Intramuscular Neural Distribution of the Serratus Anterior Muscle: Guidelines to the Injective Method for Treating Myofascial Pain Syndrome

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Abstract

The serratus anterior muscle is commonly involved in myofascial pain syndrome and is treated with many different injective methods. Currently, there is no definite injection point for the muscle. This study provides an ideal injection point for the serratus anterior muscle considering the intramuscular neural distribution using the whole mount staining method. A modified Sihler method was applied to the serratus anterior muscles (15 specimens). The intramuscular arborization areas were identified in terms of the anterior (100%), middle (50%), posterior axillary line (0%), and from the first to the ninth ribs. The intramuscular neural distribution for the serratus anterior muscle had the largest arborization patterns in the 5th to 9th rib portion between 50% and 70%, and the 1st to 4th rib portion had between 20% and 40%. Clinicians can administer safe and effective treatments with botulinum neurotoxin injections and other types of injections, following the methods in our study. We propose optimal injection sites in relation to the external anatomical line for the frequently injected facial muscles to facilitate the efficiency of botulinum neurotoxin injections. Lastly, these guidelines would assist practice more accurately without the harmful side effects of trigger point injections and botulinum neurotoxin injections.

Introduction

Myofascial pain syndrome (MPS) is extremely common, occurring in up to 95% of individuals; 9 million cases have been diagnosed in the United States ¹. Repetitive movements and incorrect posturing habits contribute to the advancement of MPS by triggering overload on a particular muscle; the serratus anterior (SA) muscle is the most commonly involved ². As a part of MPS, serratus anterior myofascial pain syndrome (SAMPS) is separately named for its frequency ². Points with taut banded parts and pinched tenderness of the muscle belly are termed myofascial trigger points (MTrPs). SAMPS occurs with deep respiratory distress while running, repetitive coughing due to respiratory disease, lifting heavy loads, and other psychological stresses ³.

The cause of SAMPS is hyperactivated SA muscle contractions ⁴⁻⁶. Pathological findings indicate an increase in the release of acetylcholine by the neuromuscular junction under relaxing conditions. Elevated and prolonged acetylcholine release generates persistent depolarization of the muscle fiber, which causes sarcomere shortening and involuntary muscle contraction ². This point is anatomically known to be the thickest muscle belly, with the most intramuscular neural arborization ⁷⁻¹¹.

The therapeutic options for MPS include releasing MTrPs using injective agents such as botulinum neurotoxin (BoNT), lidocaine, steroids, normal saline, and combinations of agents. BoNT blocks neural transmission by stalling the release of acetylcholine at the neuromuscular junction and impedes muscle contraction ¹². In myofascial pain control, BoNT injection is renowned for offering better consequences than oral medications in terms of pain management and functional movement ¹³⁻¹⁵. Therefore, BoNT is widely used as a treatment option for MPS, especially SAMPS ¹⁶⁻²¹.

At present, BoNT injection is acknowledged as the most secure and effective treatment for inactivating the muscle^{22–25}. The consequences of BoNT depend on uptake by the presynaptic membranes at the neuromuscular junction; thus, injections should be directed into the neuromuscular junction area where most neuromuscular junctions exist^{12,26,27}. The significance of utilizing neuromuscular arborization-directed BoNT injections has been verified by clinical trials in the iliopsoas and biceps brachii muscles. These injections resulted in higher pain reduction as well as volume reduction compared to conventional injections^{28,29}.

However, a precise infusion point is necessary for BoNT, as excessive amounts of BoNT may potentially cause the toxin to spread to the neighboring muscles, resulting in paralysis^{30,31}. The adverse effect of paralyzed muscle is reported in cases of overdose of BoNT^{32–34}. Moreover, repetitive and overdose BoNT injections build up antibodies that will result in an insufficient treatment effect^{30,31,35,36}. Additionally, a previous study indicated neuropathy due to mechanical damage subsequent to injection in the intramuscular nerve trunks and nerve entering point, where the nerve penetrates the muscle³⁷. Consequently, BoNT should be injected into the arborized regions to enhance efficacy and decrease adverse effects. To direct the injection points while preventing these adverse effects, numerous studies have revealed the intramuscular neural arborization of various muscles, but not the SA^{14,38–41}.

This study aimed to suggest efficient and secure injection points for SAMPS considering intramuscular neural arborization.

Results

Running of the thoracic nerve trunk

The long thoracic nerve runs superficial to the SA muscle and pierces the muscle at each level until the 7th rib. Thirteen of the 15 specimens had a trunk of the long thoracic nerve running on 30 to 50% throughout the level of the 1st to 7th rib. The other two had the long thoracic nerve running down on the 40 to 50% at the level of the 1st to 4th rib and 30 to 40% at the level of the 5th to 7th rib.

Intramuscular arborization patterns of the SA muscle

Twelve of the 15 SA muscles had two regions in which the arborization patterns were the largest: in the 6th to 9th rib portion had between 50% and 70% and the 1st to 5th rib portion had between 20 and 40%, following three anatomical lines: anterior (100%), middle (50%), and posterior axillary line (0%) (Fig. 1). The other two had the largest patterns in the 4th to 9th rib portion, between 50% and 60%; the 1st to 3rd rib portion had between 20% and 30%. The last muscle had the largest patterns in the 4th to 9th rib portion, between 50% and 70%; the 1st to 3rd rib portion had between 30 to 40%.

Discussion

The SA muscle is a flat and wide muscle covering the lateral ribs; it is anatomically divided into three muscle bellies ². It consists of an upper, middle, and lower muscle belly, each of which contribute to the movement of the scapular bone during upper extremity actions ⁴². The upper belly of the SA lies parallel to the 1st rib and inserts into the superior angle of the scapula ⁴³. The middle belly of the SA originates from the 2nd, 3rd, and 4th ribs and inserts into the medial scapular border ⁴³. The lower muscle belly of the SA is where the MTrPs frequently exist, originating from the 5th to the 9th ribs and inserting into the inferior angle of the scapula ^{43,44}. The SA muscle is innervated by the long thoracic nerve, which originates from the anterior rami of spinal nerves C5-C7 ⁴⁵. The long thoracic nerve runs superficially over the SA muscle along the anterior axillary line. The SA muscle is mostly involved in upper extremity movements; however, it is the prime stabilizer of the shoulder girdle and acts on shoulder flexion, abduction, and upward rotation ⁴².

MPS is a chronic pain disorder caused by MTrPs situated at the muscle belly; it has been recognized as the main cause of pain in 85% of patients attending pain clinics ^{46,47}. SA muscle MTrPs may be triggered by muscle strain during excessive running, overloaded weight lifting, or repetitive coughing, especially susceptible to torsional stresses. Another cause of MTrPs initiation in the SA muscle is breast surgery due to cancer or esthetic purposes ⁴⁸.

Studies have revealed that sarcomere shortening is related to MTrPs etiology, and the shortening is due to an increase in activation of the neuromuscular junction and its over-release of acetylcholine. In addition, a large quantity of calcium released at the sarcoplasmic reticulum over a dysfunctional ryanidine receptor causes prolonged muscle contraction ⁴⁹. Therefore, to release muscle contraction, BoNT is currently frequently used as an injective agent for MPS ⁴⁹⁻⁵¹. The primary known therapeutic effects are by releasing muscular contractions and alleviating the vicious pain cycle ⁵²⁻⁵⁴. It is also thought that the relief from the muscle tightness and the BoNT inhibit the diffusion of neurotransmitters in the peripheral nerve, avoiding peripheral sensitization ^{55,56}.

In treating MPS, it is critical to locate MTrPs, and electromyography (EMG) may help to verify the presence of MTrPs, as they are thought to have sensitized nerves that spontaneously produce low-amplitude electrical activity ^{7,57-59}. The study by Kuan et al. demonstrated BoNT injection in MTrPs and found that the injection diminished spontaneous electrical activity in MTrPs ⁶⁰. There are many studies indicating that MTrP pathophysiology appears to be associated with the intramuscular neural arborized areas, also known as identical with MTrPs ⁷⁻¹¹. A study by Xie et al. showed that both BoNT injection and lidocaine injection therapy in the intramuscular arborized area substantially lessens the intensity and frequency of pain in patients ¹⁸.

Vargas-Schaffer et al. ⁶¹ performed trigger point injection in patients with SAMPS and showed its effectiveness in pain control after three months of injective treatment. In 8 patients, the duration of SAMPS was approximately 19 months. With the patient in a lateral decubitus position, the injections were conducted over the midaxillary line on the 5th to the 7th ribs.

Many studies have described frequent SAMPS incidence after breast cancer treatment^{48,62–64}. Lacomba et al.⁴⁸ reported a prevalence rate of 45% for SAMPS one year after breast cancer surgery. Layeeque et al.²¹ observed 48 breast cancer patients who underwent mastectomy and observed post-surgical pain; 22 patients were treated with BoNT in the SA and pectoralis major muscle, and 26 control group patients were treated with medication. The BoNT-treated group reported significant pain reduction compared to the pain medication group.

Neuromuscular junctions are the underlying causes of MPS; therefore, injecting BoNT and other injective treatments such as lidocaine, steroids, and normal saline are frequently performed to target the neuromuscular junctions^{65–67}. Unlike oral medications and lidocaine injections that have short-term effects, the effectiveness of BoNT treatment in MPS has been known to continue for up to 4 months^{66,67}.

As BoNT acts on the neuromuscular junction, accurate anatomical knowledge of the neuromuscular arborization patterns of the SA muscles is vital for achieving the highest relief with the smallest possible dose of BoNT. Although BoNT procedures are minimally invasive compared to surgical intervention, there is a probability of damaging the nerve trunks that are not present near the neural arborized area. Therefore, precise knowledge of the anatomical features of the SA muscle should be considered. In this study, we carried out Sihler's staining, which is a whole mount staining procedure that stains myelin sheaths and is effective in tracing the nerve endings without destroying the nerves^{14,38–40,68}. The application of Sihler's staining to the SA muscle will enable an accurate and thorough understanding of the neural distribution.

Moreover, identifying the neural arborization area of the SA muscle is important in diagnosing long thoracic nerve palsy⁶⁹. Surface electromyography in the SA muscle is challenging because multiple thin digitations make it difficult to place the electrode for recording⁷⁰. When detecting long thoracic nerve palsy, the technical limitations of electromyography are interrupted signals from the neighboring muscles and difficulty with accurate electrode placement since the SA is not a bulky muscle.

At present, there is no standardized injection or EMG points of the SA muscle. In this study, we suggest that electromyography and injective treatments including BoNT, lidocaine, normal saline, steroids should be administered in the three regions in the middle portion, between the 6th to 9th rib portion and the 1st to 5th rib (Fig. 2). Surgeons should be aware that they must inject over the bony rib with patients holding their breath to avoid iatrogenic pneumothorax.

Methods

This study was performed in accordance with the principles outlined in the Declaration of Helsinki. Informed consent and approval were obtained from the families of the cadavers before the dissections were performed. All cadavers used in this study were legally donated and approved from ethics committee of the Surgical Anatomy Education Center, Yonsei University College of Medicine (approval code 20 – 006; approval date: May 5th, 2020). A total of 15 SA muscles from Korean cadavers (5 men

and 4 women with a mean age of 76.6 years; range, 73–95 years) were dissected and modified Sihler staining was applied to clarify the intramuscular neural arborization patterns.

Before dissection, the SA muscles were aligned in their anatomical positions. The arborizing patterns of the SA muscles were tracked according to the three anatomical lines: anterior (100%), middle (50%), posterior axillary line (0%), and from the first to the ninth ribs (Fig. 3).

The SA muscles underwent Sihler staining, as modified by Liem and Douwe van Willigen ⁷¹.

This technique involves several steps to acquire the visual representation of the intramuscular neural arborization pattern. The changes over Sihler's method of the SA specimens are shown in Fig. 4.

Following Sihler staining, the SA muscles were divided into 10 sections according to the vertical lines from the anterior and posterior axillary lines and the curved lines of the first to ninth ribs.

Modified Sihler staining

Fixation. The SA muscles were stored for one month in a container filled with 10% un-neutralized formalin. The solution was replaced with fresh solution whenever it turned cloudy.

Maceration and depigmentation: the fixed SA specimens were washed in running water for an hour. Then, they were placed for one month in a container filled with 3% aqueous potassium hydroxide and hydrogen peroxide solution.

Decalcification: the depigmented SA specimens were then placed in Sihler I solution, a compound of glycerin, glacial acetic acid, and aqueous chloral hydrate.

Staining: the decalcified SA specimens were then stained with the Sihler II solution, a compound of glycerin, aqueous chloral hydrate, and acetic acid. The staining process takes 30–35 days for intramuscular nerve visualization.

De-staining: the stained SA specimens were cleansed in a container filled with Sihler I solution. This step is to de-stain the SA muscle fibers so that only the intramuscular nerve distributions are visualized.

Neutralization: the de-stained SA specimens were neutralized in clean water for half an hour. Consequently, the SA specimens were placed in a solution of 0.05% lithium carbonate.

Clearing: finally, the neutralized SA specimens were taken into the clearing stage with glycerin by increasing the concentrations from 20–100%. This stage took nearly 4–5 hours.

List Of Abbreviations

Myofascial pain syndrome (MPS), serratus anterior (SA), serratus anterior myofascial pain syndrome (SAMPS), myofascial trigger points (MTrPs), botulinum neurotoxin (BoNT), maceration and depigmentation (MD), decalcification, staining (ST), and clearing (CL), anterior axillary line (AA), posterior axillary line (PA)

Declarations

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Author Contribution

KHY: research concept, study design, and writing of the manuscript

JHL: research concept and study design

KKS: literature review and data collection

HJK: reviewing/editing a draft of the manuscript, Supervise the manuscript

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Conflicts of interest/Competing interests

The author(s) declare no competing interests.

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Figures

Figure 1

The result of Sihler's staining of the serratus anterior muscle. The intramuscular neural distribution of the serratus anterior muscle is observed with enlarged views.

Figure 2

The long thoracic nerve runs superficial to the SA muscle and pierces into the muscle at each level until the 7th rib. The specimens had a trunk of the long thoracic nerve running on 30 to 40% throughout the level of 1st to 7th rib (green shaded). The intramuscular arborization patterns were the largest: in the 6th to 9th rib portion had between 50% to 70% and the 1st to 5th rib portion had between 20 to 40%. The injection should be guided to these arborized areas.

Figure 3

Specimens were harvested according to two anatomical lines: anterior axillary line (AA) and posterior axillary line (PA). The AA was 0% to PA of 100%, respectively.

FX

MD

ST

CL

Figure 4

The serratus anterior muscle underwent modified Sihler's method. The method consists of stages of fixation (FX), maceration and depigmentation (MD), decalcification, staining (ST), and clearing (CL).