Functional Reconstruction of Post-Burn Hand Contractures

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ABSTRACT Most patients who have survived severe burn injury may not have truly escaped the aftermath of severe scars which is post burn contractures. Hands are one of the most prevalent site of burn injury leading to contractures, which are important in terms of function and cosmesis. There is great deal of functional limitation, whereof contractures in both hands can make a burn survivor a total cripple. Moreover poor cosmetic result must also be considered as it gives impact towards patient’s self-esteem and quality of life. Treatment algorithm must be based on clinical presentation and severity of range of motion. Release of contracture, wound resurfacing and choice of reconstructive procedures must be based on timing of scar maturity as well as through a case-by case approach.

KEYWORDS post burn, hand contracture, reconstruction, management

Introduction

Burn injury is the second leading trauma-related cause of death worldwide.[1] Post-burn contractures are one of the common complications of burn injury, aside from scar deformity and tissue defect.[2] Hands are the region with a high frequency of occurrence in a burn injury.[2] A study reported that up to 39% of burn injuries involve the upper extremity, three while in severe burn cases, 80% of cases result in hand contracture.[4] It was also stated that patients with 15% of total body surface area (TBSA) burn might have sustained burns to the hand and upper extremity as well.[5,6]

Although burn-in hands is calculated as less than 5% of total body surface area, however, it must be noted that any burns in the hand region is considered as severe and is one of the criteria for referral to burn centre according to the American Burn Association and American College of Surgeons.[3] Burn contractures cause obvious body disfiguration and several other psychosocial symptoms such as pruritus or pain. In particular, postburn contracture of the hands may give an impact towards limiting patient’s daily functional ability as well as aesthetic appearance. The goal of treatment should first be to improve function particularly in essential regions of the body, including the hand.[7] Therefore it is crucial that cases of postburn hand contractures can be prevented and appropriate treatment done comprehensively.

Pathogenesis

It is generally accepted that scars are pathologic wounds deriving as a response towards different injuries including burn.[8] The presence of exuberant scars results in scar contracture which may cause a great deal of deformity and dysfunction.[8] A study reported that inadequate initial burn management and physical therapy might cause the transformation of burn contractures.[9,10] One of the proposed origins of scar contracture is the myofibroblast. Myofibroblast has a significant role in the wound healing phase particularly at the proliferative stage.[8] It is developed from fibrocytes and fibroblasts which have differentiated as a response to inflammatory factors. Therefore myofibroblasts possess features of an intermediate cell type, owning characteristics of that between fibroblast and smooth muscle cells.[8]

During the proliferative stage, activated fibroblast induces the differentiation of myofibroblast, which function to contract the wound and stimulate re-epithelialization.[8,10] This process continues up to the healing stage where remodelling of scar tissue begins to initiate. At this phase, myofibroblast is persistently activated, resulting in an imbalance between deposition and

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degradation of the extracellular matrix.[8] Myofibroblasts in the hypertrophic scar and keloid tissues may persist for long periods, producing a-smooth muscle actin, TGF-β1 and other associated growth factors such as connective tissue growth factor (CTGF) and platelet-derived growth factor (PDGF).[8,9] These cytokines can both upregulate or downregulate the contraction of myofibroblast.[8] Contraction during the repair phase is aimed to close the original wound site leading to wound healing. On the other hand, a persistent contraction which progresses after wound healing, in turn, creates morbidity of scar contractures, functional loss as well as poor aesthetic.[6] However, in some other cases, it has also been shown that contracture may occur secondary to the existing split-thickness skin graft.[4] This may explain how contracture is not only due to skin loss or previous injury, but may also develop due to the different growth pattern between previous burn scar and the surrounding normal tissues.[9] Due to the complex cellular factors that may involve in the pathogenesis of contracture, there is no single treatment method that has been proven effective in all cases of post-burn contractures.[3]

**Clinical presentation**

Burn contractures have a higher chance of forming when deep dermal or full-thickness burns did not undergo early surgical excision and in turn, left to heal by secondary intention.[11] Several characteristics distinguish burns at dorsal and volar skin of the hands. Burns at palmar skin often can heal completely well.[11] This is due to the thicker glabrous skin at the palm and volar fingers, highly keratinized, and able to withstand significant shearing force.[12] This also explains for a decreased tendency of full-thickness burn injuries at the palmar side.[12] Additionally, the palmar fascia and fibrous septae layers are capable of providing a protective covering of the flexor tendons and digital neurovascular bundles.[11] So although it might take approximately three weeks for the burn to undergo epithelialisation, however, it often leaves an only mild scar and contracture.[12] Since burns at the palm usually heal spontaneously due to the depth of the skin, often debridement and spontaneous separation alone are sufficient.[12] In cases where the palms sustain a full-thickness burn, an autograft from the sole of foot region is recommended as it matches the keratinocyte function to that of the palmar of the hand.[9,11]

This is different from the outcome of burns at dorsal skin. The dorsal hand is a thin and pliable part of the skin which can easily be damaged by contracture.[11] Moreover, the extensor tendons are more superficial and pose a higher chance of injury from burn exposure.[13] Therefore more soft tissue reconstruction by skin graft or flaps are done at dorsal hand burns than palmar burns due to its ability for better healing and its thick features.[6] However, in children, most hand burns occur at the volar skin as a result of grasping a hot object.[11] A study discovered that the frequent site of burn injuries in children is at the palm and volar fingers.[14] At first, it is often asymptomatic in children, which tends to be neglected over time while a contracture continues to develop slowly.[14] A study of 61 children with burn contractures discovered that pediatric burn patients with ten-year neglect had worse outcomes than those presenting with a five to 10-year neglect.[15] Contracture at the volar skin requires multiple surgical corrections during their lifetime, as the developing bones and joints may be deformed over time as well.[15] Burn injury of the hands may present in a typical feature of wrist extension, metacarpophalangeal (MCP) joint hyperextension, and interphalangeal (IP) joint flexion which as a whole make up for the burn claw deformity appearance.[3] (Figure 1) This deformity primarily occurs at the dorsal skin and the extensor apparatus. A large contribution of burn claw deformity is due to several risk factors, namely oedema of the joint, immobility and joint distension.[11] In burn injuries especially with a large total burn surface area, aggressive fluid resuscitation is warranted in order to maintain intravascular volume and prevent evaporative losses.[13] This fluid build-up can cause third spacing with severe edema of any extracellular spaces of the body as well.[16] Due to this fluid retention and edema of the joints surrounding the body, MCP tends to be extended than flexed due to the large joint space that is maintained at this position.[11] Extension of the MCP tends to be maintained over a long period of time, causing the collateral ligaments of the MCP to shorten.[11] Over time, movement of the ligaments towards a passive flexion of the MCP will be prevented. As a result of this prolonged extension of the MCP, there is a greater

**Figure 1:** Claw hand deformity with flexion of MCP[3].

**Figure 2:** Classification of contracture on MCP joint[11].

**Figure 3:** Incision of surgical contracture release[9].
flexion force of the IP joints causing a flexion deformity and intrinsic minus positioning.[17] The final position of the hand forms the claw hand deformity, with the wrist extended due to the dorsal skin contracture, alongside the thumb which is flexed at the IP joint and adducted towards the side of the palm.[11,17] In order to combat these series of deformities, splinting during preoperative and postoperative management should be done to maintain normal alignment of the ligament and joints.[16]

### Classification

Post-burn hand contractures are classified into four grades of severity according to McCauley.[18] (Table 1) This classification helps in determining the appropriate surgical or non-surgical treatment that should be given.

Patients with hand contractures of Grade I and II are well managed with non-surgical management aiming for reducing scars, and physiotherapy to rehabilitate functionality of the hands.[11] While grade III and IV are further classified as flexion, extension or mixed deformities. Another study stated that extension contractures of the MP joint could be classified into three types according to the range of motion.[19] (Figure 2)

Type I constitutes contractures limited to less than 30° when the wrist is flexed maximally. Type II involves both skin and MCP joint capsule, causing a failure to reach 30° of passive flexion even when wrist has been extended maximally.[11] Type III is the most severe type, where the MCP joint is fixed regardless of any position as it usually involves bone or articular deformity as well.[11,19]

### Treatment

#### Acute hand burn management

Burn injury at deep or full-thickness that is not able to heal within three weeks is indicated to undergo surgery.[11] Hence early excision and grafting is the mainstay of surgical treatment for burn injuries.[11] For acute wound resurfacing, a split-thickness skin graft is the preferred choice of treatment.[17] While it is generally accepted that graft contracture is inversely proportional to graft thickness itself, however, a prospective RCT found that thickness of split-thickness skin graft does not affect the range of motion in a burn injury.[17,20] Choice of skin substitute in terms of cost and patient’s preference must
also be considered in patient-to-patient basis. While donor site skin graft is generally used, however, for the better aesthetic result, there are other choices of skin substitutes that can be used. Acellular dermal matrices are increasingly used as it offers better aesthetic result for patients prone to forming hypertrophic scars and keloids.[17] However, no further clinical benefit has been shown concerning the impact towards burn contracture itself.[11,17]

### Non-surgical management

Burn contractures can start to appear from months to years after initial burn injury.[3] For patients with thickened scars presenting a few months after injury along with a minimal limited range of motion change, several applicable treatment modalities range from early splinting, compression garment, and scar massage.[11] These may prevent the transformation of burn contracture, decrease any degree of deformity present, as well as avoid the need for further surgical reconstruction.[21] Other prevention measures such as applying anti-deformity orthosis fabrication and avoiding direct sunlight exposure are also recommended.[3,17] The principle of burn surgery is to delay any secondary procedures until scars have matured which can take up to 1 year long.[18] It is fundamental to wait for scars to fully mature, as immature scars are often hypervascular and can excessively bleed which cause poor skin graft take and wound healing process.[1] A study reported that performing surgery on immature scars can increase the risk of its recurrence.[18] Therefore while scars are still immature, multimodal non-operative efforts can still be performed. Other procedures commonly done by dermatologists such as intrallesional steroid injection and laser-based therapies can be administered.[22] These are useful even for both maturing and mature scars of the hand.[18,22] However for contractures with a significant change in range of motion, early surgical correction is indicated to prevent further deformity in joints or bones particularly in developing children.[3] For these cases, non-surgical treatment alone has little role in reversing the scarring process, let alone in reducing the severity of contracture.[17]

### Surgical management

Contracture must be surgically released with proper technique. Contracture release should be performed with a bilateral fish-tailed incision which is at the meridian of joint and fish-tailed at both ends of the scar, extending up to the normal medial and lateral tissues.[18] This technique is useful as it will add the size of the defect, which will be covered later on. (Figure 3)

| Grade  | Description                                      |
|--------|--------------------------------------------------|
| Grade I| Symptomatic tightness but no limitations in range of motion, normal architecture |
| Grade II| Mild decrease in range of motion without significant impact on activities of daily living, no distortion of normal architecture |
| Grade III| Functional deficit noted, with early changes in normal architecture of the hand |
| Grade IV| Loss of hand function with significant distortion of normal architecture of the hand |

**Subset classification for Grade III and Grade IV contractures:**
- A: Flexion contractures
- B: Extension contractures
- C: Combination of flexion and extension contractures

A study has also recommended the use of an algorithm to determine the surgical intervention needed according to the range of motion of extremity. Mild contractures are considered when there is more than 50% of joint range of motion, while severe contracture presents with less than 50% of joint range of motion.[9] (Figure 4)

In mild contracture, z-plasty is done to lengthen and transpose the scar. By transposing the flap, the scar gets narrowed, and the central limb is lengthened. It will then be followed by incision of the flap tips perpendicular to the central limb to ensure there are adequate skin and soft tissue.[26] As a result of the transposition, and the irregular borders can function as

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a cover-up of the scar itself.[26] There are other variations of Z-plasty such as opposite running YV-plasty, W-plasty, 5 or 4 flap-plasty and multiple Z-plasty.[11] (Figure 5) It is more applicable to do these variations in the mature scar, as immature scars are still very much inflamed and susceptible to developing flap necrosis.[9]

In severe contracture, with less than 50% of the joint range of motion, more varied surgical approaches are required.[9] This is because there is inadequate adjacent tissue to release or lengthen the contracture.[9] For severe contracture, a full-thickness skin graft is similarly preferred due to less risk of recurrence and better color and texture match than split-thickness graft.[26] Another concern to be considered is the fact that full-thickness graft may not be suitable in large burns with limited available skin to harvest. Hence this makes flap a more recommended option in large burns.[8,11] It must be noted that the deformity resulting from burn injury aftermath is not limited to contractures alone. There is a high probability that secondary changes might also occur in the joints, ligaments, or tendons of the hand.[27] All of this concuring might cause poorer hand function which requires reconstruction efforts.[27] It is best prioritized that reconstruction is aimed to restore the function of the hand as a whole, rather than restoring the range of motion of every digit of the hands.[23,27]

Prevention and Post-operative Care

There are several different preventive measures of post-burn hand contracture. After any surgical procedure, the burned hand must be elevated and splinted to prevent ligament or joint contracture.[11] Early splinting followed by aggressive physical therapy are fundamental elements in prevention of post-burn hand contracture as they have been shown to decrease incidence of contracture.[10] Splinting is maintained at an anti-deformity position where the wrist is extended at 30 degrees, the MP joint flexed at 90 degrees, the IP joints fully extended and the thumb is abducted maximally.[24,28] It has been reported that use of splinting at the earliest possible stage is crucial in the prevention of contracture.[17,25] Any periods of delay or splinting can increase risk of developing contractures. Wound dressing must be appropriately cared for as bulky dressing may reduce the efficacy of thermoplastic splints.[29] Alignment of the joint can be better maintained using Kirschner (K) wires. (Figure 6) These K wires will then be removed after wound healing has completed, and the position of the hands can then be maintained with splinting.[12]

Patients who underwent non-operative contracture treatment can be started for early mobilization with a supervised range of motion, while for cases which have undergone operative procedures it can be initiated within one to two weeks after surgery.[30] Additionally, after the epithelialization phase, silicone sheet and compression garments can be applied for 23 hours each day up until six months of duration.[9,18] Patient at the sub-acute phase is suitably managed with pressure garments and silicone sheet as these can cause pressure effect and a state of tissue hypoxia which in turn can help minimize scar and contracture from developing.[31] Close monitoring must be followed up by both patient and family members to prevent burn contractures from re-developing in the future.

Conclusion

In conclusion of the review, it is evident that post-burn hand contractures are one of the leading outcomes in burn injury that must be minimized by choosing appropriate prevention and treatment strategies. Postburn hand contractures should be evaluated for severity of degree based on the range of movement in individual joints. In the majority of cases, contracture release by multiple Z-plasty followed by skin grafting is adequate management. However, choice of skin graft and further need for flaps must be considered to restore full function of the hands. Post-operative prevention and rehabilitation strategies must still be maintained to reduce recurrence and improve functional outcome in the long-term.

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Competing Interests

Written informed consent obtained from the patient for publication of this case report and any accompanying images.

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