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Current Treatment on Compartment Syndrome of the Hand

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ABSTRACT

Compartment syndrome is a critical condition characterized by elevated pressures within constricted myofascial compartments, leading to vascular compromise, hypoxia, and potential irreversible injury. While commonly affecting the forearm and lower leg, compartment syndrome of the hand is rare and poses unique diagnostic and therapeutic challenges. The pathophysiology involves increased intracompartmental pressure from various etiologies, such as trauma, edema, or external compression, culminating in a cycle of ischemia and worsening edema. Rhabdomyolysis, defined by rapid muscle tissue degradation and release of intracellular components into the bloodstream, is intricately linked to compartment syndrome, with each condition potentially exacerbating the other. Elevated serum creatine kinase and myoglobin levels are hallmark diagnostic markers of rhabdomyolysis.

Hand compartment syndrome, despite its rarity, necessitates prompt identification and surgical intervention. The hand's complex anatomical structure comprises ten compartments, each at risk for ischemic injury under increased pressure. Clinically, hand compartment syndrome manifests as severe pain disproportionate to injury, edema, and abnormal posturing. Diagnosis relies on clinical suspicion, supported by intracompartmental pressure monitoring. Emergent fasciotomy remains the definitive treatment, requiring multiple incisions to decompress affected compartments. Magnetic resonance imaging (MRI) is valuable for assessing tissue damage and guiding management strategies. This review underscores the importance of early recognition and timely intervention in compartment syndrome and highlights the interdependent relationship between compartment syndrome and rhabdomyolysis.

KEYWORDS: Hand, compartment syndrome, rhabdomyolysis

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INTRODUCTION

Compartment syndrome is a serious disorder resulting from elevated pressures within constricted myofascial compartments. Compartment syndrome predominantly occurs in the forearm and legs, particularly the lower leg. Nonetheless, infrequent instances of compartment syndrome affecting the hand have been documented. Swift identification and urgent fasciotomy to alleviate compartment pressure are essential to avert irreversible injury. The defining characteristic of untreated compartment syndrome is increased compartment pressure, resulting in vascular compromise and diminished perfusion. The cycle of elevated pressure persists as capillary permeability rises due to tissue injury, hence worsening compartment edema. In the absence of treatment, necrosis occurs. Rhabdomyolysis is a disorder characterized by the breakdown of muscle tissue and the subsequent release of muscle components into the bloodstream. Compartment syndrome, which results in muscle breakdown, is intricately linked to rhabdomyolysis-induced edema that raises compartment pressure, rendering the two intrinsically co-dependent in constricted myofascial compartments. Imaging is crucial for assessing compartment syndrome and tracking the disease's course from edema to myonecrosis. Magnetic resonance imaging (MRI) is the optimal modality for assessing the degree of tissue damage and formulating therapeutic strategies.

Compartment syndrome and rhabdomyolysis

Compartment syndrome arises from elevated pressure within constricted myofascial compartments encased by dense connective tissue or bone. Vascular collapse and hypoxia resulting from increased pressure are the defining characteristics of compartment syndrome. Increased pressure may result from either a rise in intracompartmental volume or external compression. Intracompartmental causes of pressure rise include edema, hematoma, and fracture, while external compression factors encompass burns, extended immobility, and tight wrapping. An increase in pressure results in venous obstruction and arterial collapse, capillary ischemia, and nerve injury. As the energy-dependent transcellular pumps malfunction due to ischemia, muscle cell swelling occurs, exacerbating compartmental pressures and perpetuating the cycle of hypoxia and muscle injury. The clinical presentation varies according to the severity of the damage and typically encompasses disproportionate pain, weakness or paralysis, hypoesthesia or paresthesia, as well as tightness and pallor due to circulatory compromise. Timely identification and prompt fasciotomy are essential for decompressing the afflicted compartment and averting further muscle damage. Monitoring intracompartmental pressure is crucial for assessing compartment pressures. A compartment pressure exceeding 30 mm Hg has been demonstrated to induce considerable clinical muscle ischemia and can assist the clinician in determining the necessity for urgent fasciotomy. Extended compartment pressure results in reversible damage after 4 hours and irreversible myonecrosis and nerve injury by 8 hours, necessitating surgical excision of necrotic tissue.

Rhabdomyolysis is a recognized complication of compartment syndromes. Rhabdomyolysis is defined as the rapid degradation of muscle tissue, resulting in the loss of myocytes and the consequent release of intracellular components into the bloodstream. Aside from compression-induced injury, various other etiologies of rhabdomyolysis have been recognized, including trauma, intense physical exertion, ischemia, burns, autoimmune disorders, seizures, extended immobility, and toxins, encompassing medicines, pharmaceuticals, and alcohol misuse. The clinical manifestation of rhabdomyolysis and its treatment alternatives are diverse due to the multitude of underlying etiologies, varying from mild to severe depending on the degree of muscle injury.

Figure 1. Compartment syndrome of the hand

Rhabdomyolysis may result in many consequences, with acute renal injury being the most prevalent. Additional recognized concerns encompass electrolyte imbalance resulting from muscle breakdown, fluid loss, acidosis, and disseminated intravascular coagulation. Moreover, compartment syndrome may arise as a complication of

rhabdomyolysis due to the escalating edema within constricted compartments, resulting in heightened intracompartmental volume.

The diagnosis of rhabdomyolysis is established through laboratory data that assess indicators of muscle degradation. These results indicate high serum creatine kinase (CK), particularly the CK-MM subtype, which serves as the most sensitive marker of muscle degradation. Creatine kinase (CK) levels increase between 2-12 hours following the first muscle injury, peaking at 24-72 hours, and subsequently exhibit a progressive drop over 7-10 days for a resolving injury. CK may remain in instances of ongoing injury, as observed in compartment syndrome. A value of five times the usual limit is typically recognized as a sign of rhabdomyolysis. Additional indications are serum and urine myoglobin, which, when aberrant, serve as reliable biomarkers of rhabdomyolysis. Elevation of serum myoglobin is deemed pathognomonic for rhabdomyolysis.

Compartment syndrome is a clinical diagnosis, and no imaging required for initial assessment or for emergent fasciotomy.

With MRI enhancing accuracy by assessing muscle involvement and ischemic changes. Early muscle damage appears as edema on T2W MRI sequences. Although nonspecific, muscle edema can indicate conditions like myositis.

Chronic untreated myonecrosis could be represented as, an overall reduction in muscle mass.

Hand compartment syndrome

Hand compartment syndrome is rare and results from the same broad reasons previously identified, such as trauma, drug overdose, and crush syndrome. The hand can be anatomically categorized into 10 distinct compartments, comprising the hypothenar, thenar, adductor, carpal canal, finger, and four interosseous compartments. The vascular supply to the hand is derived from deep and superficial arches supplied by the ulnar and radial arteries. The predominant symptom of hand compartment syndrome is edema, accompanied by abnormal posturing and discomfort that is disproportionate to the injury, worsened by passive stretching. The diagnosis is frequently established through clinical suspicion, however intracompartment pressures may assist in both diagnosis and monitoring of the hand. Emergent fasciotomy is the principal intervention for hand compartment syndrome. Due to the scarcity of comprehensive data on hand compartment syndrome, a firm consensus for its diagnosis is absent, necessitating the clinician's clinical judgment. Hand compartment syndrome typically necessitates several incisions to alleviate pressure in all affected compartments.

Fasciotomy technique

Standardized incisions are essential for managing compartment syndromes of the hand and fingers to reduce morbidity, due to the restrictive skin envelope and intricate anatomical structures within these compartments. Longitudinal incisions on the volar side, aligned with the radial and ulnar borders of the thenar and hypothenar eminences, are delineated to enhance the release of these muscle compartments while safeguarding neurovascular bundles. Typically, carpal tunnel releases for upper extremity compartment syndrome are executed via extensile approaches linking to the forearm fasciotomy; however, they may also be performed in isolation, necessitating a release of 4–5 cm into the volar forearm fascia. The release of the interosseous spaces on the dorsal side is typically executed through two longitudinal incisions situated above the first and second, as well as the third and fourth interosseous spaces. The incisions run parallel to the metacarpal shafts, necessitating careful preservation of a sufficiently wide skin bridge. When releasing finger compartments, it is imperative to prevent additional morbidity by avoiding inadvertent damage to the dominant sensory nerves. Consequently, radial incisions are executed on the thumb and index finger, while ulnar incisions are made on the index, middle, and ring fingers. The unilateral, midaxial incisions penetrate the Cleland ligament, which serves as the dorsal roof of the neurovascular bundle, thereby alleviating compression on these structures.

Figure 2. Fasciotomy

Figure 3. Postoperative incisions

CONCLUSION

Compartment syndrome is a potentially devastating condition requiring prompt recognition and intervention to prevent irreversible damage. Although more commonly associated with the forearm and lower leg, hand compartment syndrome presents unique challenges due to its rarity and the complex anatomy of the hand. Early diagnosis relies on clinical acumen, supported by tools such as intracompartmental pressure monitoring and imaging modalities like MRI. Emergent fasciotomy remains the cornerstone of management, emphasizing the need for timely surgical decompression to preserve function.

The intricate relationship between compartment syndrome and rhabdomyolysis underscores the importance of understanding their shared pathophysiology. Rhabdomyolysis, both a consequence and contributor to compartment syndrome, compounds the clinical course through edema and systemic complications. Recognition of this interplay is essential for comprehensive management, including monitoring creatine kinase and myoglobin levels to assess muscle injury severity.

Overall, multidisciplinary care is critical to optimize outcomes in patients with compartment syndrome, particularly in rare presentations such as those involving the hand. Advances in diagnostic modalities and a deeper understanding of associated complications, like rhabdomyolysis, are pivotal in improving patient care and preventing long-term morbidity.

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