Volumetric Muscle Loss

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Abstract

Prevention of infection, as well as bone covering and healing, is paramount in the management of limb injury with associated muscle injury. Volumetric muscle loss (VML) is the traumatic or surgical loss of skeletal muscle with resultant functional impairment. No standardized evaluation protocol exists for the characterization and quantification of VML. Clinical photographs and video recordings, range of motion measurements, manual muscle strength testing, and isokinetic muscle function testing may prove to be useful in documenting VML. Current treatment options include functional free muscle transfer and the use of advanced bracing designs. Advances in powered bracing and regenerative medicine may one day provide additional therapeutic options. Further research on VML is warranted.

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High-energy civilian trauma and combat-related extremity wounds often involve injury to both bone and soft tissue. Management of these injuries is initially centered on achieving bone healing and on preventing or treating infection.[1] Even with bone healing and adequate management of infection, some patients demonstrate persistent functional deficits related to tissue loss resulting from their initial injuries and related surgical procedures. We define volumetric muscle loss (VML) as the traumatic or surgical loss of skeletal muscle with resultant functional impairment. VML is a substantial treatment challenge for military physicians.

Extremity wounds constitute the majority of injuries sustained by soldiers during Operation Enduring Freedom and Operation Iraqi Freedom.[2] These wounds occur secondary to an explosion in >75% of cases.[2] Masini et al[3] established that extremity injuries "require the greatest utilization of resources for inpatient treatment in the initial postinjury period, cause the greatest number of disabled soldiers, and have the greatest projected disability benefit costs." VML undoubtedly contributes to this burden;[4] however, the impact of VML in these injuries is poorly documented, difficult to characterize, and poorly understood. Additional research is required to understand the significance of VML for patients and the military health care system.

Evaluation and treatment of patients with VML requires the expertise of a multidisciplinary team that includes orthopaedic surgeons, physical and occupation therapists, and orthotists and/or prosthetists. Effective communication among team members depends in part on the accurate characterization of the injuries and functional deficits. Accurate representation of a patient's injuries is difficult because of the varied distribution of injury types and wound locations. The establishment of a standardized protocol for the characterization and quantification of VML could facilitate patient care and may prove valuable in tracking patient progress

Table 1

Types of Volumetric Muscle Loss and Treatment Options

Type	Treatment Options
Partial compartment loss below the knee	Bracing, regenerative medicine[a]
Partial compartment loss above the knee	Powered bracing,[a] regenerative medicine[a]
Total compartment loss below the knee	Bracing
Total compartment loss above the knee[b]	Powered bracing[a]

[a] Possible future therapeutic option
[b] No previously identified cases at our institution

and conducting future research.

Most of our current work on VML has focused on the lower extremity because we are seeing an increased number of wounded service members who request late amputation due to functional deficiencies following limb reconstruction.[5] VML can be subdivided into two categories: partial compartment loss and total compartment loss. Total compartment loss is characterized by the loss of the nerve that supplies the involved compartment. Lower extremity injuries can be further subdivided into above-knee and below-knee VML. Currently, treatment options are more limited for above-knee VML than for below-knee VML (Table 1).

Current protocol at our institution for the evaluation of patients with VML consists of clinical photographs and videos, range of motion (ROM) measurement, manual muscle strength testing, and isokinetic muscle function testing. Photographs are obtained to document the extent of wounds and atrophy of surrounding muscles. Videos facilitate gait analysis and the evaluation of other functional movements.[6] These images can be added to the electronic medical record to facilitate access by all members of the medical team. A goniometer is used to collect ROM measurements. Manual muscle testing is documented using the British Medical Research Council scale.[7] A Biodex System 3 isokinetic dynamometer (Biodex Medical Systems, Shirley, NY) is used to further assess muscle function.[8-10] This protocol, which supplements the standard history and physical examination conducted at office visits, standardizes the evaluation of VML and facilitates coordinated care by the medical team.

Current management options for VML include functional free muscle transfer and the use of advanced bracing. Research into regenerative medicine and powered bracing is ongoing.

Functional free muscle transfer has been used at civilian medical centers to restore motor function and joint movement.[11-13] Lin et al[12] reported successful functional free muscle transfer for the management of traumatic composite soft-tissue and motor unit defects of the lower extremity. Although promising, these procedures are complex; success hinges on using a highly skilled surgical team and on proper patient selection. Donor site morbidity and the technical expertise required to perform these techniques may limit widespread use. Furthermore, results with free tissue transfer have been mixed in patients with combat-related extremity injuries.[14]

Advances in regenerative medicine, such as the use of extracellular matrix scaffolds and mesenchymal stem cells, hint at future therapeutic options for the management of VML.[15-18] Research into a biologic scaffold solution for VML is under way.[19] However, extracellular matrix scaffolds are limited to patients with partial compartment loss above or below the knee. Use of biologic scaffold is limited because it requires the presence of a nerve and remaining adjacent muscle in the compartment.[15] Stem cell solutions may have similar limitations.

Advanced bracing strategies are currently being employed by the limb salvage team at our institution.[20] These braces are carbon fiber, energy-storing ankle-foot orthoses; their construction combines lessons learned from both bracing and prosthetics. Although these braces have the advantage of being a nonsurgical treatment option, they require custom fabrication and are expensive to build. We use advanced bracing for partial and total compartment loss below the knee. Bracing solutions have not yet been developed for compartment loss above the knee. Powered bracing is one potential solution to above-knee VML, but bulk and weight limit the use of this technology.

VML is a significant cause of disability for civilian patients with high-energy trauma and for service members with combat-related extremity wounds. However, it is difficult to evaluate and quantify. A standardized protocol that includes photographs, video, ROM measurements, manual muscle strength testing, and isokinetic muscle function testing can facilitate documentation and management of VML. Current treatment options include functional free muscle transfer and bracing. Future treatment may incorporate regenerative medicine techniques or powered bracing. Further research is needed to better characterize, understand, and treat VML.

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