Materials and methods

Thirty cases (18 male; 12 female) of burn scar contracture involving the hand and wrist were studied between September 2008 to February 2010. All the cases were having flexion contracture following thermal burn of more than one year duration. Cases with unilateral involvement of hand and wrist were only included so that the findings could be compared with the normal side. According to the severity of contracture, the cases were divided into mild, moderate and severe categories. Patients with any pre-existing bony abnormality or myoneural disease were excluded from the study. Written informed consent was taken from the patients. The work has been approved by the ethical committee of our institute.

Clinically the midforearm girth was measured from fixed bony landmark and compared with the normal limb. The girth measurements were taken at midforearm 7.5 cm from the tip of olecranon on the normal and affected side.

The contractures were graded in the following manner:

Mild: Contractures up to 30 degree involving three or more fingers distal to the metacarpophalyngeal (MP) joint with involvement of proximal interphalyngeal (PIP) joint and distal interphalyngeal (DIP) joint which could be passively brought to full extension.

Moderate: 30–60 degree contracture involving the MP, PIP and DIP joints of fingers including palm that could not be completely extended passively. These were associated with/without dorsal subluxation or dislocation of joints with radiological evidence. Some of them had multiple syndactylised webs.

Severe: More than 60 degree contracture with multiple joint involvement of fingers, palm and wrist. Majority of the joints were markedly stiff and associated with reduced joint space, subluxation or dislocation. There was also associated hypertrophic scarring and syndactylised web. The authors also highlighted the changes in the bones and joints of postburn contractures by macroradiographic study [1].

Nerve conduction studies were carried out on median, ulnar and radial nerves. Motor nerve conduction studies were carried out using the belly tendon montage. The active recording electrode (G1) was placed on the centre of the muscle belly and the reference electrode (G2) distally over the muscle tendon (3–4 cm distal). The stimulator was placed on the nerve to the muscle with the cathode placed closest to recording electrode.

Sensory nerve conduction studies were carried out using the orthrodromic technique. Active electrodes were placed over the wrist and the stimulation was carried out over the index finger for median nerve and over little finger for the ulnar nerve. For the median nerve G1 was placed over abductor polices brevis and G2 over first metacarpophalyngeal joint. Stimulation sites for the median nerve was at the middle of wrist, between the tendons to the flexor carpi radialis and palmaris longus and at the antecubital fossa, over the brachial artery pulsation. For ulnar nerve, G1 was placed over the abductor digiti minimi and G2 over the fifth metacarpophalyngeal joint. The stimulation sites were at medial wrist, adjacent to flexor carpi ulnaris tendon and below elbow, 3–4 cm distal to the medial epicondyle. For radial nerve, the hand was kept in prone position. The active G1 was placed two finger breadths proximal to the ulnar slyloid over the extensor indices proprius muscle and G2 was over ulnar styloid. The stimulation sites were at the forearm, over the ulnar, 4–6 cm proximal to G1 and at the elbow, in the groove between biceps and brachioradialis muscle. The nerve conductions were performed over both upper limbs with our lab standards used as reference value. The opposite normal limb served as the control.

4. Electrophysiological study

A detailed neurological examination was carried out with special attention to muscle wasting, reduced tone and muscle power of proximal unburnt forearm muscles. Patients were evaluated with nerve conduction studies of the median, ulnar and radial nerves (motor and sensory) followed by EMG examination of the proximal unburnt forearm muscles. The nerve conduction studies and electromyography (EMG) were also done in the opposite normal limb as control. The Dantech Keypoint EMG machine was used with a disposable concentric needle electrode at a constant room temperature of 27 °C.

A needle electrode or a needle containing two fine-wire electrodes was inserted through the skin into the muscle. A trained professional observed the electrical activity while inserting the electrode. The insertional activity provides valuable information about the state of the muscle and its innervating nerve. Normal muscles at rest make certain normal electrical sounds when the needle is inserted. This signifies the electrical activity of the muscle at rest. Abnormal spontaneous activity might indicate some nerve and/or muscle damage. Then the patient was asked to contract the muscle smoothly. The shape, size, and frequency of the resulting motor unit potentials were judged. Then the electrode was retracted a few millimeters, and again the activity was analyzed. Such 10–20 units were collected. Each electrode track gives only a very local picture of the activity of the whole muscle. Because skeletal muscles differ in the inner structure, the electrode has to be placed at various locations to obtain an accurate study.

Muscle tissue at rest is normally electrically inactive. After the electrical activity caused by the irritation of needle insertion subsides, the electromyograph should detect no

abnormal spontaneous activity i.e., a muscle at rest should be electrically silent. The exception is the area of the neuromuscular junction, which under normal circumstances, is spontaneously active. When the muscle is voluntarily contracted, action potentials begin to appear. As the strength of the muscle contraction is increased, more and more muscle fibers produce action potentials. When the muscle is fully contracted, there should appear a disorderly group of action potentials of varying rates and amplitudes (a complete recruitment and interference pattern). Any change in amplitude, duration, recruitment and interference pattern was noted carefully.

5. Histopathology

At the time of corrective surgery of the hand, muscle biopsies measuring 1 cm × 1 cm were taken from the unburnt proximal flexor compartment of midforearm. Both longitudinal and transverse sections were fixed and stained by haematoxyline and eosine. The microscopic changes were evaluated under low power (LP, 10×) and high power (HP, 40×).

Histopathology sections were examined for atrophic degeneration, intramuscular fat, intramuscular collagen, hyperplastic muscle fibers, and hypertrophic nerve fibers. Features like sarcolemmal proliferation, hyperplasia of muscle fibers and hypertrophy of nerve fibers are suggestive of attempts of regeneration.

6. Results

There were 18 male patients (60%) and 12 female (40%). The age of the patients ranged from 5 to 40 yrs with a mean age of 28.46 yrs. They were divided in groups of 5–10 yrs (4), 11–20 yrs (6), 21–30 yrs (12) and 31–40 yrs (8). The right side was involved in 22 (73.33%) patients and left side in 8 (26.66%). Clinical atrophy was measured by difference in the girth at midforearm level 7.5 cm from the tip of olecranon on the normal and the affected side. There was no difference in the girth in mild cases. With moderate grade of contractures, the difference in girth was 1.0–1.5 cm less on the affected side. In severe contractures, the affected limb showed 1.0–2.0 cm reduction in girth.

7. Electrophysiological studies

Motor studies revealed mildly reduced compound muscle action potential (CMAP) amplitude in 20 out of 30 patients. It was normal in all parameters in other 10 patients.

Sensory studies were essentially normal in all the 30 patients.

Electromyography revealed an incomplete interference pattern in 13 patients and polyphasia (5–6 phases) in 09 patients. EMG of atrophic muscles showed proportionate decrease in muscle function with increase in grades of atrophy on histopathology.

8. Histopathological studies

Out of thirty cases, histologically mild changes were noted in 06 who had mild grade of contracture, moderate changes were noticed in 10 and severe changes in 14 cases. The changes observed were reduction in size of muscle fiber, with scattered angulated fibers. Atrophic fibers were present in groups surrounded by normal fibers (Fig. 1). Some of the fibers were hypertrophic. Sarcolemmal nuclei were at the periphery, fiber necrosis and inflammatory changes were absent. Atrophic fibers beside being small in size, demonstrated lipid droplets and loss of cross striations (Fig. 2). In advance cases fat and fibrous tissue replaced the muscle fiber (Fig. 3). Changes were classified into three groups depending upon the severity:

Mild: Involvement of less than 25% muscle fibers
Moderate: 25–50% abnormal fibers
Severe: More than 50% fibers were affected

In cases of mild severity of contractures, there was no change in the girth of forearm and histology of muscles. All the 10 cases of moderate degree of contracture had decrease in the forearm girth (.5–1.5 cm). Out of them 06 had moderate

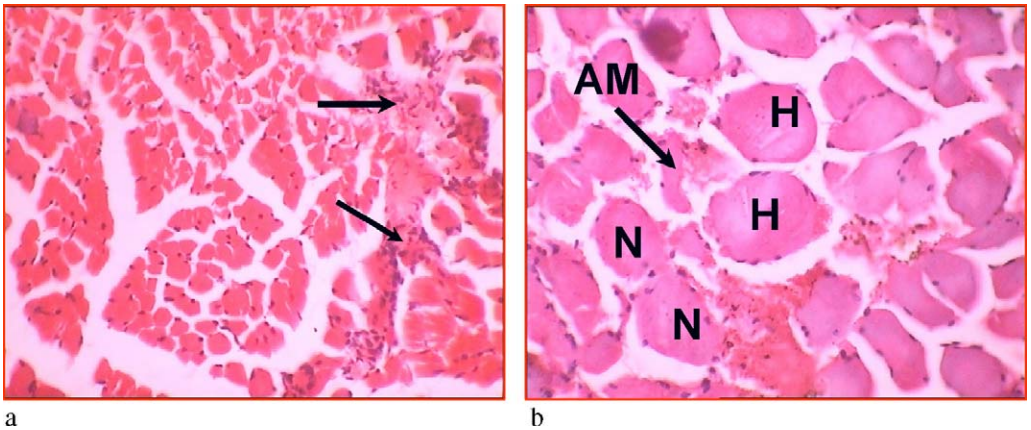

Fig. 1 – (a) Microphotograph (10×) showing groups of atrophic muscle fibers (arrows) in between normal fibers. (b) Higher magnification (40×) showing peripheral location of nuclei, hypertrophic (H) and atrophic muscle fibers (AM).

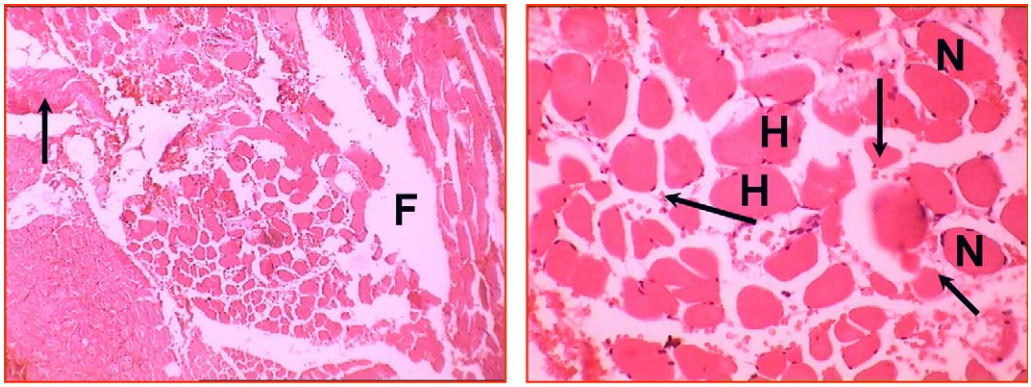

Fig. 2 – (a) Microphotograph (10×) showing atrophic muscle with increased intramuscular fat (F) and collagen (arrow). (b) Higher magnification (40×) showing large numbers of atrophic fibers (arrows), normal (N) fibers and hypertrophic (H) fibers.

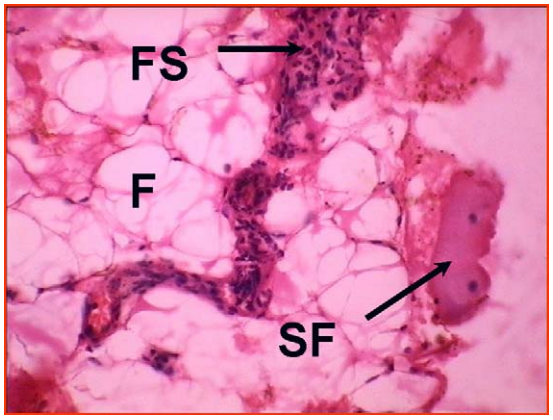

Fig. 3 – Microphotograph (40×) showing fibrolipomatous tissue replacing the atrophic muscle fibers with stray fibers (SF), fatty tissue (F) fibrous septa (FS).

histological changes and 04 had severe changes. In all the 14 cases of severe grade contracture, there was significant decrease in the girth of forearm (1–2 cm). All of them had severe grade of histological changes in the muscles (Table 1).

In 06 patients of mild grade of histological atrophy, EMG findings revealed normal amplitude, duration and interference pattern. While out of 10 moderate histological changes, there was mild decrease in CMAP amplitude in 06 patients, with normal duration and phases, and an incomplete interference pattern (IP) seen in 03 patients. In 14 patients having severe grade of atrophy, there was mild reduction in CMAP amplitude in all patients, with normal duration, polyphasia was found in 09 patients and incomplete IP in 10 patients (Table 2).

Table 1 – Correlation of clinical and histological grading.

Clinical severity	Girth		Histological grading
	Normal	Decreased	
Mild $n = 06$	06	None	Mild ($n = 06$)
Moderate $n = 10$	None	10	Moderate ($n = 06$)/severe ($n = 04$)
Severe $n = 14$	None	14	Severe ($n = 14$)

9. Discussion

Postburn contractures constitute 12% of our outpatient cases. It is much higher than international statistics of 5%. This is probably due to delay in initiation of treatment, inadequate wound management and poor compliance to physiotherapy. Such view was also expressed by Evans et al. [2]. We have included the patients who sustained thermal burn having only unilateral flexion contracture involving the hand and wrist of more than one year duration. They were of different grades of severity. During clinical examination we observed that there was decrease in limb girth of the forearm muscles proximal to the contracture. This led us to carry out this study to find out the changes in these muscles and their influence on treatment outcome. It was thought that depending on the severity of changes there might be proportionate detrimental effect on the functional recovery following corrective surgery of the

Table 2 – Correlation between histology and EMG findings.

Histology	Amplitude		Duration		Phases		IP	
	N	Abn (↓/↑)	N	Abn (↓/↑)	N	Polyphasia	N	Incomplete
Mild $n = 06$	06	00	06	None	06	None	06	None
Moderate $n = 10$	04	06 (↓)	10	None	10	None	07	03
Severe $n = 14$	None	14 (↓)	14	None	05	09	04	10

N—normal; Abn—abnormal; IP = interference pattern; ↑↓ = increase or decrease.

involved hand. Therefore, we intended to find out the correlation between the clinical atrophy of the muscles, evidenced by reduction in the forearm girth, with the electrophysiological and histological changes in these muscles. These extrinsic muscles along with the intrinsic muscles are responsible for the dynamic movement of the various joints of the hand. As per the literature, such clinical study has not been undertaken.

Histopathology of muscles revealed various atrophic changes i.e. atrophic fibers with loss of cross-striations, angulated fibers, intracytoplasmic fat vacuoles and fibrolipomatous replacement of muscle fibers besides regeneration. Features like sarcolemmal proliferation, hyperplasia of muscles are suggestive of attempts of regeneration. These findings are consistent with experimental production of disuse atrophy in animal models [3] and related human models. Kumar et al. [4] also described atrophic changes in the skeletal muscles in the form of decrease in number and size following prolonged disuse. Heffner and Balos [5] did histochemical studies of the atrophic muscles following disuse. They also demonstrated marked fibrosis and fatty infiltration as was witnessed in our study They also observed that type 2 muscle fibers are more frequently atrophied following disuse.

Six patients with mild clinical severity had normal girth of forearm muscles, mild grade atrophy and absolutely normal electrophysiological studies. In patients with moderate clinical severity ($n = 10$), forearm girth was decreased in all. Histological grading revealed moderate atrophy in 06 patients and severe atrophy in 04. Electrophysiological studies revealed decreased CMAP amplitude in 06 patients and incomplete IP in 03 patients. Patients with severe (n-14) clinical involvement revealed decreased forearm girth, severe grade of atrophy in all patients. Electrophysiology revealed reduced CMAP amplitude in all patients, polyphasia in 09 patients and incomplete IP pattern in 10 patients.

Out of 10 moderate clinical severity 04 patients had severe grade of histological changes. Whereas in all the cases of severe clinical grading there was severe grade of histological atrophy. The association of clinical severity and histological grading was significantly positive ($p = 0.003$).

Patients with mild grade of histological changes had absolutely normal EMG findings. The decreased amplitude was observed in 06 patients out of 10 having moderate histological atrophy whereas in all 14 cases of histological atrophy, there was reduction in amplitude. The statistical difference in proportion of decreased amplitude between moderate and severe histological grading was significant ($p = 0.038$). All the patients had normal duration irrespective of their histological grading. None of the cases among moderate histological changes had polyphasia. Whereas in 9 cases out of 14 with severe histological grading, there were polyphasia. The occurrence of polyphasia between moderate and severe histological grading was statistically significant (p-0.004). The incomplete IP pattern was found in 03 cases out of 10 having moderate histological changes ($p = 0.11$). Hence it was not significant. Whereas, the incomplete IP pattern was statistically significant with severe group of histological grading ($p = 0.003$).

Findings of low/absent CMAP amplitude can be found in any disorder with wasting of muscles of any etiology (neurogenic, myogenic, disuse). This is particularly relevant because if the distal muscles over which we were recording the CMAP were involved, we were bound to get an abnormal CMAP. Thus we are not implicating a neuropathy in these cases rather the disuse atrophy of muscles caused abnormal CMAP. F waves are important mainly in preganglionic lesions like GBS. Since they are 5% of CMAP they assume importance when CMAP is normal and F waves are absent, as seen with preganglionic lesions. In the present study we did not perform F waves as it was not relevant and would not have made any difference to our results.

We did not encounter any evidence of neurogenic pattern/active denneravation. Therefore we are not implicating any neuropathy in our series. Rather our findings were non specific which may be found in disuse atrophy, as has been described in literature. The amplitude in Table 2 refers to the MUAP (motor unit action potentials). In disuse atrophy we can get a varying combination of non specific abnormalities in amplitude, duration, phases or IP. The correlation between amplitude and various EMG findings showed that there was a normal EMG for mild grades of atrophy while more abnormalities were found for severe grades of atrophy.

Thus it is obvious that with increase in severity of contracture of hand and wrist, there was proportionate significant histological and electromyographical changes in the unburnt proximal extrinsic muscles. If such changes are mild and of shorter duration it may be reversible. However changes of severe grade of longer duration may be irreversible. There are few studies in the literature which have studied the elecrophysiological assessment in disuse atrophy following postburn contracture [6,7]. The movements of the various joints of the hand are modulated by intrinsic and extrinsic muscles. The intrinsic muscles may be affected directly by the burn or by the adherence of the hypertrophic scars. During the corrective surgery the scars are usually incised or excised resulting in complete release of contractures and decompression of the underlying intrinsic muscles. The involved joints are made free for future full excursion. Following this the recreated wound is resurfaced usually by split thickness skin graft. The hand is suitably splinted and physiotherapy is instituted as soon as the graft is settled. Pensler et al. [8] also thought that split skin graft is appropriate to resurface such defect. However clinicians usually ignore the status of the forearm unburnt extrinsic muscles. These muscles have significant role in the dynamics of the movements of the various joints of hand in a synchronized manner in collaboration with the intrinsic muscles.

Therefore, the abnormal changes of various degrees in the forearm muscles due to prolonged disuse may adversely affect the ultimate functional recovery of these contracted hands. It is presumed that early surgical intervention should favourably reverse these changes with full functional recovery. On the contrary, if such adverse changes persist for a prolonged period, the ultimate functional recovery may not be upto full satisfaction in spite of appropriate corrective surgery, splinting and physiotherapy.

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Conflict of interest

The authors do not have any financial and personal relationships with other people or organisations that could inappropriately influence their work.

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