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Acute Compartment Syndrome of the Hand: A Case Report and Overview

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Abstract
Acute compartment syndrome of the hand is a rare pathological condition in which the size of the compartments of the hand could be decreased or the volume of the fluid intro compartment could be increased, or both. This urgent condition, if remains undiagnostic, produce irreversible changes (which are strong related to elapsed time) and may leading to amputation or to threatening life of the patients. Most common causes presented in literature are traumatic (crush injuries, burns, closed fractures), medical (infection, bleeding disorders), iatrogenic (intravenous infiltration, arthroscopy) and vascular (arterial puncture or catheterization, venous occlusion). The purpose of this study is bimodal. Firstly, to present a 34 year-old male who, after a traffic accident, presented with open diaphyseal fractures IIIA of the left 2nd and 3rd metacarpals and a Bennett fracture of the thumb and who developed an acute compartment syndrome. Secondly, to develop a sense of suspicion of this kind of lesions in physicians in the emergency department with scope to the precocious diagnosis and treatment.
Keywords: *Compartment syndrome, hand, edema, fasciotomy, metacarpal fractures.*

Introduction

Acute compartment syndrome is a pathological condition in which the interstitial tissue pressure is increased within an enclosed fascia envelope leading to a decreased capacity tissues oxygenation. The most common localization in human skeleton, is in the forearm, and lower leg, while in hand is very rare and only a few cases have been mentioned in literature.[1,2] Ashton (1963) reported that when a strong pressure is created on a tissue, that results in vessel collapse and as interstitial pressure extends of intraluminal pressure and creates venous congestion, lead to decreased perfusion and tissue necrosis.[3] Various causes have been reported such as fractures, crush injuries, snake bites, high pressure injections, intravenous drugs, insect bites, and intravenous fluid extravasation.[4,5,6] In all these situations the size of the compartments of the hand can be decreased or the volume of the fluid can increased intro compartment or both.

Untreated or misdiagnosed, this condition is associated with significant cellular necrosis and tissue ischemia and necrosis. Seiler et al (2003) reported that compartment syndrome is a frequent source of litigation against orthopaedic surgeons for medical malpractice, while the average cost of compensation reaches 280.000$.[7,8] Rubinstein et al (2018) report that independently the severity of the acute compartment syndrome, the result on the patients may vary from minimal functional dysfunction of the hand to amputation or to loss life, while Oak et al(2016)report that once the compartment syndrome is established, the changes that occur are irreversible and are being directly related to elapsed time.[2,9] All this leads to the conclusion that not only early diagnosis but also correct treatment is necessary.

The aim of this study is to present a case report of a 34 year-old man with open diaphyseal fractures IIIA of the left 2nd and 3rd metacarpals and Bennett fracture of the first metacarpal after a traffic accident, who developed acute compartment syndrome and based on this case to develop also a sense of suspicion of this kind of lesion in physicians in the emergency with scope to precocious diagnosis and treatment.

Case Report

A 34 year-old man was transmitted in our department from another unit 5 hours after a traffic accident with the first diagnosis of open fractures IIIA of the left metacarpals (1^{st} 2^{nd},3^{rd}). After ATLS damage control, and during clinical examination we found in dorsal surface of the left hand a degloving laceration extended from the metacarpal heads (2^{nd}-5^{th}) until the base of the respective metacarpals but the fascia was intact.(Fig.1). A second laceration area was on the volar surface of the thumb extended from radial side of proximal phalange and pass over A1 pulley until middle of the 2^{nd} metacarpal on the radial side.(Fig.2) Hand was swollen especially at volar side on hypothenar area and the patient referred paresthesia of distribution of the median nerve, and severe pain during passive motion of the digits, while capillary refill was impaired. (Fig.3) In initial x-ray control, a displaced fracture of the diaphyseal of second and third metacarpal appeared and a dislocation of carpometacarpal joint of the thumb. (Fig 4(a), (b)) Patient underwent for emergency Ct/scan of the injured hand with scope to diagnose other injuries which might missed from the radiography examination. Diaphyseal fracture of 2^{nd}-3^{rd} metacarpals and a Bennett fracture of the left thumb were diagnosed. (Fig.5(a),(b),(c)) Patient admitted to the operating theatre in which under general anesthesia two dorsal fasciotomies over second metacarpal were done(with scope to open the first and second dorsal interosseous and first palmar interosseous compartment) and over fourth metacarpal(with scope to open the third and fourth interosseous compartment and second-third palmar interosseous compartment). A large hematoma with fluid was drained especially from the incision over dorsal hypothenar area. Median nerve was released via a volar approach. The fractures were reduced and stabilized with Kirschner wires. After fasciotomy the swelling was decreased, and capillary refill returned to normal, while wound remained open. Postoperative intravenous cefuroxime was administrated and a volar split was applied in a functional position of the involved hand(90° flexion metacarpophalangeal joints and 10° flexion of interphalangeal joints) and the patient after five days was discharged pain-free and without paresthesia. Ten days postoperatively a split thickness skin graft was applied on the dorsal surface of the hand while the other two skin wounds were closed secondary. Patient was instructed to do gentle stretching exercises and scar tissue mobilization, a week after surgery. Kirschner wires were removed at fourth week and a rehabilitation program was introduced to the patient. Oedema control, range of movements and strengthening were the main goals of the program. Modalities were used to control oedema and scar tissue formation combined with manual therapy which was beneficial for both tissue flexibility and increasing

range of motion. Initially passive and active range of motion exercises in wrist and fingers were performed, while more strengthening exercises were introduced later, as soon as wounds stabilized.

At five months postoperatively the patient had a sufficient range of motion and returned to previous functional activity. (Fig 6(a),(b),(c), (d), (e),(f))

Figure 1: Degloving trauma of the dorsal surface of the left hand with the fascia intact.

Figure 2; Second trauma on the volar surface of the thumb (digital nerve ulnar side-white arrow).

Figure 3: Great swelling on hypothenar area of the left hand(white arrow)

(a) (b)

Figure 4: Preoperative x-Rays of left hand,(Anteroposterior(a) and oblique (b))

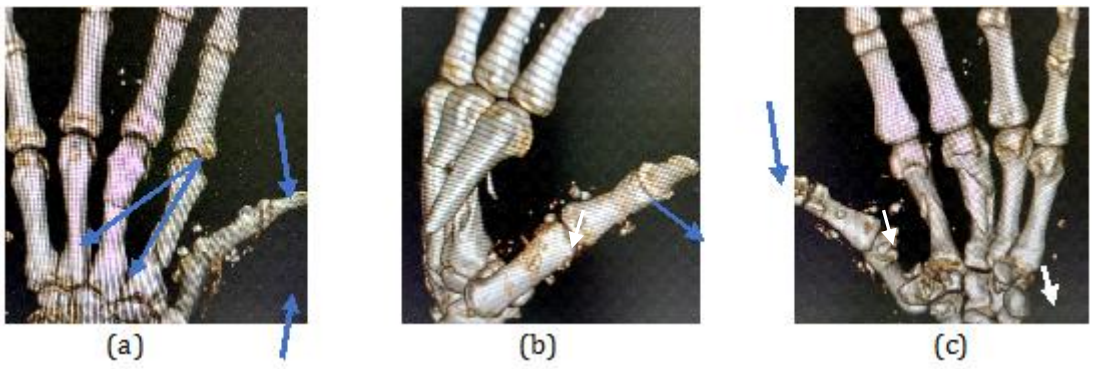
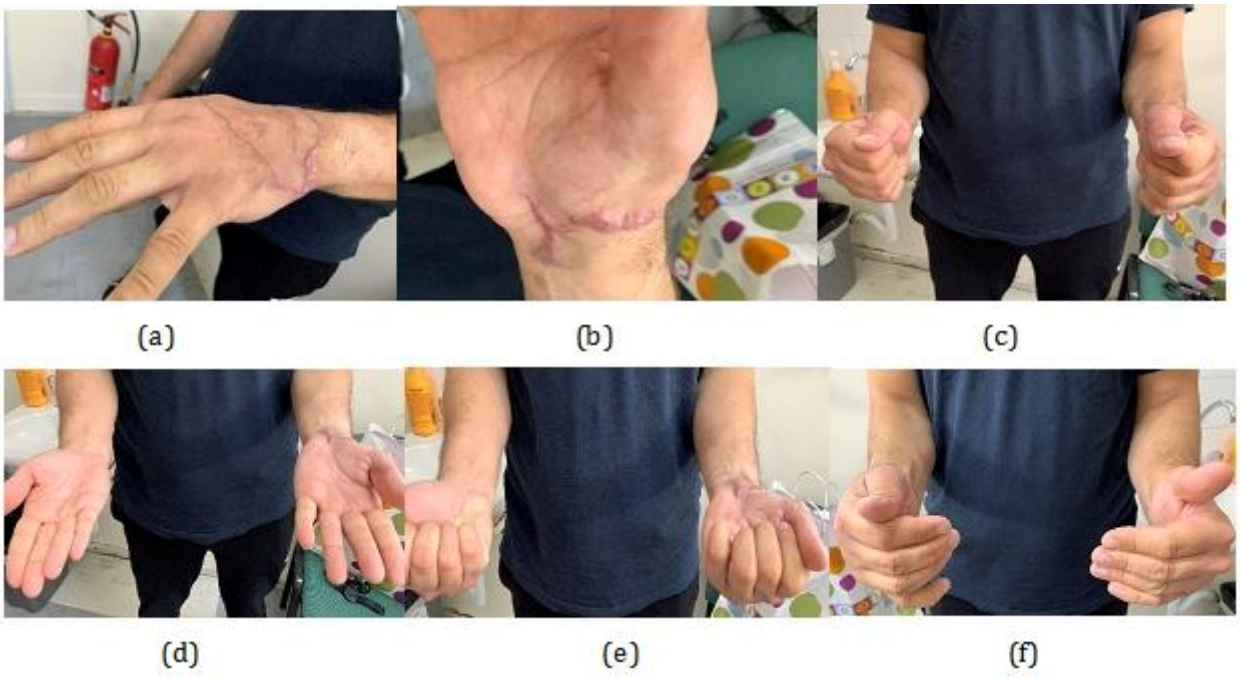


Figure 5: 3D ct/Scan which appears diaphyseal fractures (white arrow bennett fractures, blue arrow 2^{nd}-3^{rd} diaphyseal fractures)



Firure 6: Dorsal(a)and volar(b) aspect of the left hand and range of motion after five months.

Discussion

Acute compartment syndrome of the hand is a result of progressive high pressure with tightly confined myofascial compartment of the hand surrounded by thick connective tissue. Pathophysiologically, as interstitial pressure increases, capillary perfusion pressure exceeds, which leads to a narrowed arteriovenous perfusion gradient resulting decreased muscle perfusion down to the level for cellular viability.[10,11] Finally hypoxia appears, nerve dysfunction and muscles necrosis. Heppenstall et al (1998) in experimental ischemic compartment syndrome in dogs, report aggression of tissue necrosis and diminution of nerve conduction after 8 hours when tissue pressure above 40mmHg.[12]

Di Felice et al (1998) describe that anatomic hand is composed by 10 separate compartments with slight anatomic variation. There are 4 dorsal interossei compartments, 3 volar interossei compartments, thenar compartment, hypothenar compartment, and a midpalm compartment. Arterial supply originated from branches of superficial-deep arches which provided from radial and ulnar arteries.[13]

Incidence of acute compartment syndrome (ACS) of the hand is relatively rare compared with the lower extremity or forearm, but conjoint with many subjacent causes. Because this pathological condition has been reported only as case reports or small case series, a wide range of underlying causes have been proposed. Rubinstein et al(2018) categorized causes of the syndrome in four main groups: Traumatic(fractures, dislocations, blunt trauma, crush injuries, penetrating or gunshot injuries, burns, envenomation, high-pressure injection), medical (Infection, bleeding disorders, spontaneous hemorrhage, rhabdomyolysis), iatrogenic(Ischemia-reperfusion, intravenous infiltration, contrast extravasation, constrictive dressings or casts, arthroscopy, prolonged pressure from positioning), vascular(Arterial injury, arterial puncture, arterial catheterization, venous occlusion).[2] In our case, the cause was multiple metacarpal diaphyseal fractures, but the paradoxes was that while there was a degloving skin laceration on the dorsal surface of the hand the dorsal fascia was intact, and we believe that this was the reason that increased pressure from hematoma on the muscles compartment.

Griffiths (1940) establish the "5 Ps" with scope to present the clinical symptoms of compartment syndrome (pain, paresthesia, pallor, paralysis and pulselessness), but these findings more often

appear in an arterial occlusion and the author believed that arterial spasm is the predominate cause of ACS.[14] Many authors suggest that early diagnosis of the syndrome is essential for good functional outcomes so if appears "5 Ps" this indicate a delayed diagnosis with severe results.[2,5,6,7]Braunlich et al(2020) argues that there is not ledgers accepted diagnostic clinical findings and compartment pressures for the diagnosis of the acute syndrome.[5] Codding et al suggest that the initial diagnosis must be based on suspicion of the physician regardless the cause which is responsible of ACS, while Reichman(2016) suggest that diagnosis of ACS is primarily a clinical one.[10,15] Accurate clinical examination (inspection, palpation, neurovascular) of whole affected upper limb must be executed. Ouellette et al(1996) noted that the most usually clinical examination in ACS of the hand was astrained swollen hand with intrinsic minus posturing (extension of metacarpophalangeal joint and flexion of the proximal and distal interphalangeal joints).[16]

The most common symptom is severe pain independently the cause of injury which aggravated when the involved of muscles are stretched passively and required increased analgesics.[7,9,16]Bae et al(2001) in 36 cases with ACS report 90% of patients presented pain, 70% reported pain in association with another P and less of 40% presented pain with 2 or more Ps.[17] Swelling and tenderness over compartments are the second clinical sign, while pulselessness and pallor insinuate arterial compression or transection.[10,18] Paresthesias and paralysis are very late signs because acute hand compartment syndrome deprivation neurological symptoms as sensory deficiency whereas no nerves pass through hand compartments.[19] In our case, primary symptom was passive pain and extremely swelling of the hand, and based on those we continue to fasciectomy.

In situations in which diagnosis is not clear direct measurement of the intercompartmental pressure may be a supplementary tool. In literature there is no agreement according to which pressure is a strict indication for surgical treatment.[10] The prevailing opinion is that it is not so crucial the absolute compartment pressure as the intracompartment perfusion pressure.[20] Whiteside et al suggest that an absolute pressure above 50 mmHg was a indicator for muscles ischemia, while Matava et al(1994) proposed delta compartment pressures(difference of compartment pressure from the diastolic blood pressure) as the most precise diagnostic tool.[21,22] Studies in literature proposed that a absolute pressure of 15 -25 mmHg with clinical symptoms or 25 mmHg without symptoms is an indicator for ACS of the hand, while other researchers suggest that fasciotomy is indicated when intracompartment pressure in a single compartment is within 20-30mmHg of the patients diastolic blood pressure.[1,9,15,16,21,22,23]

When diagnosis is established time to start fasciotomy is the mainstay of the treatment. Hand fasciotomy includes multiple incisions with scope to expedite access to all hand compartments. Two dorsal incisions over index and ring metacarpal are recommended for release of dorsal interossei. Dissection lengthwise ulnar and radial borders of the 2nd metacarpal release the 1st dorsal interosseous, adductor pollicis, 2nd dorsal interosseous and second palmar interosseous , while dissection over 4th metacarpal(ulnar-radial) release 3rd and 4th interosseous compartments. Thenar and hypothenar compartment released with two incisions: one over radial aspect of the 1st metacarpal and the other over ulnar surface of the fifth metacarpal respectively. Finally, carpal tunnel release performed, extended at least 4cm into forearm to obtain adequate decompression of deep antebrachial fascia.[2,7,10,13]

Conclusion

Acute compartment syndrome of the hand is a rare multifactorial pathological condition, while clinical presentation is changeable and changes with time. Clinical diagnosis of the syndrome is very difficult, and the physician must do in time

for better functional outcomes for the patient. Clinical suspicion and comprehensive clinical examination are the most critical methods to establish diagnosis, accompanied with measurement of compartment pressure. Precocious fasciotomy of all the involved compartments is the only treatment with scope to decrease compartment pressure, to avoid muscles ischemia and to maximize functional results.

Conflict of Interest: The authors declare that have no conflict of interest.

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