Electrophysiological Characteristics of Localized Twitch Responses in Responsive Taut Bands of Rabbit Skeletal Muscle Fibers

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ABSTRACT. Objective: This study was designed to investigate the electromyographic characteristics of the Rabbit Localized Twitch Response (R-LTR), a brisk contraction of a certain group of rabbit skeletal muscle fibers [a responsive band] elicited by mechanical stimulation of the most pressure-sensitive site (TrS).

Methods: In this study, R-LTRs were electromyographically investigated on 9 rabbits [ages: 2-12 months]. Each animal was anesthetized in a way that preserved most peripheral reflexes mediated by the central nervous system. R-LTRs were elicited by one of three different mechanical stimuli: manual-probe stimulus [similar to snapping palpation], mechanical-tap stimulus [delivered by a sole-
Results: R-LTRs were best recorded from the responsive band [but not the surrounding muscle fibers] when the TrPs [but not the other spots in the responsive band, or any spot in the non-responsive fibers] was mechanically stimulated. Responses to stimulation were longer in duration than those to mechanical tap stimulation, which in turn were longer than R-LTRs produced by needle stimulation. This observation supports the impression that one trigger spot of the rabbit may contain multiple loci of hyperreactivity. The nearly complete loss of R-LTRs following lidocaine block or transection of the motor nerve indicates that propagation of the R-LTR is primarily via a central nervous system reflex rather than exclusively via direct muscle-fiber transmission.

Conclusion: The rabbit localized twitch responses [R-LTRs] show several similarities to, and no incompatibility with, the human local twitch response (LTR). The rabbit shows promise as an animal model for study of LTRs and possibly of taut bands and TrPs that are characteristic of myofascial pain syndrome.

KEYWORDS. Electromyogram, muscle contraction, myofascial pain syndrome, trigger point, twitch response

INTRODUCTION

The local twitch response [LTR] in man is a valuable objective sign of the myofascial pain syndrome caused by trigger points (TrPs) (1-6). When a taut band of muscle fibers containing an active myofascial TrP is snapped rapidly at that TrP [the band's most sensitive spot], an LTR can be elicited.

Clinically, it is important to elicit an LTR during TrP injection in order to assure inactivation of the TrP (1,7-9). The TrP injection is often ineffective if no LTR was elicited during the injection (8,9).

Simons (10) and others (2,11) demonstrated that LTRs in man are associated with a transient burst of electromyographic [EMG] activity. Simons (10) showed that electromyographically the LTR in man is clearly distinguishable from a tendon tap reflex. On eliciting the LTR, only the muscle fibers associated with the taut band produced action potentials, whereas motor units distributed throughout the muscle respond reflexly to a tendon tap. He also noted that the prolonged series of discharges characteristic of an LTR was in sharp contrast to the synchronized biphasic or triphasic waveforms characteristic of the tendon tap response originating in muscle spindles throughout the muscle.

Hong et al. (12) studied the EMG activity of the LTR recorded from the third finger extensor in human subjects during cuff compression of the arm. Their data suggested that the EMG activity of an LTR was conducted from the TrP to the recording site primarily via the central nervous system pathway and probably to some extent directly via muscle fibers pathway. In a later study of a patient with complete loss of nerve conduction involving the posterior cord of the right brachial plexus, Hong et al. (13) found a significant increase in, but not a complete EMG loss of, the LTR in paralyzed muscles. These data suggest that the LTR in man depends largely on a central pathway and, possibly, to some degree on a local pathway.

Options for studying basic mechanisms of LTRs and TrPs in human subjects are limited for ethical reasons. An acceptable animal model could be very helpful for more thorough investigation of the pathophysiology of TrPs.

The first description of LTRs in animals appeared in an article by Simons and Stolov (14). They reported the presence of palpable taut bands in the muscles of unanesthetized dogs. After a dog was anesthetized and that muscle exposed, a twitch response of the palpable band occurred when the band was stimulated by rubbing palpation. Although not reported in their paper, it was observed that, during preliminary screening, all animals responded to digital pressure applied to the taut band by withdrawal behavior and snarling, as if the action caused pain. Recently, a veterinarian (15,16) has reported finding TrPs in lame dogs. The lameness was usually relieved by dry needling or injection of 0.5% Lidocaine into the TrP. The veterinarian author reported that in every case, palpation of those TrPs caused the dog to react as if the TrPs responsible for the lameness were painful.

In this study, we report EMG findings of localized twitch responses in rabbit skeletal muscle [R-LTRs], which are similar to human LTRs, based on several key indices.
MATERIALS AND METHODS

Nine rabbits [age: 2-12 months] were studied. Each animal was initially anesthetized intramuscularly with a Rompun/Ketamine mixture [0.001 mg/g BW of Rompun and 0.05 mg/g BW of Ketamine] modified from the protocol of Moulder (17). To avoid depression of central reflexes, Rompun dosage was decreased, which was compensated by an increase in Ketamine. Subsequent maintenance doses were given periodically, usually every 20-30 minutes, with Ketamine only at 10-15% of the initial dose. Throughout the whole course of study, the animal preserved some centrally mediated reflexes including the corneal reflex, the withdrawal reflex, and the deep tendon reflex. The animal remained unconscious and quiet throughout testing. Respiration was monitored for change in rate or development of irregularity.

The various rabbit muscles that were exposed and studied included the gluteus medius, tensor fasciae latae, abductor cruris cranialis, vastus lateralis, biceps femoris, tibialis cranialis and gastrocnemius muscles. Exposure was sometimes bilateral in hind-limb muscles.

Identification of a Responsive Band and Trigger Spot

"Taut bands" of muscle fibers [with a firmer consistency than other adjacent fibers] were identified by finger palpation. The muscle was gently rubbed or pinched with the thumb and index on two opposing surfaces of the muscle, if accessible [such as in biceps femoris muscle], across the direction of fibers. In some "taut bands," a sudden and brief twitch of muscle fibers in a "taut band," rabbit localized twitch response [R-LTR], is observed when the most sensitive spot in this band, the trigger spot [TrS], is pinched. These "taut bands" that exhibit the twitch response are identified as responsive bands.

The R-LTR could be elicited repeatedly by stimulation of the TrS by snapping palpation with 2 fingers using a pincer technique. The force of snapping was adjusted carefully. It was just strong enough to elicit an R-LTR. Repeated excessive vigorous snapping might cause loss of the R-LTR. Through practice, the authors were able to control the snapping force satisfactorily. Unnecessary mechanical stimulation of the TrS was avoided, since desensitization of TrS can occur with frequent stimulation of the same TrS.

The R-LTR elicited by mechanical stimulation was a response of only responsive fibers in a palpable taut band and did not seem to involve adjacent fibers. The response generally was both palpable [feeling of muscle twitch] and visible. When a responsive band was tested for responsiveness along its length, usually only one location was outstandingly responsive to the stimulation; however, a considerable length of the band was responsive to some degree. The most sensitive location for eliciting an R-LTR along the band was identified as the Trigger Spot [TrS]. In this study, R-LTRs were elicited by stimulating the TrS mechanically: by snapping it manually with a blunt probe, by tapping it with a blunt probe driven by a solenoid device, or by inserting an EMG needle into it. The detailed technique of each stimulation is described in the following sections.

Identification of End-Plate Zone

In some experiments, the end-plate zone was identified as the site most responsive to electrical stimulation and was usually located in the central portion of the length of the muscle fibers.

Electromyographic Recording of R-LTRs

A two channel Cadwell Quantum-84 EMG unit [Cadwell Laboratories, Inc, 909 North Kellogg Street, Kennewick, Washington 99336] recorded EMG activity of the LTRs using either a bipolar 20-gauge or a monopolar disposable EMG needle [1.1/2 inch, 26 gauge]. Before insertion of the needle electrode, the responsive band involved in R-LTR elicited by snapping palpation of TrS was identified. Since the site of stimulation [TrS] was frequently found in the proximal end of the muscle, the recording needle [either a bipolar needle electrode, or an active needle electrode in monopolar recording] was inserted into the distal end of the same responsive band that responded to snapping stimulation with a palpable and visible R-LTR. This point of recording was located at the distal 1/4 to 1/3 of the muscle. However, in some cases where the TrS was in the distal end of the muscle, the recording electrode was placed at
the opposite end of the muscle. For monopolar needle recordings, another monopolar needle, serving as a reference electrode, was placed near the muscle tendon at the same end of the active electrode [i.e., the end opposite to the stimulation site].

In order to confirm that the recording needle was in the same band where the TrS was located, only the visible superficial responsive bands were used for EMG recording studies. Location of the band could be identified by the R-LTR movement on the surface of the muscle through a dissecting microscope, when necessary, and by palpation, during snapping stimulation of TrS. This could be further confirmed by the presence of EMG activity. The location of the needle was adjusted to record the largest amplitude of R-LTR.

The ground electrode was always placed on one of the front paws of the animal. The amplifier sensitivity was set to 500 or 1000 microvolts per vertical division. Sweep speed was 10 msec per horizontal division [100 msec across the full screen].

**Stimulation by Snapping**

Snapping stimulation was accomplished using a hand-held probe with a blunt tip 0.5 mm in diameter, it was pressed firmly against the muscle and moved briskly across the muscle perpendicular to the direction of the muscle fibers [and responsive bands]. It was usually necessary to rub the probe firmly and quickly over the muscle fibers in order to elicit a vigorous R-LTR. Light stroking with a sharp-edged probe elicits fine contractions of superficial muscle fibers. These fine contractions involve only superficial muscle fibers. They are quite different from R-LTR, and are similar to fibrillations induced by a local sarcoplemmal injury to the superficial muscle fibers. The R-LTRs are much larger and stronger contractions of multiple fascicles including deep muscle tissues.

The EMG activity was recorded in the continuous mode ["EMG program" on the Cadwell unit]. The onset of recording was controlled with a foot switch by the investigator who handled the probe.

**Stimulation by Tapping**

A solenoid-driven stimulating device was constructed that permitted synchronized triggering of the oscilloscope screen with the initiation of mechanical-tap stimulation of the TrS. This device was essentially a blunt metal probe inserted into the central tunnel of a low voltage solenoid [Figure 1]. By varying the tension of the recoil spring and the amplitude and duration of the pulse from a Grass S44 stimulator, the blunt-probe device delivered an adjustable mechanical stimulation. The EMG activity was recorded in the single triggering mode ["Motor-NCV program" on the Cadwell unit]. The TrS was stimulated by a sudden, circumscribed impact delivered with this device.

The location along the responsive band that was most responsive to solenoid-driven probe [tapping] stimulation for eliciting R-LTRs was also the location most responsive to manual-probe [snapping] stimulation.

**FIGURE 1.** Solenoid-driven blunt probe to produce mechanical-tap stimulation of a trigger spot. The end of the blunt probe had a diameter of 0.5 mm. The stimulator of the EMG unit simultaneously energized the solenoid and triggered the oscilloscope trace. The recording site was about 2 cm from the trigger spot.
Stimulation by Needling

Two channels were used to record the EMG activity from two sets of bipolar EMG needle electrodes. The static recording needle was placed in the usual recording site in the responsive band as previously mentioned [stimulation by tapping]. The stimulating needle was attached to the blunt metal probe of the same solenoid device used for mechanical-tap stimulation. This device thrust the needle into the most responsive site [TrS] of the responsive band. This stimulating needle electrode served two purposes: it produced an invasive mechanical stimulus analogous to that used when injecting a TrP clinically, and it recorded EMG activity from the needle during insertion. In this arrangement, recording from both needle electrodes was initiated simultaneously with activation of the solenoid. The latency and duration of the EMG activity recorded from the two electrodes were compared.

Recordings from Adjacent Muscle Fibers

In 4 muscles from 2 animals for the study of tapping stimulation, an additional monopolar recording needle was inserted into muscle fibers immediately next to the responsive band for recording the electrical activity of adjacent fibers to determine the extent of the response in the muscle tissue. The reference electrode for this additional recording channel was connected to the reference electrode for the first channel which recorded the EMG activity from the responsive band [to make a common reference electrode].

Stimulation of Sites Near the Trigger Spot

In 5 muscles from 2 animals for the study of tapping stimulation, five different sites in the region of one responsive band were stimulated. One stimulation site was the TrS; two sites were in that same responsive band, 1 and 3 cm from the TrS; the other two stimulation sites were 5 mm on each side of the TrS, outside of the band. The EMG responses were recorded from a pair of monopolar EMG needles in the responsive band. This examined how far the pressure sensitivity of the TrS extended.

Response to Repeated Mechanical Stimulation—Desensitization of TrS

In 10 responsive bands, the TrS was repeatedly stimulated with the blunt-probe by tapping it at a rate of 0.5-1.0 Hz, until the visible R-LTR and the EMG response disappeared.

Repeated solenoid-driven needle insertions were also performed on 8 responsive bands to assess the effects of “dry needling” in abolishing the LTR.

Local Anesthetic Block of Muscle Nerve

In 5 tibialis cranialis muscles from 3 animals, the innervating branch of the peroneal nerve was identified and carefully separated from the surrounding soft tissue. Prior to application of lidocaine, LTRs were elicited from a responsive band in the tibialis cranialis muscle by mechanical-tap stimulation and were recorded. After three to five consistent responses [minimum variation of the total duration of EMG activity] were obtained using a bipolar EMG needle, the muscle nerve [muscular branch of peroneal nerve, extra-muscular portion] was infiltrated with approximately 0.1-0.2 mL of 1% lidocaine. The EMG activity elicited by tapping was recorded immediately, and at one, two, and three minutes following lidocaine infiltration.

Transection of Muscle Nerve

In 5 tibialis cranialis muscles from 4 animals, the innervating branch of the peroneal nerve was identified and freed carefully. Prior to transection of the muscle nerve, R-LTRs were elicited in the rabbit tibialis cranialis muscle by mechanical-tap stimulation with the solenoid device. After three to five consistent responses [recorded with a bipolar EMG needle], the muscle nerve was cut with a scissors, and the TrS was again stimulated mechanically to elicit an R-LTR.

Analysis of Electromyographic Data

Waveforms with an amplitude less than 100 microvolts were disregarded as artifact or noise. The maximal amplitude was mea-
sured from the positive peak to the negative peak of the largest waveform. The total duration of the R-LTR was measured from the onset of the initial deflection of the first qualified waveform to the end of the deflection of the last qualified waveform. Two-way t-test was applied for statistical analysis. A P value equal to or less than 0.05 was considered as statistically significant.

RESULTS

Only a few responsive bands, sometimes none, were found superficially in any one muscle. Sometimes, R-LTRs were palpable [as a muscle twitch] but not visible due to the depth of their location. The number of responsive bands varied from muscle to muscle, and also from animal to animal. However, there was a tendency for responsive bands and LTRs to be more common in some muscles [biceps femoris, tibialis cranialis, and extensor digitorum communis] and less common in others [biceps brachii, triceps brachii, and flexor carpi radialis]. It was our impression that older rabbits had more responsive bands and TrSs than younger animals.

Frequently, this TrS was located in the proximal part of the muscle at a point between 20% and 40% of the muscle length. When the end-plate zone was identified, it was usually located at the central portion of the muscle. In only a few cases [less than 5%] was the TrS found at mid-muscle region, in the end-plate zone.

Figure 2 shows typical examples of the EMG recordings of R-LTRs elicited by the three different methods of mechanical stimulation. The mean maximal amplitude and mean duration of R-LTR in the rabbit biceps femoris muscle are listed in Table 1. There was no significant difference in the maximal amplitude of R-LTRs among these three groups. The mean duration of R-LTRs elicited by snapping was 127 ± 26 msec, which is significantly longer [P < 0.01] than that of R-LTRs produced by tapping or needling [86.6 ± 16.4 msec and 35 ± 14.7 msec respectively]. The mean duration of R-LTRs elicited by tapping was significantly longer [P < 0.01] than that of needle-elicited R-LTRs.
| TABLE 1. Mean Maximal Amplitude and Mean Duration of EMG Activity of Rabbit Localized Twitch Responses Recorded from Responsive Bands in Biceps Femoris Muscles When the Most Sensitive Site of the Band Was Stimulated by Snapping, Tapping, or Needling. |
|-----------------|-------------|-------------|
|                  | SNAPPING    | TAPPING     | NEEDLING   |
| Number of responsive bands tested | 7           | 10          | 5           |
| Maximal Amplitude [mV] | 1.6 ± 0.6  | 1.5 ± 0.6  | 1.1 ± 0.3  |
| Duration [msec] | 127.0 ± 26.0  | 86.6 ± 16.4 | 35.0 ± 14.7 |

*Mean duration by snapping was significantly longer [P < 0.01] than the mean duration by tapping or by needling.

**Mean duration by tapping was significantly longer [P < 0.01] than the mean duration by needling.

Stimulation by Needling

An example of an R-LTR elicited by inserting a needle into the TrS and recorded from a static needle placed 2 cm away from the TrS in the same responsive band appears in Figure 2, Tracing 2. Frequently two or occasionally more than two distinct groups of discharges appeared in response to mechanical probe tapping.

Stimulation by Tapping

In general, R-LTRs were much more difficult to elicit by tapping stimulation than by snapping stimulation. Many times, no R-LTR could be detected electromyographically by tapping even though an EMG response was easily obtained from the same responsive band by snapping stimulation. This was at least partly due to the fact that firm pressure could be applied to TrSs in the deeper portion of the muscle by snapping stimulation, while deeper responsive fibers were shielded by overlying muscle fibers from the relatively light taps delivered by the solenoid. In all cases, the visible and EMG recorded R-LTRs induced by the tapping stimulation were shorter than the corresponding responses induced by snapping stimulation. However, the EMG responses of R-LTRs elicited by tapping stimulation, when obtained, were morphologically more consistent than those elicited by snapping stimulation.

An example of an R-LTR elicited by tapping stimulation of a responsive band appears in Figure 2, Tracing 2. Frequently two or occasionally more than two distinct groups of discharges appeared in response to mechanical probe tapping.

Recordings from Adjacent Muscle Fibers

Four muscles from two animals were studied. Consistently, very little, if any, EMG activity was recorded in response to tapping stimulation of the TrS when the recording needle was placed outside the responsive band in non-responsive band fibers 5 mm to each side of the TrS [Figure 4]. These results agree with the visible and palpable indications that R-LTRs are limited to the stimulated responsive band.

Stimulation of Sites Near the Trigger Spot

Five muscles of two animals were studied. There was little, if any, EMG activity recorded when sites other than the TrS were stimulated. As shown in Figure 5, stimulation of the responsive band 1 and 3 centimeters from the TrS produced minimal and inconsistent EMG responses. Essentially no EMG response was observed to stimulation applied on either side of the responsive band 5 mm from the TrS. This demonstrated that the TrS is localized within a responsive band and that stimulation of the adjacent non-responsive muscle fibers is incapable of eliciting a localized
FIGURE 3. Simultaneous EMG recordings from two bipolar needles in the gluteus superficialis muscle of a rabbit [two months of age]. The stimulating needle [A] was inserted into the most sensitive area of the responsive band, and the static needle [B] was placed in the responsive band 20 mm distal to the stimulating needle. The dotted line marks the onset of the first deflection of the baseline in Trace A. The amplitude of the needle insertion activity [Trace A] was much higher than that of LTR [Trace B].

![EMG recordings](image)

**TABLE 2. Mean Maximal Amplitude and Mean Duration of EMG Activity Recorded from a Responsive Band at Two Different Sites When the Most Sensitive Site of the Band Was Stimulated by Needle Insertion.**

<table>
<thead>
<tr>
<th></th>
<th>RECORDED FROM THE STIMULATING NEEDLE [AT TrS]</th>
<th>RECORDED FROM THE STATIC NEEDLE [2 cm from TrS]</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>N = 6</td>
<td>N = 6</td>
</tr>
<tr>
<td>Maximal Amplitude [mV]</td>
<td>2.3 ± 0.6</td>
<td>1.1 ± 0.3*</td>
</tr>
<tr>
<td>Duration [msec]</td>
<td>88.2 ± 18.0</td>
<td>14.5 ± 4.2*</td>
</tr>
</tbody>
</table>

*Both duration and maximal amplitude of R-LTRs recorded from the static needle [not in the TrS] were significantly less (P < 0.01) than the R-LTRs recorded by the stimulating needle.

TrS = trigger spot.

twitch response. The zone of pressure responsiveness of the TrS appears to lie within a region no larger than 1 cm × 0.5 cm.

**Response to Repeated Mechanical Stimulation**

Rapid mechanical stimulation by tapping or needling of one site caused progressive decrease in the evoked R-LTRs. The number of stimuli required to cause failure of the R-LTR was variable from band to band. The average number of tapping stimuli at the TrS that ended the R-LTR was 9.7 ± 4.7 based on 10 responsive bands in three animals. The average number of needle insertions into the TrS required to terminate the R-LTR was 7.4 ± 3.9 based on a study of 8 responsive bands in three animals. However, the subsequent needle insertion might not follow the same track as previous insertions. There is no statistically significant difference between these two groups in the number of stimuli required to inactivate the R-LTR.

**Local Anesthetic Block of Muscle Nerve**

Table 3 summarizes the changes in R-LTRs consistently observed after lidocaine infiltration of five muscle nerves in three
FIGURE 4. Electromyographic recordings of rabbit localized twitch responses obtained from monopolar needles at three sites in or near the responsive band. Tracings observed 5 mm to each side of the responsive band showed only distant EMG waveforms indicating that the twitch response was restricted to the muscle fibers within the responsive band. The responses were elicited by a solenoid-driven tap at the trigger spot.

FIGURE 5. Electromyographic recordings of rabbit localized twitch responses elicited by tapping the trigger spot and four locations removed from the trigger spot. Responses were unobtainable by tapping at the sites 5 mm to each side of the trigger spot, outside the responsive band. A greatly attenuated response was recorded by tapping the responsive band 1 cm from the trigger spot, and essentially no response was recorded by tapping 3 cm from the trigger spot in the direction of the recording electrode.
TABLE 3. Mean Maximal Amplitude and Mean Duration of Localized Twitch Responses in Rabbit Tibialis Cranialis Muscle Induced by Mechanical-Tap Stimulation Before and After Lidocaine Block of the Muscle Nerve.

<table>
<thead>
<tr>
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<th>BEFORE BLOCK</th>
<th>AFTER BLOCK</th>
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<tbody>
<tr>
<td></td>
<td>N = 5</td>
<td>N = 5</td>
</tr>
<tr>
<td>Maximal Amplitude [mV]</td>
<td>1.4 ± 0.4</td>
<td>0.4 ± 0.2*</td>
</tr>
<tr>
<td>Duration [msec]</td>
<td>82.0 ± 19.7</td>
<td>13.8 ± 4.6*</td>
</tr>
</tbody>
</table>

*Values after nerve block were significantly smaller [P < 0.01] than those before nerve block.

animals. As shown in Figure 6, immediately following lidocaine infiltration of the muscle nerve, the late portion of the EMG activity of the R-LTR elicited by tapping stimulation disappeared completely. The early portion of the EMG activity showed remarkably decreased amplitude and duration immediately after block, and nearly completely disappeared 2-3 minutes later. Visible twitch responses usually disappeared immediately following lidocaine infiltration of the muscle nerve. These data offer indisputable evidence that much of the R-LTR response is mediated by the nervous system. There may be a local muscle fiber response as shown in the early portion of the response.

**Transection of Muscle Nerve**

As shown in Figure 7, there was minimal EMG response to tapping stimulation after the muscle nerve was severed. The data are summarized in Table 4.

When recordings were made from static and stimulating needle electrodes following transection of the muscle nerve, the usual insertional activity was recorded from the stimulating needle (Figure 8, Trace A), but again, only vestigial early responses were obtained from the static needle electrode (Figure 8, Trace B) as compared to normal responses with intact nerve (Figure 3, Trace B). These results again demonstrate that the central nervous system is involved in the R-LTR.

**DISCUSSION**

Visible and electromyographically demonstrable R-LTRs were elicited in certain groups of rabbit skeletal muscle fibers [the responsive band] by mechanical stimulation of a most pressure sensitive spot [TrS] in such band.

**Propagation of the R-LTR**

The long duration sinusoidal waveforms remaining after local anesthetic block and after transection of the muscle nerve are not characteristic of twitch response action potentials. Some waveforms in the early activity are so consistently and precisely [with same latency and same wave form] present from tracing to tracing that
FIGURE 7. Electromyographic activity of localized twitch responses recorded from the rabbit's tibialis cranialis muscle with a bipolar needle prior to, and following, transection of its peroneal nerve supply. The responses were elicited by mechanical-tap stimulation of a rabbit tibialis cranialis muscle. Activity prior to nerve transection is shown in the upper five tracings. Vestigial rabbit localized twitch responses [lower five tracings] were recorded following transection of its peroneal nerve supply.

they are considered artifacts from the stimulation device, as in Figures 6 and 7.

The EMG activity of R-LTR recorded from the needle in a responsive band at a distance from the TrS might have three possible origins. One origin could be direct propagation of action potentials along the muscle fibers from the TrS to the recording needle. Such action potentials would have originated in the muscle fibers as a direct result of the mechanical stimulation. The nearly complete loss of the R-LTR after anesthetic block or after transection of the muscle nerve makes it unlikely that direct propagation plays a significant role. The insertion potentials recorded from the EMG needle during penetration of the muscle do not, for the most part, represent propagated action potentials initiated in the muscle fibers by the trauma of insertion. If they did, those muscle fibers should evidence physical contraction and propagated EMG activity whenever the needle was inserted anywhere in the muscle. This twitch response should be equally observable in control site penetrations away from a responsive band; however, it is not observed in these other areas. Also, this potential source of LTRS should be unaffected by anesthetic block or transection of the muscle nerve. The twitch response essentially disappeared when the TrS was stimulated by needle penetration under those circumstances. Finally, if insertion potentials were a major source of the LTR, the response should be unobtainable or minimum [with a short duration] by snapping palpation when the recording needle was not near the stimulating site, unless a strong contraction due to R-LTR was elicited.

Another origin of the R-LTR might be neurogenic at the TrS. Action potentials that were propagated by afferent fibers to the spinal cord would activate alpha motor neurons supplying motor units in the immediate vicinity of the TrS. Swett et al. (18) demonstrated that the location of contraction areas on the exposed muscle
FIGURE 8. Electromyographic recording following transsection of muscle nerve. Trace A shows the "normal" insertional potentials recorded from a stimulating needle electrode [bipolar] inserted mechanically into the most sensitive part of the responsive band. Trace B shows the vestigial response recorded from the static needle, which was located 20 mm distal to the stimulating needle. The dotted line marks the onset of the first deflection of the baseline in Trace A.

surface in response to stimulation of natural motor nerve rootlets and teased filaments in cats corresponded remarkably well to the appearance of the R-LTRs that we see. The loss of the R-LTR by blocking or transsection of the muscle nerve [the muscular branch which innervated that muscle] indicates that a major component of the R-LTR is mediated via the central nervous system. The reduc-

tion of the R-LTR as the site of stimulation progresses along the responsive band from the TrS toward the recording needle indicates that the response is not initiated equally well by stimulation anywhere along the responsive band, but is much stronger when it is elicited at the TrS. This indicates that the afferent nerve endings or receptors which initiate the reflex R-LTR are located specifically in the region of the TrS.

A third possible origin of the response is "insertion" potentials from the recording needle caused by movement of the muscle fibers in contact with that needle tip. This might arise from transmission of the initiating mechanical impulse along the muscle, or by muscle movement with regard to the needle as a result of the muscle contraction associated with an action potential arising by one of the first two mechanisms of origin. In the latter case, any insertion potentials would result from muscle contraction in response to propagated action potentials.

Propagation of the mechanical impulse is, by itself, an unlikely source of the LTR for a number of reasons. 1. A poor response appeared in the needles placed 5 mm to either side of the responsive band. Any mechanical impulse should affect those needles as well as the one within the responsive band. 2. The effect of a mechanical disturbance should increase, not decrease, as the site of stimulation is moved closer to the recording electrode. 3. A direct response to the mechanical impulse would be unaffected by anesthetic block or transsection of the muscle nerve. In fact, the residual waveforms observed on the baseline in these experiments may be the contribution of the mechanical impulse. If so, it is only a small part of the full response.

Even if the mechanical impulse did sometimes make an appreciable contribution to the total electrical response of the LTR, it would represent at most an additional "noise."

No effort was made to calculate the latency of the R-LTR following mechanical stimulation due to the difficulty in identifying the exact onset of the mechanical stimulation [contact of the probe or needle with the muscle fibers]. Accurate determination of the time between activation of the solenoid and probe impact on the muscle was not possible because the solenoid [with the probe] was hand held. The first deflection of the baseline was not considered a reli-
able marker of the arrival of the mechanical impulse at the needle because it was quite variable from TrS to TrS in amplitude, polarity, and latency [8-15 msec]. Latency issues need to be studied.

In summary, an R-LTR is propagated primarily via the central nervous system. Based on the current study, it was not possible to evaluate which afferent fibers [small or large] are involved.

**Multiple Loci Hypothesis**

The responses were longest in duration when elicited by snapping stimulation, shorter in those elicited by tapping, and shortest in those elicited by needling. This may occur because the duration of a response is related to the extent of the sensitive area stimulated. In snapping stimulation, the whole cross section of the responsive band is stimulated. However, in the tapping stimulation, only an area approximately the size of the probe is stimulated. When needling, an even smaller [needle-point size] spot is stimulated.

These observations lead to a hypothesis: a TrS may consist of several small [needle-point size] loci which are sensitive to mechanical stimulation [Figure 9]. Many such loci would be stimulated simultaneously by snapping stimulation, and only a limited number would be stimulated by tapping stimulation. Probably only one locus would ordinarily be stimulated by one insertion of a needle.

The possibility of a variable number of responsive loci at one TrS would account for the variations in the palpable size of TrPs in human subjects, if the same principle applies to TrPs. When injecting a human TrP site, one frequently can elicit a number of LTRs by "peppering" the TrP region with the needle, but not by reinserting the needle along the same path.

**Comparison of Rabbit TrSs and Human TrPs**

This study raises the possibility that a trigger spot [TrS] in a responsive band of a rabbit muscle is analogous to a TrP in a human taut band and that the R-LTRs are analogous to human LTRs. This study demonstrated five similarities between the rabbit R-LTR and the human LTR: 1. a twitch response is elicited by mechanical stimulation of a sensitive spot [TrS in rabbit or TrP in human] which is usually located at one end of a band of responding muscle fibers [responsive band in rabbit or taut band in human (5,6)]; 2. similar EMG activity is recorded during a twitch response of the responsive band in rabbit muscle and taut band in human muscle (2,10-13); 3. no EMG activity can be recorded [electrical silence] from the rabbit responsive band or from the human taut band (2,11,12,19) when the muscle is at rest; 4. twitch responses are diminished after repeated mechanical stimulation to the most sensitive site [TrS or TrP (8,9)]; 5. twitch responses are diminished after blockage of transmission of the innervating nerve in rabbit or human subjects.

None of the characteristics that were observed for R-LTRs were incompatible with the observed characteristics of human LTRs.
However, before the rabbit can be accepted unequivocally as an animal model for myofascial TrPs, a number of additional features need to be studied including: 1. additional assessment of animal pain and tenderness (15,16); 2. measurement of the compliance of the responsive band compared with surrounding muscle in the rabbit and in the human subjects; 3. comparison of the EMG signature of rabbit TrSSs and human TrPs (20).

CONCLUSION

The rabbit localized twitch responses [R-LTRs] show several similarities to, and no incompatibility with, the human local twitch response [LTR]. The rabbit presents a promising prospect as an animal model for a better understanding of local twitch responses, and probably of taut bands and trigger points.

REFERENCES
