Ultrasound Findings of Delayed-Onset Muscle Soreness

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The purpose of this series was to retrospectively characterize the ultrasound findings of delayed-onset muscle soreness (DOMS). The Institutional Review Board approved our study, and informed consent was waived. A retrospective search of radiology reports using the key phrase "delayed-onset muscle soreness" and key word "DOMS" from 2001 to 2015 and teaching files was completed to identify cases. The sonograms were reviewed by 3 fellowship-trained musculoskeletal radiologists by consensus. Sonograms were retrospectively characterized with respect to echogenicity (hypoechoic, isoechoic, or hyperechoic), distribution of muscle involvement, and intramuscular pattern (focal versus diffuse and well defined versus poorly defined). Images were also reviewed for muscle enlargement, fluid collection, muscle fiber disruption, and increased flow on color or power Doppler imaging. There were a total of 6 patients identified (5 male and 1 female). The average age was 22 years (range, 7–44 years). Of the 6 patients, there were a total of 11 affected muscles in 7 extremities (1 bilateral case). The involved muscles were in the upper extremity: triceps brachii in 27% (3 of 11), biceps brachii in 18% (2 of 11), brachialis in 18% (2 of 11), brachioradialis in 18% (2 of 11), infraspinatus in 9% (1 of 11), and deltoid in 9% (1 of 11). On ultrasound imaging, the abnormal muscle was hyperechoic in 100% (11 of 11), well defined in 73% (8 of 11), poorly defined in 27% (3 of 11), diffuse in 73% (8 of 11), and focal in 27% (3 of 11). Increased muscle size was found in 82% (9 of 11) and minimal hyperemia in 87.5% (7 of 8). The ultrasound findings of DOMS include hyperechoic involvement of an upper extremity muscle, most commonly appearing well defined and diffuse with increased muscle size and minimal hyperemia.

Key Words—delayed-onset muscle soreness; injury; muscle; musculoskeletal ultrasound

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Abbreviations
DOMS, delayed-onset muscle soreness; MRI, magnetic resonance imaging

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There are many causes of muscle pain, which include muscle strain, contusions, and tears; another cause of muscle pain is delayed-onset muscle soreness (DOMS), which is considered a type 1 muscle strain.[1,2] Delayed-onset muscle soreness is the development of pain, soreness, or stiffness of the activated musculature after intense physical activity due to muscle microtrauma, resulting in inflammation and edema.[2] The onset of symptoms is approximately 24 hours after the activity, peaking at 48 to 72 hours, and resolving within 5 to 7 days after the inciting activity.[2,3] Delayed-onset muscle soreness can predispose to increased risk of further injury,[1] hence the importance of accurate diagnosis.

The findings of DOMS have been described on magnetic resonance imaging (MRI), which include edema and increased size of the affected muscle.[3–5] Little has been written with regard to ultrasound findings associated with DOMS. One study by Tagliafico et al[6] in 2013 showed a single example of increased echogenicity of the brachialis muscle with DOMS. In addition, a recent study by Yu et al[7] in 2015 described an increased pennation angle of the muscle and the muscle thickness in DOMS. To our knowledge, no articles have been published fully characterizing the ultrasound features of DOMS.

In our clinical practice, we have imaged patients who present for ultrasound evaluation of muscle pain with clinical findings of DOMS. Understanding the distribution, echogenicity, and other ultrasound imaging of DOMS is important for an accurate diagnosis. The purpose of this series was to retrospectively characterize the ultrasound imaging features of DOMS.

Materials and Methods

The Institutional Review Board approved our study, and informed consent was waived. A retrospective search of radiology reports from 2001 to 2015 was completed using the key phrase "delayed-onset muscle soreness" and key word "DOMS" to identify cases. This search was supplemented by a search of one of the authors' personal teaching cases.

The sonograms were reviewed by 3 fellowship-trained musculoskeletal radiologists by consensus. Sonograms were retrospectively characterized with respect to echogenicity (hypoechoic, isoechoic, or hyperechoic relative to uninvolved muscle), distribution of muscle involvement, as well as intramuscular pattern (focal versus diffuse and well defined versus poorly defined). Muscle enlargement was assessed by comparing to the unaffected area of muscle and contralateral unaffected side. Images were also reviewed for fluid collection (well-defined anechoic area with increased posterior through-transmission) and increased flow on color or power Doppler imaging. The patients' medical records were retrospectively reviewed, and demographic, clinical, and laboratory data were recorded and described. Available correlative imaging was also reviewed.

Results

There were a total of 6 patients identified, which included 5 male and 1 female patients (Table 1). The average age was 22 years (range, 7–44 years). In 1 patient, there was bilateral involvement, resulting in a total of 7 extremities. Only upper extremity muscles were involved, with 3 muscles affected in 1 extremity, 2 muscles in 2 extremities, and 1 muscle in the remaining 4 extremities, resulting in a total number of 11 muscles involved for review. Specific muscle involvement included triceps brachii in 27% (3 of 11), biceps brachii in 18% (2 of 11), brachialis in 18% (2 of 11), brachioradialis in 18% (2 of 11), infraspinatus in 9% (1 of 11), and deltoid in 9% (1 of 11). The patient with involvement of 3 muscles in an extremity included the biceps brachii, brachioradialis, and brachialis (Figure 1). The 2 patients with involvement of 2 muscles in an extremity included the deltoid and triceps brachii (Figure 2) and brachialis and bicep brachii (Figure 3), respectively. The 1 patient with bilateral involvement had triceps brachii muscle involvement on each side.

Retrospective review of the sonograms showed an abnormal hyperechoic appearance to the muscle in 100% (11 of 11; Figures 1–3). The borders of the abnormal hyperechoic area were well defined in 73% (8 of 11) and poorly defined in 27% (3 of 11). The extent of the abnormal hyper-

Table 1. Patient Characteristics

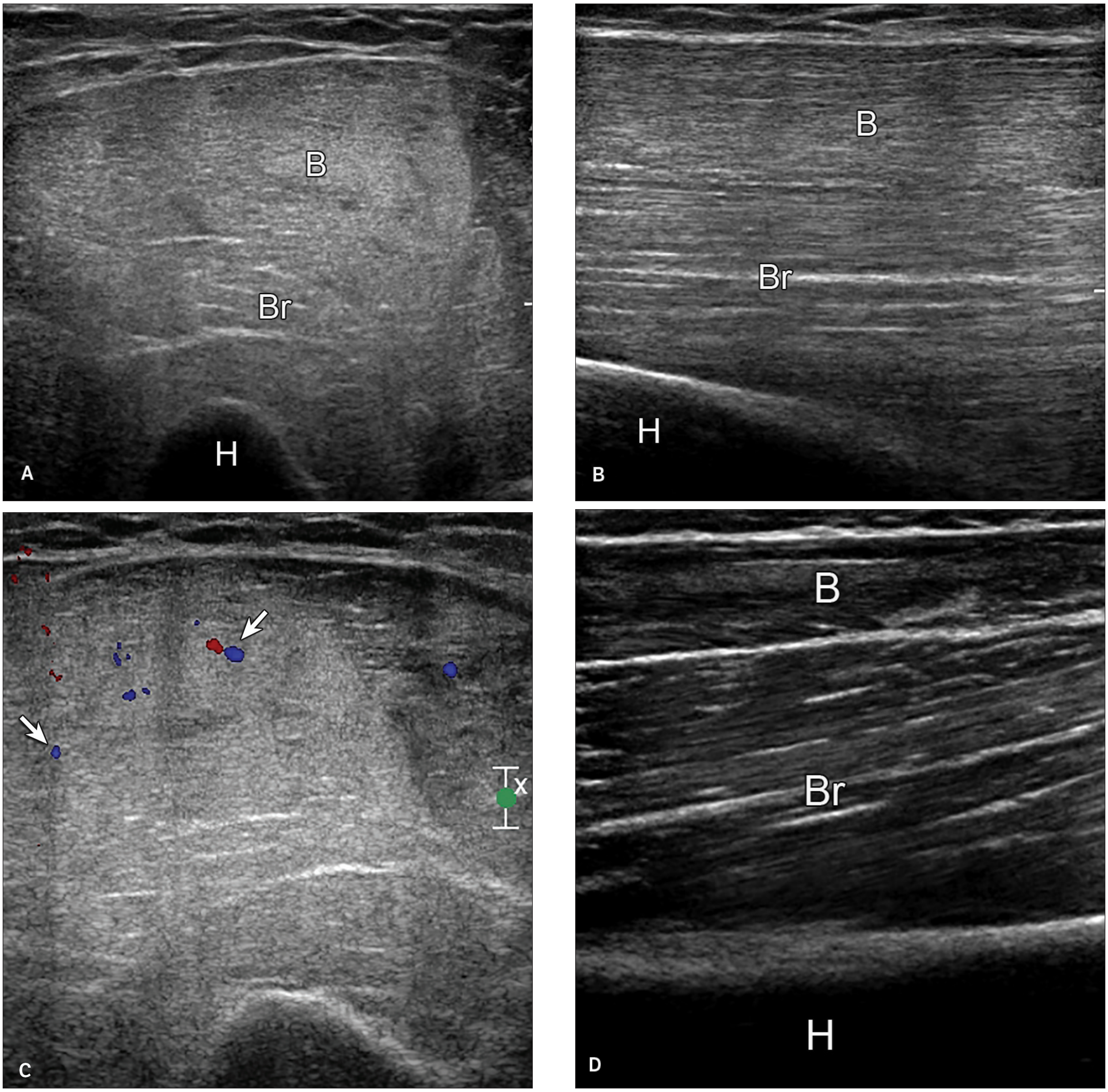
Patient	Muscle	Side	Echo	Definition	Extent	Size	Hyperemia	Tear	Fluid
1	Biceps	Right	Hyper	Well	Diffuse	Increased	Minimal	No	No
	Brachialis	Right	Hyper	Well	Diffuse	Increased	Minimal	No	No
	Brachioradialis	Right	Hyper	Poor	Focal	Increased	Minimal	No	No
2	Deltoid	Left	Hyper	Poor	Focal	None	Minimal	No	No
	Triceps	Left	Hyper	Well	Focal	None	NA	No	No
3	Brachioradialis	Left	Hyper	Poor	Diffuse	Increased	None	No	No
4	Infraspinatus	Right	Hyper	Well	Diffuse	Increased	Minimal	No	No
5	Triceps	Left	Hyper	Well	Diffuse	Increased	Minimal	No	No
	Triceps	Right	Hyper	Well	Diffuse	Increased	Minimal	No	No
6	Biceps	Right	Hyper	Well	Diffuse	Increased	NA	No	No
	Brachialis	Right	Hyper	Well	Diffuse	Increased	NA	No	No

NA indicates not applicable.

echoic area was considered diffuse in 73% (8 of 11) and focal in 27% (3 of 11). Overall muscle size was increased in 82% (9 of 11) and normal in 18% (2 of 11). Color or power Doppler images were available in 73% (8 of 11), which showed scattered pixels of increased flow in 87.5% (7 of 8; Figure 1C) and no flow in 12.5% (1 of 8). In no cases were there muscle fiber disruption or fluid collections noted.

With regard to available clinical information, 1 patient with unilateral involvement of the biceps brachii and brachialis (16-year-old male) developed symptoms after using the weight room (Figure 3). In 1 patient (14-year-old male) with bilateral triceps brachii involvement, the inciting activity event was reported as performing "100 push-ups," and he had a markedly elevated creatine phos-

Figure 1. Images from a 27-year-old male patient with DOMS affecting the brachialis and biceps brachii. Sonograms of the anterior arm short axis (**A**) and long axis (**B**) to the humerus (H) show diffuse and well-defined increased echogenicity of the biceps brachii (B) and brachialis (Br) muscles with foci of hyperemia (**C**, arrows) on color Doppler imaging. Note normal musculature of contralateral asymptomatic arm long axis to the humerus (**D**).



phokinase value of 36,716, consistent with the clinical diagnosis of rhabdomyolysis. One patient with involvement of the deltoid and triceps brachii (32-year-old female) in 1 extremity developed symptoms after swimming (Figure 2). Another patient with solitary involvement of the brachioradialis (44-year-old male) developed symptoms after golfing. In the remaining patients, the inciting physical event was not detailed in the clinical records or was not available. The average interval between the onset of symptoms and the ultrasound examination was 8.5 days (range, 1–19 days). None of the patients had MRI of the involved muscle.

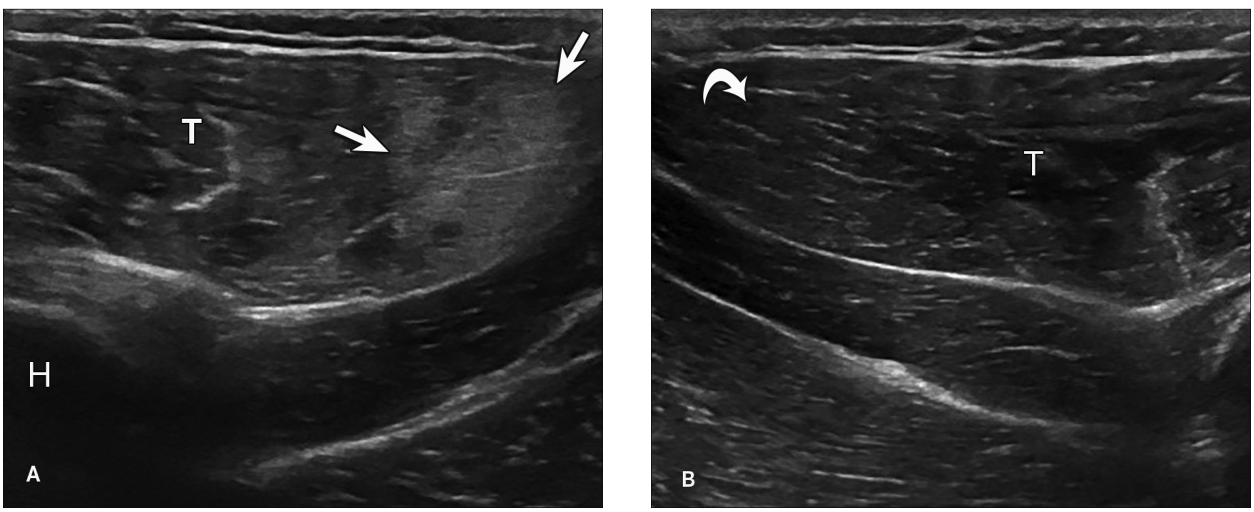
Discussion

Clinical findings of DOMS after muscle exertion may be severe and warrant imaging evaluation. There are only limited studies evaluating the imaging findings of DOMS. The results of our series show that DOMS most frequently involves the upper extremity musculature and characteristically appears as muscle enlargement with areas of diffuse and well-defined increased echogenicity as shown on ultrasound imaging.

Delayed-onset muscle soreness is a symptom that may occur after intense exercise or submaximal muscle exertion and is considered a type 1 muscle strain. It is often associated with eccentric muscle contractions, in which a muscle is lengthening while attempting to develop force and shorten.[4,8] There are several proposed mechanisms of DOMS that may contribute to symptoms, which include lactic acid accumulation, muscle spasm, connective tissue damage, muscle damage, inflammation, and enzyme efflux.[1] It is believed that microtrauma to muscle and adjacent connective tissues causes inflammation and a shift of fluid.[2] Delayed-onset muscle soreness can be associated with elevated serum muscle protein levels, such as creatine kinase, and in severe situations rhabdomyolysis and compartment syndrome.[3,4] Magnetic resonance imaging has shown an increase in muscle edema volume with DOMS, which correlates with creatine kinase and symptoms.[4] Typical onset of DOMS is within 24 hours of activity, peaking by 48 to 72 hours; however, it may not fully subside for up to 10 days.[8] Of interest, the symptoms associated with DOMS are subsequently reduced if the original inciting activity is repeated later.[3,4]

Imaging findings of DOMS have been only briefly described in the literature. On MRI, DOMS may produce muscle enlargement and increased edema.[3–5] The latter peaks several days after the inciting activity but may persist up to 75 days.[3] There is very little in the literature describing the ultrasound findings of DOMS. A study by Dierking et al[8] in 2000 showed an increase in the cross-sectional area of the biceps brachii with DOMS as measured with ultrasound, but this measurement lacked sensitivity in the diagnosis when compared to creatine kinase, muscle shortening, and subjective muscle soreness. In contrast, a study by Yu et al[7] in 2015 showed statistically significant increases in muscle thickness and the pennation angle of the medial gastrocnemius as measured with ultrasound as DOMS progressed over time. One additional report showed increased echogenicity of

Figure 2. Images from a 32-year-old female patient with DOMS after swimming affecting the triceps brachii. Sonogram of the posterior arm (**A**) short axis to the humerus (H) shows focal and well-defined increased echogenicity (arrows) within the triceps brachii (T) muscle. Note normal musculature (**B**, curved arrow) of the contralateral asymptomatic arm short axis to the humerus.



the brachialis in a patient with DOMS.[6] There are no studies to date that fully characterize the ultrasound features associated with DOMS.

The results of our series demonstrate that DOMS presents on ultrasound imaging as an enlarged muscle with well-defined diffuse hyperechogenicity correlating with the site of the patient's symptoms. An abnormal poorly defined or focal area of muscle hyperechogenicity may occur but less commonly. The finding of increased echogenicity likely correlates with muscle edema of DOMS as described in the literature when imaged with MRI.[3,4] Infiltrating edema through muscle tissue creates increased interfaces that produce reflective echoes during ultrasound imaging, which has also been described with other causes of muscle edema and inflammation.[9] Most patients (87.5%) showed increased flow on color and power Doppler imaging, which appeared as scattered pixels of flow related to hyperemia. Regarding the distribution of muscle involvement, it is interesting that no patients had lower extremity involvement. This finding is in contrast to the study by Megliola et al,[5] which described DOMS of the lower extremity in European football players and is likely explained by a selection bias. Because ultrasound examinations were performed at only a single time point in our patients, we were unable to determine what changes occurred over time and when the ultrasound findings resolved.

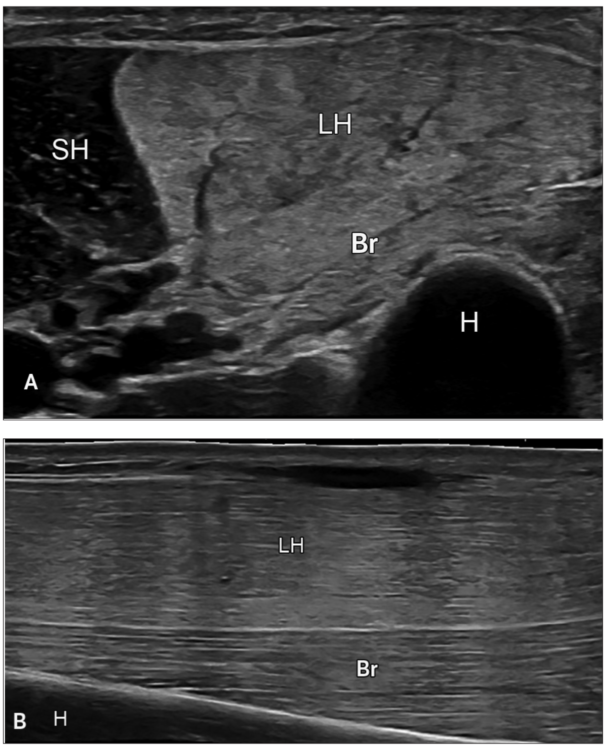


Figure 3. Images from a 16-year-old male patient with DOMS after weight lifting affecting the brachialis and biceps brachii. Sonograms of the anterior arm short axis (**A**) and long axis (**B**) to the humerus (H) show diffuse and well-defined increased echogenicity of the biceps brachii long head (LH) and brachialis (Br) muscles with a normal biceps brachii short head (SH).

Our study was limited by its retrospective design. In addition, the study was limited by the small sample size, likely in part because many patients may not present for clinical assessment or imaging. Another limitation was the absence of lower extremity cases. Further study is required to determine whether the observed ultrasound findings can be applied to other muscle groups. Pennation angles were not recorded, as measurements were deemed difficult because of the retrospective design and increased echogenicity of the musculature. Last, the retrospective design did not allow us to determine how the ultrasound findings changed over time and when they resolved.

In conclusion, the ultrasound findings of DOMS include hyperechoic involvement of an upper extremity muscle, most commonly appearing well defined and diffuse with increased muscle size and minimal hyperemia. Prospective studies are needed to assess how these muscle findings change over time.

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