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Original Article

Fasciotomy Procedures on Acute Compartment Syndromes of the Upper Extremity Related to Burns

Adem Özkan[1], Sadık Şentürk[2], Zekeriya Tosun[3]

ABSTRACT

Compartment syndrome is a serious complication of extremity burns. The goal of this study is to review cases with upper extremity compartment syndrome that had fasciotomy and to underline the significance of emergency fasciotomy procedures. The medical records of 43 patients who had fasciotomy because of compartment syndrome of the upper extremity between 2007 and 2013 were retrospectively reviewed. Etiology, age, sex, fasciotomy area, the period between the burn and fasciotomy, and treatment options were evaluated. Patients with arm, forearm, and hand or digit fasciotomy were presented. Scalding and electric were the predominant cause among all patients. While 12 patients were adults, 31 of them were children and the patients' ages ranged between 1 and 39. Defect areas formed after fasciotomy were closed with skin grafts and primary closure. Length of hospital stay in electrical burns group was significantly longer than in other burn groups (p<0.002). Burn injuries of the upper extremity are frequently seen. Most of the patients with circular burns occur compartment syndrome. Compartment syndrome is a surgical emergency requiring rapid diagnosis and treatment by urgent fasciotomy procedure. Thus, early diagnosis and adequate surgical decompression prevents function losses in the affected extremity.

Key words: *Burn, upper extremity, compartment syndrome, fasciotomy*

Üst ekstremitenin yanığa bağlı akut kompartman sendromlarında fasyotomi uygulamalarımız

ÖZET

Kompartman sendromu ekstremite yanıklarının ciddi bir komplikasyonudur. Bu çalışmanın amacı, üst ekstremite kompartman sendromu olan ve fasyotomi yapılan hastaları gözden geçirmek ve acil fasyotomilerin önemini vurgulamaktır. 2007-2013 yılları arasında üst ekstremitenin kompartman sendromu nedeniyle fasyotomi uygulanan 43 hastanın kayıtları retrospektif olarak gözden geçirildi. Etyoloji, yaş, cinsiyet, fasyotomi alanı, yanık ile fasyotomi arasındaki zaman ve tedavi seçenekleri değerlendirildi. Kol, ön kol, el veya parmak fasyotomisi olan hastalar sunuldu. Haşlanma ve elektrik en sık yanık nedeni idi. Hasta yaşları 1 ile 39 arasındaydı ve 12'si erişkin 31'i çocuktu. Fasyotomi sonrası oluşan defekt alanlar deri grefti ile ve primer kapatıldı. Elektrik yanıklarında hastanede kalma süresi diğerlerine göre anlamlı derecede daha uzundu (p<0.002). Üst ekstremitenin yanık yaralanmaları sık görülmektedir. Sirküler yanıklı hastaların çoğunda kompartman sendromu gelişmektedir. Kompartman sendromu, hızlı tanı ve fasyotomi ile tedavisi gereken cerrahi acildir. Bundan dolayı, erken tanı ve yeterli cerrahi dekompresyon etkilenen ekstremitede fonksiyon kaybını önlemektedir.

Anahtar Kelimeler: *Yanık, üst ekstremite, kompartman sendromu, fasyotomi*

[1]*Department of Plastic and Reconstructive Surgery, Pamukkale University Faculty of Medicine, Denizli,* [2]*Department of Plastic and Reconstructive Surgery, Mevlana University Hospital, Konya,* [3]*Department of Plastic and Reconstructive Surgery Selcuk University Faculty of Medicine, Konya, Turkey.*

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Correspondence: *Dr. Adem Özkan,*
Pamukkale Üniversitesi. Tıp Fakültesi Plastik, Rekonstrüktif ve Estetik Cerrahi AD. 20070 Kınıklı / Denizli
Phone: 02582965790 Fax: 0258296 17 65
E-mail: ademo@pau.edu.tr

INTRODUCTION

Compartment syndrome (CS) is a condition formed by irregularities in the function and circulation of the tissue because of the increased interstitial tissue pressure in a limited fascial area (1). This is caused by the prolonged interstitial tissue pressure brought about by blunt or penetrant trauma, infections, burns, and vascular injuries. Compartment syndromes of the upper extremity are frequently seen in the arm, forearm, and the hands, the most frequent being the forearm (2). There are also isolated compartment syndromes such as ancenous and pronator quadratus (3, 4).

In compartment syndromes, if timely diagnosis and decompression by fasciotomy are not obtained, ischemic contractures in the muscles that even lead to amputation following necrosis and nerve damage are formed (5). Therefore, fasciotomy performed with early diagnosis becomes an extremity saving procedure.

This study presents compartment syndromes of the upper extremity related to burning, our fasciotomy procedures and their results, and it underlines the significance of clinical evaluation and early intervention in fasciotomy.

MATERIAL AND METHODS

The medical records of patients, who had been admitted to the Plastic Surgery Clinics of Medical Faculty and Konya Practice and Research Hospital because of CS related to burns in the upper extremity and who had had fasciotomy between March 2007 and April 2013, were retrospectively analyzed. 11 patients who also had fasciotomy related to factors other than burns in the upper extremity were excluded from the evaluation. Statistical analysis was performed with Chi-Square test. Comparisons were considered statistically significant at the $p<0.05$

The patients were evaluated through parameters as the cause of burn, age, sex, fasciotomy area, fasciotomy hour, defect closing period, closing method, and hospitalization period. Compartment syndrome diagnoses were clinically obtained. All the cases had full dermatomy and fasciotomy under general anesthesia. 2 types of volar incision were used in forearm fasciotomy procedures (Figure 1A). The dorsal, volar, and the adductor compartment of the thumb in the hand were freed by two longitudinal incisions passing through the 2nd and 4th metacarpi in the dorsal of the hand (Figure 1B). The non-dominant sides were used in finger fasciotomies (Fig. 1C). Cutaneous nerves and veins were preserved. Guyon's canal and carpal tunnel were decompressed in patients with symptoms of ulnar and median nerve dysfunction.

The defective areas formed after fasciotomy were closed by skin grafts following local wound care or they were primarily closed in appropriate cases. The patients were followed for a period of about 4 to 11 months (mean 7.5 months).

RESULTS

A total of 43 patients had fasciotomy 27 of these patients were male and 16 were female. The patients' mean age was 11.8 years old. All patients were categorized with regard to age into two groups : preschool (0-7 years of age) and postschool (8 years of age and after years)

All patients were categorized according to aetiology into four groups: scalding, flame, electric and chemical. The causes of burns in the cases were found to be hot water in 16 patients (37%), electric current in 15 (35%), flame in 7 (16%), and chemical burn in 5 (12%). Scalding most common caused in preschool ($p<0.002$). Electric predominated in postschool ($p<0.014$).

Fasciotomy procedures were performed on the forearm in 13 cases, on the forearm and the hand dorsal in 11, on the forearm, hand dorsal, and the digits in 7, on the hand dorsal only in 4, on the hand dorsal and the digits in 4, and on the whole upper extremity in 4.

The average fasciotomy time was 5.3 hours following trauma. The defective areas formed after fasciotomy were closed on average day 10. While graft repair alone was performed on 20 of the patients, primary and graft repair were done in 12, primary repair were done in 4, and 4 were left to secondary healing. Two patients received forearm level amputation while one had above-elbow amputation (Total 43 case). The amputation rate was 0.6% in all patients. The average hospitalization period was 14 days. Length of hospital stay in electrical burns were 21.4 days. Hospitalization time in electrical burns group was significantly longer than that in other burn groups ($p<0.002$). Length of hospital stay in scald burns group was significantly lower than other burn groups ($p<0.001$). There were no significant relation between the age groups and hospitalization period ($p=0.39$). Patients' features are summarized in Table 1.

***Table 1**. Features of patients*

Patient No	Sex/Age	Aetiology	Fasciotomy Place	Trauma-Fasciotomy Time (Hour)	Reconstruction Type	Fasciotomy-Reconstruction Time (Day)	Hospitalization Period (Day)
1	M/7	Scald	FA	3	STSG	8	12
2	F/3	Scald	FA	4	Secondary	10	8
3	F/2	Flame	FA+DM	5	FTSG	12	17
4	F/5	Electric	FA+DM	3	STSG	14	22
5	F/18	Flame	FA	5	STSG	7	13
6	M/13	Electric	FA+DM	4	STSG	15	23
7	F/5	Scald	FA	2	Secondary	13	10
8	F/11	Electric	FA+DM	3	STSG	10	16
9	M/8	Flame	DM	4	STSG	12	17
10	M/6	Electric	FA	5	STSG	10	18
11	M/28	Electric	A+FA+DM	6	Forearm amputation	-	35
12	M/8	Electric	Bil. F+FA	9	Forearm amputation	-	29
13	F/12	Electric	Fi+FA+DM	3	Upper elbow amputation	-	32
14	M /15	Flame	Bil. FA+DM	7	STSG	11	16
15	M/11	Scald	Bil. FA+DM	5	STSG	7	13
16	M/2	Scald	DM	4	Secondary	12	12
17	M/14	Scald	FA+DM	8	Primary+FTSG	8	14
18	M/26	Chemical	FA+DM+Fi	9	FTSG	14	20
19	M/15	Electric	FA	5	Primary+FTSG	12	19
20	M/1	Scald	FA	2	STSG	8	14
21	F/1	Scald	FA+DM	4	Primary+FTSG	7	14
22	M/25	Chemical	FA	3	Primary	5	7
23	M/1	Scald	DM	6	Primary+FTSG	7	11
24	M/28	Chemical	Bil. DM+Fi	8	STSG	14	21
25	M/15	Electric	FA	3	Primary	9	14
26	F/6	Chemical	FA+DM	6	Primary+FTSG	10	15
27	M/39	Electric	A+FA+DM	4	STSG	12	18
28	M/11	Electric	FA+DM	3	STSG	13	20
29	M/8	Electric	FA+DM	6	FTSG	11	17
30	M/31	Electric	FA+DM+Fi	5	Primary+STSG	14	22
31	M/29	Electric	A+FA+DM	6	Primary+FTSG	12	18
32	F/7	Scald	FA	4	Primary+FTSG	8	12
33	M/19	Scald	FA	3	Primary	6	8
34	F/7	Flame	FA	8	STSG	7	11
35	F/3	Scald	DM+Fi	4	STSG	9	14
36	M/3	Flame	Bil. FA+DM+Fi	5	STSG+FTSG	10	19
37	M/9	Electric	A+FA+DM	4	Primary+STSG	13	18
38	M/19	Chemical	Bil. DM+Fi	5	STSG	12	20
39	F/1	Scald	FA+DM	3	Primary+STSG	8	14
40	M/3	Scald	DM	5	Secondary	11	10
41	M/8	Flame	DM+Fi	4	STSG	13	19
42	F/6	Scald	FA+DM	4	Primary+STSG	9	16
43	M/26	Scald	FA	3	Primary	7	9

F:Female, M:Male, FA: Forearm, A:Arm, Fi: Finger, DM: Dorsal metacarpal FTSG: Full thickness skin graft, STSG: Split thickness skin greft, Bil:Bilaterally

DISCUSSION

Compartment syndrome (CS) is caused by burns, crush injuries, penetrant or non-penetrant traumas, proximal artery injuries, arterial or venous extravasations and infections (6). CS is a condition that necessitates early diagnosis and emergency fasciotomy. If no intervention is done amputations become inevitable (5).

Compartment syndrome is clinically diagnosed by intracompartmental pressure measurement (2). Diagnosis by pressure measurement is not practical because of the high number of patients in our country's emergency departments and it sometimes gives way to misleading results (7). Especially symptoms and findings like pain outside the injury zone and passive extremity movements, paresthesia, numbness, changes in capillary filling, perfusion changes like decrease in pulse or pulselessness, muscle weakness (8) are significant factors for CS diagnosis and fasciotomy indications. CS diagnosis and fasciotomy indications were achieved through clinical evaluation in all

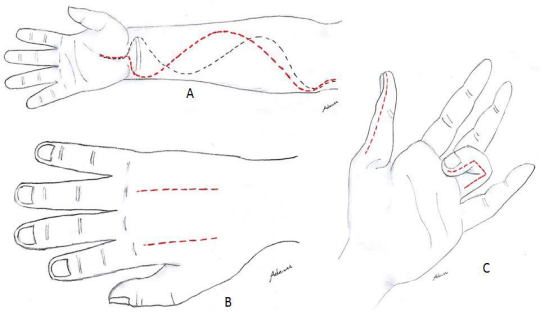

***Figure 1**. Fasciotomy incisions in the forearm, hand and fingers.*
A: Preferred incision figures which were used in forearm fasciotomy procedures and radial and ulnar pedicule flaps that can be used to close up the wrist
B: Incisions used to free the dorsal, volar, and adductor compartment of the thumb in the hand
C: Incisions with non-dominant sides in digit fasciotomies. The thumb was opened up from the radial side while the other fingers were opened up from the ulnar side.

***Figure 3**. Upper: Electric current burn, Below: Arm-forearm following fasciotomy; edema and burns in the muscles attract attention.*

the cases. Since it is recommended that physicians should not have second thoughts about freeing the compartment in evident and suspected CS cases (9, 10), these cases also received fasciotomy.

The first eight hours in the evaluation of compartment syndrome is called the "early phase" while the time that exceeds eight hours is called the "late phase" (2). The period between the start of the increase in post-traumatic intracompartmental pressure and the fasciotomy procedure is very critical and the procedure should be performed within this early phase. If reperfusion is not achieved within this period irreversible tissue injury takes place (2, 11). The late period is characterized by increase in vascular permeability, cellular anoxia, local metabolical changes, cell death, and the secretion of catabolic enzymes. Irreversible damage to the muscles starts to take place in this period. This condition ends in a process including ischemic contracture in the extremity and even amputation. Irreversible peripheral nerve changes are added to the condition, in addition to muscle necrosis, in extremity ischemia that exceeds 12-24 hours (11). All the cases, except two, were diagnosed within this critical period and received fasciotomy. A case with electric burn received fasciotomy in the late phase because of a delay in the transfer to our hospital from other medical centers, while another case with chemical burn had fasciotomy in the late phase because of delayed edema.

***Figure 2**. Upper left and right; fire burn of both hands and the forearm. Below left; the hand dorsal. Below right; forearm following fasciotomy.*

Since the nature of the compartment syndrome cannot be exactly foreseen in especially patients with electri-

cal current burns, early fasciotomy procedure does not guarantee the prevention of amputation (2). In two of the three cases with high-voltage transmission line burns amputation was inescapable because of the continued destructive effect of electrical current on the muscles despite early phase fasciotomy.

Compartment syndrome is most frequently seen in the forearm in the upper extremity (2). There are three compartments in the forearm and these are volar, dorsal, and mobile wad. Since there are connections among these compartments, single fasciotomy performed from the volar area suffices for forearm decompression (12). Single volar fasciotomy incision was used in all the forearm fasciotomy procedures and it was sufficient in all the cases (Figure 2, 3).

Defective fields are formed following fasciotomy that generally necessitate skin grafts. Limited fasciotomy incisions which are done in order to prevent the formation of such defects in the treatment of acute compartment syndromes do not bring about significant benefits. Longitudinal incisions which allow the muscle to be seen and evaluated should be preferred since the skin forms a barrier against the increasing extremity pressure. Insufficient skin incisions both pressure the tissue beneath and skin itself goes into necrosis because of the tension (7). In all the cases full dermatomy and fasciotomy were performed and the incisions were lengthened as necessary. Therefore, defect repair by graft was performed in 32 (74%) cases. Although endoscopic fasciotomy was "applicable" it is not recommended in acute compartment syndromes of the upper extremity (2).

We were found that scalding was the predominant cause of burn injury preschool age group, similar to previous reports from our country (13). Electric burn was the most common cause of burn injuries in postschool age group. Our data showed that electrical burn required longer hospital stay, more surgery and increased incidence of permanent complications.

The fact that more than half of the patients (23 cases) were younger than 10 years old and the fact that the mean age was 11.8 years old are indicators of how serious burn cases are seen in early ages in our country. According to literature, burns are frequently seen in preschool period. It was reported that 75.7% of the cases of burning in childhood were between the ages of 0-6 in a ten years study conducted in Adana (14). Approximately 92% of the cases in other study were between the age of 0 and 6 (15). This studies in our country support us. Necessary awareness raising in order to prevent burn cases which lead to significant psychological problems in patients is just as important as the treatment method of the patients admitted to our clinics because of burns.

It is well known that delays in fasciotomy lead to insufficient results and these results in turn lead to extremity amputations in acute compartment syndromes (1). Rapid diagnosis and timely intervention for patients presenting with burns depend on the awareness of the emergency surgery physician that compartment syndrome might take place.

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