Muscle Contusion Injuries: Current Treatment Options

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Abstract

Muscle contusion is second only to strain as the leading cause of morbidity from sports-related injuries. Severity depends on the site of impact, the activation status of the muscles involved, the age of the patient, and the presence of fatigue. The diagnosis has traditionally been one of clinical judgment; however, newer modalities, including ultrasonography, magnetic resonance imaging, and spectroscopy, are becoming increasingly important in both identifying and delineating the extent of injury. Although controlled clinical studies are scarce, animal research into muscle contusions has allowed the description of the natural healing process, which involves a complex balance between muscle repair, regeneration, and scar-tissue formation. Studies are being performed to evaluate the effects of anti-inflammatory medications, corticosteroids, operative repair, and exercise protocols. Prevention and treatment of complications such as myositis ossificans have also been stressed, but recognition may improve the outcome of these ubiquitous injuries.

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Traumatic muscle contusion is a common cause of soft-tissue injury in virtually all contact sports. In fact, contusion and strain injuries make up approximately 90% of all sports-related injuries.[1,2] Other than strain injuries, contusion caused by impact with a blunt, nonpenetrating object is the most frequent muscle injury.[3]

The symptoms of a contusion injury are often nonspecific, and include soreness, pain with active and passive motion, and limited range of motion. Without a straightforward history of impact to the area, the diagnosis often becomes one of exclusion. Many contusion injuries go unreported and untreated.

Healing of these injuries is a complex phenomenon depending on multiple factors, both within and outside the control of the clinician. No universally accepted treatment modalities have been developed. Most treatments follow the "RICE" principle (rest, immobilization, cold, and elevation) at least in the short term, but clinicians differ as to the best long-term treatment.

Common sites of contusion injuries include the anterior, posterior, and lateral aspects of the thigh and the upper arm in the region of the brachialis (causing "tackler's exostosis"). Contusions in the area of the quadriceps and the lateral thigh may cause excessive hematoma to accumulate due to the large potential space.[4] A frequent complication is ossification of the hematoma in response to mechanisms that are as yet unclear. It is generally felt that injury sufficient to cause proliferative repair is essential to the development of myositis ossificans.[5] At the level of the muscle fibers, capillary bleeding and edema can lead to hematoma formation and can cause compartment syndrome in areas in which the volume is limited by the fascial envelope.

There are a number of common types of muscle injuries (Table 1). Several excellent reviews of muscle strain injuries[2,6,7] and of exercise-induced muscle injury[8-10] have appeared in the recent literature, but there have been none that summarize the body of literature dedicated to muscle contusion injury. There are, however, a large number of studies, especially those reporting on animal research, that detail the mechanisms of injury, the natural history, and the effects of various treatment modalities. The lessons learned in the laboratory can now begin to be translated to the care of the injured patient.

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Table 1
Common Types and Causes of Muscle Contusion

- Exercise-induced injury ("delayed onset muscle soreness")
- Strain
- Laceration
  - Traumatic
  - Surgical
- Vascular
  - Tourniquet
  - Traumatic vascular injury
- Infectious
  - Bacterial
  - Viral
- Neurologic
  - Denervation
    - Viral (central or peripheral)
    - Traumatic (central or peripheral)
  - Neuropathic
    - Metabolic
    - Viral
    - Genetic
- Myopathies

Mechanisms of Injury

The clinical entity of a muscle contusion injury is most often seen after a direct blow to an extremity. In football, this frequently occurs in the anterior, medial, or lateral thigh in the area of the muscle belly of the quadriceps femoris.[11] The greatest number of quadriceps contusions in one study occurred in tackle football, although the percentage of injuries was higher in rugby, karate, and judo.[11] In soccer, after the widespread adoption of the use of shin guards, the thigh is now the most commonly injured area as well. However, these injuries have been reported in virtually all contact sports.

The injury is associated with pain and swelling, a decreased range of motion of joints spanned by the injured muscles, and occasionally a permanent palpable mass.[11] In animal studies, at a microstructural level, contusion injury usually causes a partial rupture of the muscle, capillary rupture, and infiltrative bleeding, leading to hematoma formation within the developing gap and around the intact muscle fibers, edema, and inflammation.[12] Despite all these changes, some functional capacity usually remains in the affected muscle.[13,14] The architecture of the damaged muscle bed is a mix of disrupted muscle cells and collagen connective tissue. The healing process is a delicate balance between the formation of scar tissue by fibroblasts and the regeneration of normal muscle by migrating myoblasts.

Injury Severity

Information regarding the structural, cellular, and biochemical events in contusion injury is essential to the rational application of sports therapy. Studying these injuries is difficult, however, because of the inherent variability in severity. In contrast, the research setting provides a means to control many of the confounding variables involved in muscle contusion research. Models of contusion that have been developed use spring-loaded hammers, crushing hemostat forceps, reflex hammers, and a variety of other devices to cause single or multiple contusion injuries ranging from the mild to the severe in rodents and nonhuman primates. Only two, however, have been able to deliver a standardized crush injury. Järvinen and co-workers[15-17] developed a rat model of muscle contusion injury involving the use of a spring-loaded hammer and compared the effects of mobilization and immobilization on the healing process. They found that early mobilization increased the tensile strength of the muscle compared with similarly injured muscles immobilized in a plaster cast.[15-17] Stratton et al[18] used a drop-mass technique that delivers a single blow to muscle to study the effects of therapeutic ultrasound on the injury.

A problem common to all of these models, however, is the inability to characterize the injury in terms of force, displacement, energy, and impulse of the impact actually experienced by the target muscle. Crisco et al[19] developed a model to record these variables in the production of a standard, reproducible muscle contusion injury to the rat gastrocnemius-soleus muscle complex. Others have used this same model to observe a standard contusion injury that causes hematoma formation, with disruption of individual muscle fibers but preservation of others, a brisk inflammatory reaction, and marked interstitial edema.[20]

The extrinsic factors that affect injury severity have not been well documented. The debate continues in the sports arena as to whether athletes should "tighten up" before impact during athletic contests in order to minimize injuries. In studies of muscle strain injury, it has been shown that an activated or contracted muscle will absorb more energy and require a much higher force to failure than passively stretched muscle.[2,21]

Crisco et al[22] showed that contracted muscle was able to absorb more energy during impact than relaxed muscle. The peak force recorded was less pronounced than that in passively impacted muscle. This is complicated, however, by the fact that the impacted legs were an in vivo composite of skin, muscle, fascia, and bone. Contraction simply stiffened the muscle relative to the bone, allowing protection from injury.

Later experiments by Beiner[23] continued the work of Crisco et al[22] and found that the relaxed muscle-bone composite was significantly ($P<0.05$) stiffer than the contracted muscle-bone composite. This was due to the fact that on impact some of the bulk of the relaxed muscle parted, concentrating the force of the impacting sphere on part of the muscle near the bone. In contrast, the contracted muscles were able to absorb energy by displacing less, distributing the force over the entire muscle belly, and avoiding severe damage to any one area. Energy absorbed was 10% more than in the relaxed muscle-bone composite (*P*<0.05). These concepts are illustrated by Figure 1, showing that two peaks are present for impacts to relaxed muscle, one for initial impact on the muscle and the second as the impactor compresses the remaining muscle and hits the bone. Changing the shape of the impacting surface into a bar rather than a sphere changed the injury slightly, but did not seem to change the overall force-generating capacity of the muscles following injury.

To model the effect of constraining hard or soft padding or taping on muscle injury, Beiner[23] analyzed the effects of muscle contraction with exterior constraint (by enclosing the entire leg in a narrow-walled chamber during impact), which limited the extent of the lateral deformation available to the muscle as it absorbed impact. This seemed to cause a much more severe injury. When the muscle was externally constrained during impact, the force-displacement curves of the contracted and relaxed muscle-bone composites were comparable. The injury was 11% greater for constrained muscles in subsequent contractile testing (*P*<0.05). Constraining the muscle also caused the energy absorbed to increase by approximately 11%, as occurs with contraction. It may be that the muscle could not deform while constrained, resulting in more severe injury.

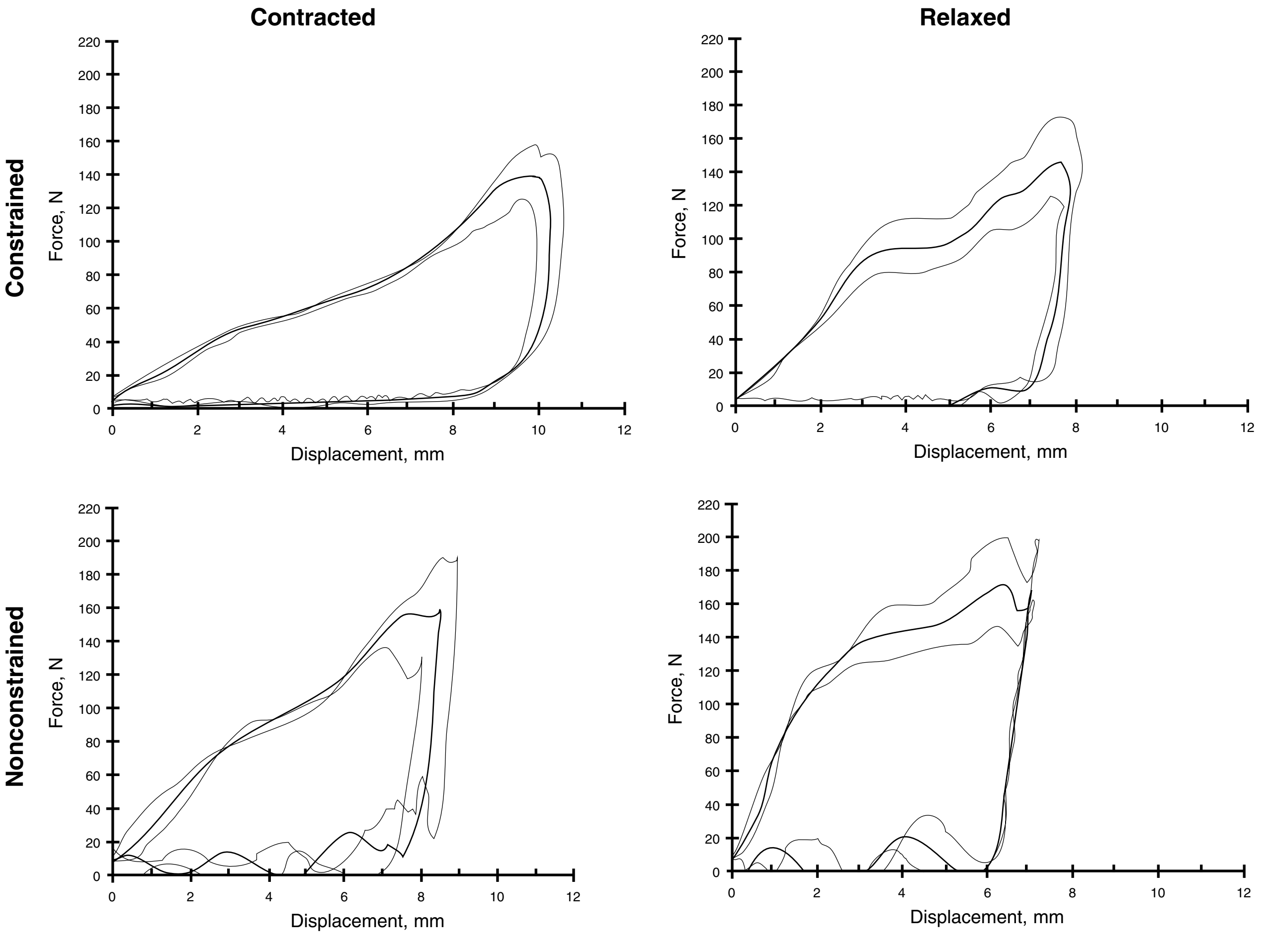

Figure 1 Force-displacement behavior of rat gastrocnemius-soleus muscle complex impacted in either the contracted or relaxed state with a drop-mass technique. The constrained muscles were held with walls on either side, limiting their lateral displacement. Constraining and contraction caused the peak forces to be distributed over a broader area, changing the impulse to the muscles. All impact stimulation was at 100 Hz and 70 V, with a 0.1-msec pulse duration and 1.5-sec train duration. Curves are mean ± SD (N = 27).

Beiner[23] found that both the status of the activation of the muscle during impact (contracted versus relaxed) and the relative level of external constraint of the muscle predicted the force the muscle could generate in contractile testing. Contracted muscle generated a 10% increased force relative to relaxed muscle ($P<0.05$), while constrained muscle was weaker by 11%. Clinical correlates to external constraint include design of pads; the relative volume of muscle that is protected by an enclosing hard plastic pad may affect how the muscle absorbs the energy of impact. More research is needed in this area before further recommendations can be made in the sports arena regarding equipment design and protective measures for impact.

Fatigue has been shown to affect the ability of stretched muscle to withstand injury,[24] as has temperature[25]; no similar studies have been performed in the setting of contusion injury. Fatigue lessens the ability of a muscle to fully contract, and contraction seems to protect the muscle from injury, but a direct causal relationship has yet to be established. Physiologists have long known that muscles operate best within a certain temperature range. Warm-up before exertion thus has obvious benefits, but a direct relationship between overheating, fatigue, and injury has not been delineated.

Muscles in young rats seem to undergo more intense inflammation, with more proliferation of fibroblasts and production of collagen, than old muscles.[26] Young muscles also heal more rapidly and more completely, suggesting the greater power of young regenerating tissue to respond to injury.

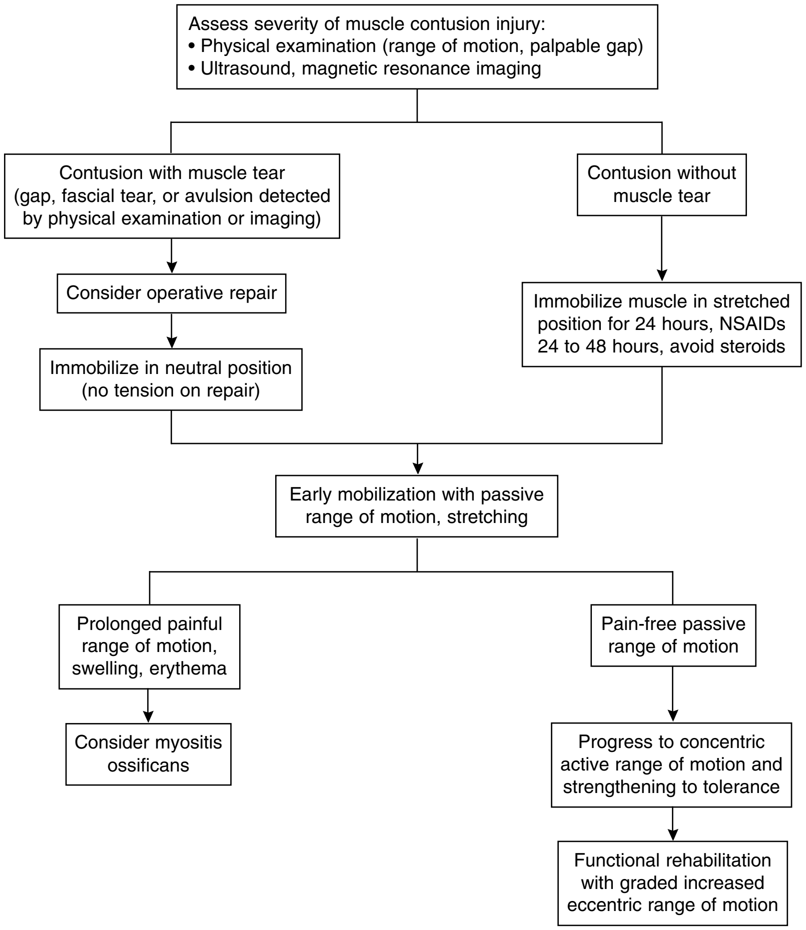

Figure 2 Algorithm for the evaluation and treatment of muscle contusion injuries. NSAIDs = nonsteroidal anti-inflammatory drugs.

Diagnosis

The clinical diagnosis of contusion injury is often fairly direct (Fig. 2). The patient experiences local swelling, tenderness, pain, and impaired athletic performance. The extent and type of soft-tissue injury, however, are less readily established. Many researchers have attempted to demonstrate the usefulness of imaging in determining the extent and the healing of contusion injury. Ultrasound has been used successfully to distinguish pervasive swelling and edema from a localized, circumscribed hematoma.[27] It has also been advocated as a noninvasive aid in determining when to consider surgical evacuation of the hematoma and when to choose the less aggressive compression and early mobilization.

Magnetic resonance (MR) imaging has also been used to evaluate patients with the clinical signs and symptoms of contusion injury, but its role is currently limited to selected patients. It is most useful in the subacute setting when a definite history of trauma is lacking.[28] Although the clinical uses of MR imaging in following contusion injury are less well defined, it has been shown to be more sensitive than computed tomography (CT) for the detection of hemorrhage.[29] It may allow sequential follow-up during healing, and the addition of contrast material may enhance injury recognition and evaluation of the extent of injury.[30]

Standard MR imaging provides information regarding the site and extent of injury, but MR spectroscopy, in limited use for some years, can also be used to estimate the ratio of inorganic phosphate to phosphocreatine, which reflects the metabolic response to muscle injury.[31]

The Healing Process

Fisher et al[32] gave a detailed account of the ultrastructural events after muscle contusion injury to the rat gastrocnemius muscle. Figure 3 shows the histologic appearance of normal healing of contused muscle. Muscle consists primarily of tissue derived from cells of two separate and distinct lineages: fibroblasts and myoblasts. After injury, the damaged segments show gross tearing and degeneration. A large number of mononuclear cells are drawn to the injured area, with an intense inflammatory response and interstitial edema. By 24 to 48 hours, there is an increase in the number of sarcolemmal nuclei, with activation and proliferation of the satellite myogenic cells lying between the basal lamina and the plasma membrane of the muscle fibers. By day 3, regenerating muscle cells display central nuclei and reorganizing sarcomeres. By day 6, focal interstitial collagen formation suggests minimal to mild scar formation. After 14 to 21 days, no residual evidence of the injury is apparent.

Lehto and Järvinen[33] described the important role played by the basal lamina in the regeneration of muscle. If it is intact, it acts as a barrier to fibroblast infiltration and as a scaffold for myoblast proliferation. With more severe injuries, when the gap in the damaged muscle fibers is larger, the ruptured gap can be filled with proliferating granulation tissue and later by a connective tissue scar.[16,34] As described by Lehto and Järvinen,[33] healing of injuries is dependent on several factors: damage to the neural input, vascular ingrowth, oxygen supply, the rate

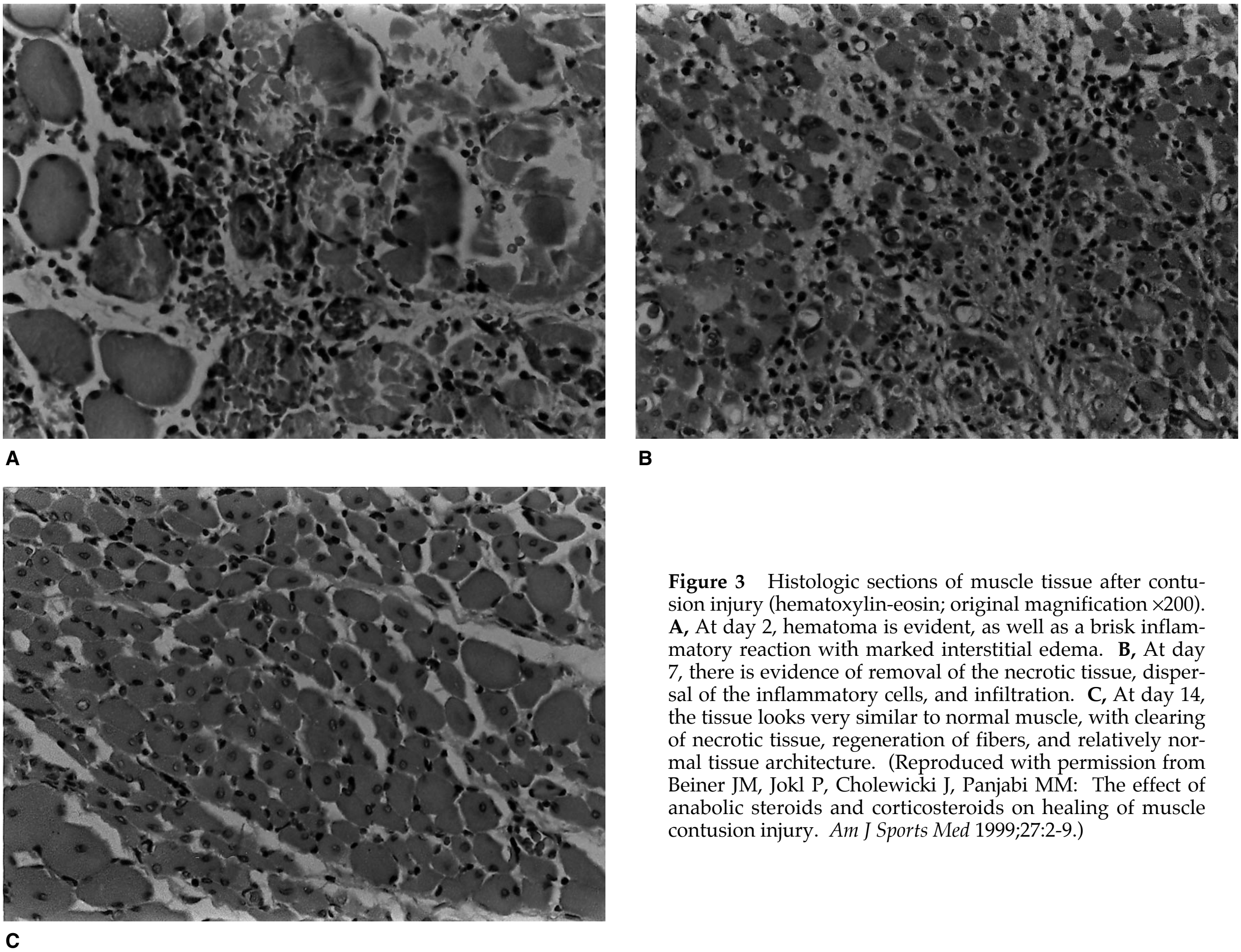

Figure 3 Histologic sections of muscle tissue after contusion injury (hematoxylin-eosin; original magnification ×200). **A,** At day 2, hematoma is evident, as well as a brisk inflammatory reaction with marked interstitial edema. **B,** At day 7, there is evidence of removal of the necrotic tissue, dispersal of the inflammatory cells, and infiltration. **C,** At day 14, the tissue looks very similar to normal muscle, with clearing of necrotic tissue, regeneration of fibers, and relatively normal tissue architecture. (Reproduced with permission from Beiner JM, Jokl P, Cholewicki J, Panjabi MM: The effect of anabolic steroids and corticosteroids on healing of muscle contusion injury. *Am J Sports Med* 1999;27:2-9.)

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