ULTRASOUND ARTICLE

Ultrasound-Guided Interventional Procedures
Myofascial Trigger Points With Structured Literature Review

Dinesh Kumbhare, MD, MSc, FRCPC, Dhanveer Singh, BSc,† Alasdair Rathbone H., BKin,‡ Madison Gunn, BSc,§ Liza Grosman-Rimon, PhD,* Brian Vadasz, MSc,* Hance Clarke, MD, PhD,|| and Philip W.H. Peng, MBBS, FRCPC, Founder (Pain Medicine)***

Abstract: Ultrasound-guided injections in pain medicine are a common intervention. They have been used to manage myofascial trigger points (MTrPs) in different muscles of the body. The main objectives of this article were to review ultrasound-guided injection techniques used for treating MTrPs. We also summarize the anatomy and sonoanatomy of MTrPs using the upper trapezius muscle as an example.

(*Reg Anesth Pain Med* 2017;42: 407–412)

Myofascial pain syndrome (MPS) is a common regional musculoskeletal pain syndrome that can cause local or referred pain.[1–3] It is characterized by myofascial trigger points (MTrPs), which are hard, palpable, discrete, localized nodules located within taut bands of skeletal muscle and can be painful on compression.[4,5] The syndrome affects primarily adults and predominantly females.[6,7] The prevalence of myofascial pain varies from 21% of patients seen in general orthopedic clinics and 30% of general medical clinic patients with regional pain, to as many as 85% to 93% of patients presenting to specialty pain management centers.[6–8] In 1985, it was estimated that 44 million Americans had myofascial pain problems,[9] a number we believe to be higher today.

The pathophysiology of trigger point formation is not fully understood. It has been reported that physical overloading of the muscles is a key factor.[4,10] Additionally, acute trauma or repetitive microtrauma has been implicated in the formation of trigger points owing to the mechanical stress inflicted on muscle fibers.[11] Lack of physical activity, prolonged poor posture, vitamin deficiencies, sleep disturbances, and joint problems may all increase the risk of developing the microtrauma and thus increase the likelihood of developing trigger points.[12] In our opinion, microtrauma is a potential theoretical risk. Once a trigger point has developed, decreased ATP and glycogen concentration, increased release of substance P, acetylcholine, bradykinin, serotonin, and prostaglandin occur within the MTrP. These are associated with increased receptor sensitivity that may overstimulate local afferent sensory nerves causing the perception of pain in a trigger point.[4,13,14] These latter issues are part of central sensitization and neurogenic inflammation. This article is focused on critically reviewing the techniques used for injection, and so these theories will not be expanded upon further. Injections are one of the main treatment modalities used to manage the trigger point clinically.[11,12]

From the *Division of Physical Medicine & Rehabilitation, Department of Medicine, University of Toronto, Ontario, Canada; †Royal College of Surgeons in Ireland, Dublin, Ireland; ‡University of Western Ontario, London, Ontario, Canada; §Queen's University, Kingston, Ontario, Canada; ||Department of Anesthesia, Toronto General Hospital, Toronto, Ontario, Canada; and **Department of Anesthesia, Toronto Western Hospital, Toronto, Ontario, Canada.

Accepted for publication November 30, 2016.

Address correspondence to: Dinesh Kumbhare, MD, MSc, FRCPC, Division of Physical Medicine & Rehabilitation, Department of Medicine, University of Toronto, 550 University Ave, Toronto, Ontario, Canada M5G 2A2 (e-mail: dinesh.kumbhare@uhn.ca).

The authors declare no conflict of interest.

ISSN: 1098-7339
DOI: 10.1097/AAP.0000000000000572

Myofascial Trigger Points in Clinical Practice

Simons[4,5] was the first to describe the following criteria for the identification of trigger points by palpation: a taut band, local tenderness, pain recognition, referred pain, a local twitch response (LTR), and the "jump sign." Investigators in this study did not define the criteria for the clinical identification of taut bands but rather provided a list of signs. Because many of the MTrP clinical criteria are nonspecific and overlap with other causes of regional pain, diagnosis can be difficult.

According to a systematic review by Tough et al,[15] the originally proposed criteria are used inconsistently in research. Many studies included only subsets of the criteria. More than half of all studies that were reviewed used 2 criteria: (1) tender point in a taut band and (2) predicted or recognized pain referral.[15] The lack of acceptance of standardized criteria has made it difficult to analyze and compare results from different studies and over time has led to a change in the way MTrPs were diagnosed, leading to variable diagnoses by physicians.

An attempt to standardize diagnostic criteria has been made by surveying practicing physicians on the importance of having diagnostic criteria for MPS. Both recent surveys[16,17] assessing physicians' opinion agreed that point tenderness and reproduction of pain are key to diagnosis, while autonomic symptoms are unnecessary. Rivers et al[16] used their survey results and proposed the following diagnostic criteria based on physicians' consensus:

1. A tender spot is found with palpation, with or without referral of pain ("trigger point") *and*;
2. Recognition of symptoms by patient during palpation of tender spot *and*;
3. At least three of the following:
   a. Muscle stiffness or spasm
   b. Limited range of motion of an associated joint
   c. Pain worsens with stress
   d. Palpation of taut band and/or nodule associated with a tender spot

Why Palpation is Not Enough: the Need for Diagnostic and Therapeutic Ultrasound Guidance

Until now, the diagnosis of MPS has relied solely on the physician's ability to identify MTrPs. The detection of a palpable abnormality is generally associated with pain, which is subjective, and detection can be hampered especially when physicians do not use effective palpation techniques. Since palpation lacks objectivity, it presents a major problem for physicians because a lack

of quantification can prevent an accepted diagnosis from being reached and hinder progress in future studies. Previously published reviews[18,19] on the reliability of manual palpation for MTrP localization generally report poor agreement and reliability. In addition to the shortcomings of palpation, there is no established criterion standard test for diagnosing MTrPs. Therefore, the physicians are left to rely on the presence (or absence) of a collection of clinical signs and symptoms to determine the existence of a MTrP. Physicians combine these results to arrive at a conclusion regarding the diagnosis of a MTrP. Therefore, clinical detection rates with physical examination are low and have unacceptably poor inter-rater reliability. This is extremely important, as injection-based therapies for MTrPs are centered on the insertion of a needle into these nodules.[20]

The lack of inter-rater reliability may be related to the small size of MTrPs. A recent ultrasound (US) study of MTrPs in the ankle and foot region found that MTrPs ranged in size from 0.05 to 0.21 cm^2, with a mean of 0.09 cm^2.[21] Moreover, Sikdar et al[22] previously attempted to use US imaging to visualize and characterize trigger points within the trapezius muscle. They observed that MTrPs appear as discrete, focal, hypoechoic regions with an elliptical shape and a size of approximately 0.16 ± 0.11 cm^2.[11,22,23] These small sizes of the MTrPs identified using US imaging present a difficulty when localizing trigger points by palpation. A study that examined intra-rater reliability of trigger point localization in the upper trapezius found a 0.15-cm test-retest mean difference in localization between examinations.[24] Therefore, before accounting for the difficulty of palpating while injecting, the mean difference in localization is approximately the average size of a trigger point. This suggests that there is a large margin of error that can lead to incorrect trigger point injection (TPI). Given this information, we suggest that accurate injection is challenging without image guidance. The poor detection accuracy of MTrPs is highly likely the reason that previous studies[25,26] have failed to identify benefits from TPIs. Therefore, we believe that the use of an imaging modality is necessary to improve MTrP detection rate, reliability, and diagnostic objectivity.

Diagnostic US has been used extensively in medical office settings to provide noninvasive, real-time imaging of muscle, tendon, fascia, blood vessels, and other soft tissues. Although US is a low-risk procedure,[22,27–30] it is not used routinely for diagnosing MTrPs. Several studies that assessed MTrPs using US imaging were able to distinguish between active MTrPs, latent MTrPs, and normal tissue.[17,22,27,28,31–33] These studies describe the shape, and hemodynamic and viscoelastic properties of MTrPs using various US techniques, including B-mode, Doppler, and elastography US.[17,22,27,28,31–34] Of all these techniques, B-mode is used most often in clinical practice and, therefore, we concentrate on this for our review. Currently there are no studies that examine the use of elastography in TPI. Future studies should investigate the use of elastography for injecting the MTrP.

The Sono-Anatomy of Trigger Points

When performing US, from the top, the image consists of skin, subcutaneous tissue, fascia, and then skeletal muscle. We display a picture of an anatomical dissection next to an image of B-mode US to show the comparable structures to allow appropriate identification. The convention for imaging is to align the transducer longitudinally along the course of the fibers. The image can show "speckling," which is small irregular white regions within the muscle fiber. These can represent fascia, aponeuroses, and intramuscular adipose tissue. These are best characterized with small movements (along the skin surface, and tilting) of the transducer.

We have performed a critical review of the physical characteristics of MTrPs and potential findings upon US examination. Results are summarized in Table 1.[35]

Work by Sikdar et al[22] describes MTrPs as hypoechoic, whereas other studies[29,30] report hyperechoic MTrPs. These studies have many inherent methodological flaws, including insufficient sample size and a lack of randomization and/or blinding. In addition, there is no inter-rater reliability data available. Thus, although most of the available literature suggest that MTrPs can be identified on B-mode US as hypoechoic regions with measurable viscoelastic properties (viscosity and stiffness), there is no definite consensus in the literature.

Ultrasound also offers the ability to dynamically image the immediate response to injection therapy. Niraj et al[36] reported that injection causes a trigger point to become prominent on US. In addition, it has now been acknowledged that the observation of an LTR during MTrP injection, which is identified most clearly using US imaging, predicts a better clinical response to injection therapy.[37]

An important element to consider when assessing the possible applications of US in TPIs is the operator-dependent nature of this imaging modality. For US to be used in a clinical setting, the practitioner must be familiar with regional musculoskeletal anatomy as well as the sonoanatomy of MTrPs (Figs. 1, 2). The

TABLE 1. Myofascial Trigger Point Characterization Using US Examination and Diagnostic Criteria

MTrP Characterization	
Physical Characteristics	**US Examination**
A taut band	Spherical/Elliptically shaped or a bandlike area (Bmode)
Local tenderness upon palpation	Hypoechoic—appearing as darker gray areas (Bmode)
Local pain heightens with use	Stiffer—reduced vibration amplitude (Elastography)
Pain recognition	High peak systolic velocity and low diastolic peak systolic velocity than normal muscle tissue (Doppler)
Referred pain	Retrograde diastolic flow (Doppler)
Local twitch response (LTR)	Blood volume at MTrP increased (Doppler)
Restricted range of motion	Increased outflow resistance/vasoconstriction (Doppler)
Reproducible pain pattern	
Weakness without atrophy	

The column on the left outlines the clinical and physical characteristics of myofascial pain syndrome and MTrPs. The column on the right shows the features of US imaging and what different US modes may display.

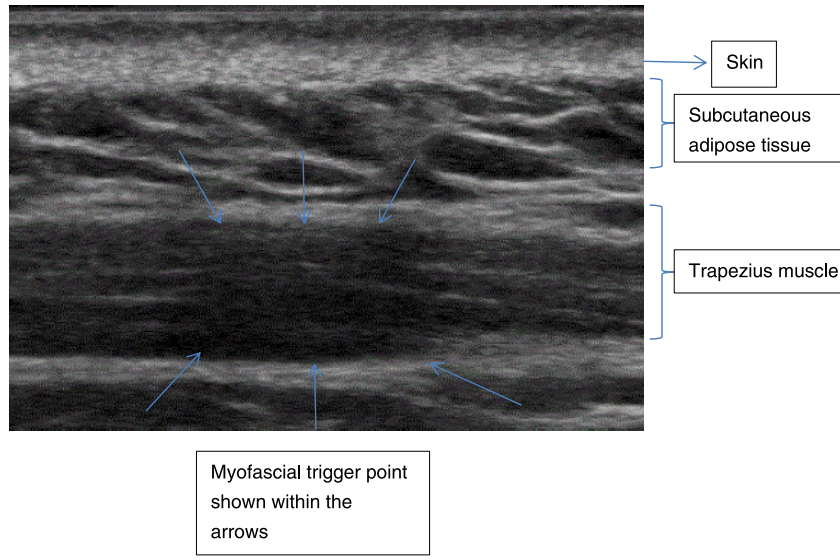

FIGURE 1. B-mode US image of MTrP.

physician should also know how to navigate in a 3-dimensional environment by mentally integrating the 2-dimensional information provided by the US probe. In addition, they should be able to rapidly process the visual information presented and consistently maneuver the US transducer to detect MTrPs.

METHODS

Ultrasound-Guided Injections: Identifying the Evidence

To identify previous reports and relevant studies, we conducted an extensive review. We reviewed all articles that were full peer-reviewed systematic reviews or randomized controlled trials detailing the use of TPIs in patients with chronic nonmalignant pain of musculoskeletal origin that had persisted for at least 3 months. Studies on patients with pain secondary to a defined systemic disease, such as cancer or diabetes, were excluded unless the data subset included patients with chronic musculoskeletal pain, and their data could be separated from the aggregate data. Moreover, animal studies, non-English articles, and articles describing injection techniques for regions other than the head, neck, and trapezius muscle were excluded. This decision was made to focus the review on the most commonly injected muscle, the upper trapezius muscle.

The Evidence

Our systematic review identified 31 references of which only 2 studies used US to localize MTrPs. The remaining studies used either a "blind technique" or did not adequately describe their method of injection. Our review of the articles revealed that the blind technique indicated that the study authors palpating the painful region and then injecting at that location without the use of

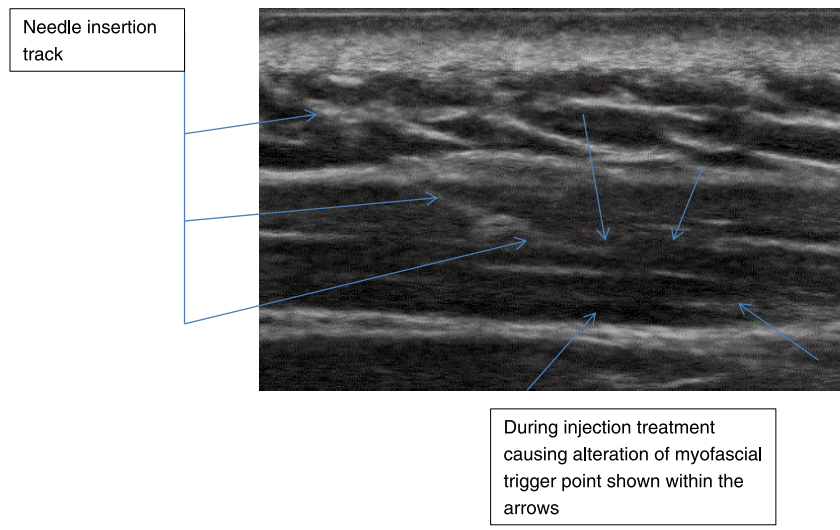

FIGURE 2. B-mode US image demonstrating injection of the MTrP with the needle insertion track and alteration of the trigger point during injection.

an imaging modality. The results from these studies indicate variable improvements in visual analog scale pain ratings.

The 2 studies[38,39] that used US demonstrated significant improvements in pain ratings, increased the LTR elicitation, and significantly reduced the number of MTrPs needled, as well as the number of treatment sessions. The studies are summarized in Table 2.

However, as mentioned earlier, all of these techniques that use dry or wet needling, corticosteroids, nonsteroidal anti-inflammatory drugs, botulinum A toxin, or local anesthetics rely on accurate identification and localization of MTrPs.[26,40] In our opinion, the efficacy of these methods would be enhanced if the physician were able to more accurately localize the trigger point, which can be achieved through the use of an imaging modality. We believe there is strong justification to use US-guided TPI given the results of the 2 studies using US guidance, and strong reasoning that visualization with US is more likely to offer improved identification and localization of trigger points than often unreliable manual palpation. In our opinion, US-guided injection is more likely to avoid inaccurate insertion of the needle and therefore prevent adverse consequences to patients. Ultrasound guidance is low risk and improves accuracy in treatment.

DISCUSSION

Ultrasound Injection Technique

Recognizing that some experts will disagree on approach, we suggest physicians follow the steps below to effectively use the injection technique in conjunction with an imaging modality such as US. These recommendations are based on our literature review of the limited studies using US guidance and our expert opinion.

1) The physician should locate a trigger point by manual palpation starting with the locations as described by Travell and Simon.[41,42] If the physician is unable to detect a trigger point at this anatomical location, he or she should methodically scan the entire region of the muscle surrounding the locations described by Travell and Simon[41,42] to locate or rule out the presence of a structural entity. If the physician detects a palpable nodule, the US probe should be applied to this specific region.
2) The trigger point should be identified on US as a spherical or elliptical shaped object or band that is hypoechoic on B-mode US. Owing to the need for post–image acquisition processing associated with elastography and Doppler US with the current technology, these techniques cannot be used in the clinic. If there is a detectable structural lesion, use US to guide the injection; however, if there is no detectible structural lesion, do not inject. Do not proceed to the next step.
3) After the trigger point has been identified, the physician should use B-mode US with a linear probe in a longitudinal orientation located over the identified trigger point and insert the needle using the sterile technique at approximately a 30-degree angle and visualize the needle going into the trigger point. It is important to note that the "out of plane" approach has major disadvantages, since the needle cannot be tracked while it is inserted through the tissues to reach the trigger point. However, some experts prefer this technique, and it can be used if the injector is comfortable with it.

TABLE 2. Summary of US-Guided Injection Efficacy Trials

Author	N	Location	Injectate and Intervention	Localization & Technique	Findings
Bubnov et al[38] (2012)	44	Shoulder muscles	DN, TPI	Localization: manual palpation Technique: US guided	The pain level had improvement from 7.5 to 1.1 on VAS at 24 hours after procedure compared to 7.4 to 4.2 the US-guided group ($P < 0.001$). LTR was elicited in 100% in group A compared to 14 % in group B ($P < 0.001$). There were registered significant correlations in 2 groups between level of eliciting, intramanipulation soreness, and the pain relief effect. Pain and trigger point recurrence was significantly lower with DN. MTrPs DN with US is preferred over TPI.
Bubnov et al[39] (2013)	133	Pterygopalatine muscle	DN	Localization: clinical (palpatory) established landmarks Technique: US guided	Pain, as measured on a VAS; 0-10, showed significant reduction ($P < 0.001$) from 7.2 to 1.1 at 24 hours after DN with US in the intervention group (pain level decreased in 84% of the subjects) compared to improvement from 7.4 to 2.7 at 24 hours after dry needling without US guidance (pain level decreased in 63.5% of the subjects) in the control group ($P < 0.001$). There were significant correlations registered between the level of eliciting LTR during needling and the pain-relief effect (VAS decreased more than average percentage; $r = 0.717$). Ultrasound guidance significantly increased the pain relief effect, increased the level of eliciting LTR, and significantly decreased the average number of needled TPs and the average number of Tx sessions.

DN, dry needling; TPs, trigger points; Tx, treatment; VAS, Visual Analog Scale.

4) Once the needle has been placed into the correct location, the injectate can be delivered. If no injectate is used (ie, dry needling), then the needle should be inserted and withdrawn from the trigger point repeatedly.
5) The physician should then observe for the LTR and then withdraw the needle, applying pressure over the injection site and ensuring hemostasis is achieved.
6) At this point, the physician should scan the region to observe the structural characteristics of the trigger point. The trigger point may change in shape, decrease in size, or disappear completely. If this is not observed, then the physician should repeat the injection process previously described, particularly if no LTR was observed.
7) Seventh, the physician should document the observations, as well as the degree of pain relief and change in range of motion and compare them to follow-up assessments.
8) Repeat injections should be considered if initial relief (>30%) was obtained and maintained beyond 3 half-lives of the injected medication, but partial or complete relapse occurs by follow-up. There are 2 reasons for using 3 half-lives. The first is that we would prefer not to attribute therapeutic success if a placebo effect could be present. Second, the other reason to perform a TPI is to reduce nociceptive input, and therapeutic benefit should outlast the time of drug action. In this way, the physician can accurately determine the effect of the TPI on the spinal cord segment. We recommend providing the patient with a data collection diary or form to track their responses.

Potential Complications of the MTrP Injection

As with any minimally invasive technique, there are potential risks involved. Adverse effects can be classified as (1) fibrosis and contractures, (2) nerve injury, (3) abscesses, (4) gangrene, and (5) local and systemic reactions.[43] Fibrosis and contractures of skeletal muscle are the most common complications seen. A large-volume injection into a small muscle can also give rise to ischemia, muscle necrosis, and later fibrosis and muscle contracture.[44,45] Infection at the site of injection, abscess, or gangrene are possible rare complications, which can be minimized by using the sterile technique and avoiding injection of immune-compromised patients. Importantly, nerve injury has also been described but can be avoided by accurately visualizing the needle tip on US during the injection process. Local erythema, bleeding, and pain can also occur. If the injection causes the muscle to go into spasm, then decreased range of motion could also occur. These effects are typically self-limited and respond to local physical modalities. They should be monitored if they persist. Systemic toxicity of any injectate must be considered but can be avoided by choosing injectates that have minimal systemic absorption from intramuscular injections and by accurately visualizing the needle tip using US during the injection process to avoid intravascular injection.

CONCLUSIONS

Myofascial trigger points are very common in clinical practice. They are managed by injection therapies, but there is no consensus about the technique for injection. Our critical review provides 2 studies that used US guidance for injection of the MTrP. Most of the research to date used the "blind" technique. The blind method may result in poor localization of the MTrP. Further work is required to develop US-based criteria, quantify its reliability, and determine its clinical use. However, in the interim, there is strong reason to believe that US-guided TPIs offer potential benefits to patients, including improved localization, injection into the MTrP, and reduction of adverse events. We have outlined recommendations for a safe and effective method for TPIs. Future studies would benefit from using the technique as a standard to allow for more accurate comparisons between studies. We suggest that randomized multicenter studies should thoroughly investigate the clinical outcomes of US-guided injection versus nonguided techniques. We suggest that the use of US is an optimum technique for localizing trigger points and improved accuracy for the delivery of injectates. As a result, less medication would be used, which prevents medication and injection-related adverse events while offering the maximum benefit to the patient.

REFERENCES

1. Gerwin RD. Classification, epidemiology, and natural history of myofascial pain syndrome. *Curr Pain Headache Rep*. 2001;5:412–420.
2. Gerwin RD. Diagnosis of myofascial pain syndrome. *Phys Med Rehabil Clin N Am*. 2014;25:341–355.
3. Lavelle ED, Lavelle W, Smith HS. Myofascial trigger points. *Anesthesiol Clin*. 2007;25:841–851, vii-iii.
4. Simons DG. Myofascial pain syndrome due to trigger points. In: Goodgold J, ed. *Rehabilitation Medicine*. St Louis, MO: Mosby Co; 1988:686–723.
5. Simons DG. New views of myofascial trigger points: etiology and diagnosis. *Arch Phys Med Rehabil*. 2008;89:157–159.
6. Skootsky SA, Jaeger B, Oye RK. Prevalence of myofascial pain in general internal medicine practice. *West J Med*. 1989;151:157–160.
7. Kaergaard A, Andersen JH. Musculoskeletal disorders of the neck and shoulders in female sewing machine operators: prevalence, incidence, and prognosis. *Occup Environ Med*. 2000;57:528–534.
8. Gerwin RD. A study of 96 subjects examined both for fibromyalgia and myofascial pain. *J Musculoskeletal Pain*. 1995;3(suppl 1):121.
9. Fricton JR, Kroening R, Haley D, Siegert R. Myofascial pain syndrome of the head and neck: a review of clinical characteristics of 164 patients. *Oral Surg Oral Med Oral Pathol*. 1985;60:615–623.
10. Ay S, Evcik D, Tur BS. Comparison of injection methods in myofascial pain syndrome: a randomized controlled trial. *Clin Rheumatol*. 2010;29:19–23.
11. Alvarez DJ, Rockwell PG. Trigger points: diagnosis and management. *Am Fam Physician*. 2002;65:653–660.
12. Han SC, Harrison P. Myofascial pain syndrome and trigger-point management. *Reg Anesth*. 1997;22:89–101.
13. Jensen R, Rasmussen BK, Pedersen B, Olesen J. Muscle tenderness and pressure pain thresholds in headache. A population study. *Pain*. 1993;52:193–199.
14. Thompson JM. The diagnosis and treatment of muscle pain syndromes. In: Braddom RL, ed. *Physical Medicine and Rehabilitation*. Philadelphia, PA: WB Saunders; 2000:934–956.
15. Tough EA, White AR, Richards S, Campbell J. Variability of criteria used to diagnose myofascial trigger point pain syndrome—evidence from a review of the literature. *Clin J Pain*. 2007;23:278–286.
16. Rivers WE, Garrigues D, Graciosa J, Harden RN. Signs and symptoms of myofascial pain: an international survey of pain management providers and proposed preliminary set of diagnostic criteria. *Pain Med*. 2015;16:1794–1805.
17. Grosman-Rimon L, Clarke H, Mills PB, Chan AK, Rathbone AT, Kumbhare D. Clinicians' perspective of the current diagnostic criteria for myofascial pain syndrome [published online ahead of print November 11, 2016]. *J Back Musculoskelet Rehabil*.
18. Lucas N, Macaskill P, Irwig L, Moran R, Bogduk N. Reliability of physical examination for diagnosis of myofascial trigger points: a systematic review of the literature. *Clin J Pain*. 2009;25:80–89.

19. Myburgh C, Larsen AH, Hartvigsen J. A systematic, critical review of manual palpation for identifying myofascial trigger points: evidence and clinical significance. *Arch Phys Med Rehabil*. 2008;89:1169–1176.
20. Nickl S, Terranova LM. Trigger point injections. In: Spinner DA, Kirschner JS, Herrera JE, eds. *Atlas of Ultrasound Guided Musculoskeletal Injections*. New York: Springer; 2014. 89–99.
21. Zale KE, Klatt M, Volz KR, Kanner C, Evans KD. A mixed-method approach to evaluating the association between myofascial trigger points and ankle/foot pain using handheld sonography equipment: a pilot study. *J Diagn Med Sonogr*. 2015;31:210–220.
22. Sikdar S, Shah JP, Gebreab T, et al. Novel applications of ultrasound technology to visualize and characterize myofascial trigger points and surrounding soft tissue. *Arch Phys Med Rehabil*. 2009;90:1829–1838.
23. Wong CS, Wong SH. A new look at trigger point injections. *Anesthesiol Res Pract*. 2012;2012:492452.
24. Barber M, Bertoli P, Cescon C, Macmillan F, Coutts F, Gatti R. Intra-rater reliability of an experienced physiotherapist in locating myofascial trigger points in upper trapezius muscle. *J Man Manipulative Ther*. 2012;20: 171–177.
25. Scott NA, Guo B, Barton PM, Gerwin RD. Trigger point injections for chronic non-malignant musculoskeletal pain: a systematic review. *Pain Med*. 2009;10:54–69.
26. Soares A, Andriolo RB, Atallah AN, da Silva EM. Botulinum toxin for myofascial pain syndromes in adults. *Cochrane Database Syst Rev*. 2014; 7:CD007533.
27. Sikdar S, Ortiz R, Gebreab T, Gerber LH, Shah JP. Understanding the vascular environment of myofascial trigger points using ultrasonic imaging and computational modeling. *Conf Proc IEEE Eng Med Biol Soc*. 2010; 2010:5302–5305.
28. Turo D, Otto P, Shah JP, et al. Ultrasonic characterization of the upper trapezius muscle in patients with chronic neck pain. *Ultrason Imaging*. 2013;35:173–187.
29. Shankar H, Reddy S. Two- and three-dimensional ultrasound imaging to facilitate detection and targeting of taut bands in myofascial pain syndrome. *Pain Med*. 2012;13:971–975.
30. Lewis J, Tehan P. A blinded pilot study investigating the use of diagnostic ultrasound for detecting active myofascial trigger points. *Pain*. 1999;79:39–44.
31. Sikdar S, Kim Y, Leotta DF, Primozich JF, Beach KW. Ultrasonic techniques for assessing wall vibrations in stenosed arteries. *Conf Proc IEEE Eng Med Biol Soc*. 2004;2:1325–1328.
32. Shamdasani V, Bae U, Sikdar S, et al. Research interface on a programmable ultrasound scanner. *Ultrasonics*. 2008;48:159–168.
33. Ballyns JJ, Shah JP, Hammond J, Gebreab T, Gerber LH, Sikdar S. Objective sonographic measures for characterizing myofascial trigger points associated with cervical pain. *J Ultrasound Med*. 2011;30: 1331–1340.
34. Shah JP, Phillips TM, Danoff JV, Gerber LH. An in vivo microanalytical technique for measuring the local biochemical milieu of human skeletal muscle. *J Appl Physiol (1985)*. 2005;99:1977–1984.
35. Kumbhare DA, Elzibak AH, Noseworthy MD. Assessment of myofascial trigger points using ultrasound. *Am J Phys Med Rehabil*. 2016;95:72–80.
36. Niraj G, Collett BJ, Bone M. Ultrasound-guided trigger point injection: first description of changes visible on ultrasound scanning in the muscle containing the trigger point. *Br J Anaesth*. 2011;107:474–475.
37. Rha DW, Shin JC, Kim YK, Jung JH, Kim YU, Lee SC. Detecting local twitch responses of myofascial trigger points in the lower-back muscles using ultrasonography. *Arch Phys Med Rehabil*. 2011;92:1576–1580.
38. Bubnov RV, Gandurska-Pavlenko O. The trigger points dry needling and injection technique under ultrasound guidance for shoulder myofascial pain treatment. A comparative study [Abstract]. *Eur J Neurol*. 2012;19 (suppl 1):625.
39. Bubnov RV, Wang JW. Clinical comparative study for ultrasound-guided trigger-point needling for myofascial pain. *Med Acupunct*. 2013;25: 437–443.
40. Baldry P. Management of myofascial trigger point pain. *Acupunct Med*. 2002;20:2–10.
41. Travell JG, Simons DG. *Myofascial Pain and Dysfunction: The Trigger Point Manual*. Baltimore, MD: Williams & Wilkins; 1983. The Upper Extremities; vol 1.
42. Travell JG, Simons DG. *Myofascial Pain and Dysfunction: The Trigger Point Manual*. Baltimore, MD: Williams & Wilkins; 1983. The Lower Extremities; vol 2.
43. Beecroft PC, Kongelbeck SR. How safe are intramuscular injections? *AACN Clin Issues Crit Care Nurs*. 1994;5:207–215.
44. McCloskey JR, Chung MK. Quadriceps contracture as a result of multiple intramuscular injection. *Am J Dis Child*. 1977;131:416–417.
45. Norman MG, Temple AR, Murphy JV. Infantile quadriceps-femoris contracture resulting from intramuscular injections. *N Engl J Med*. 1970; 282:964–966.