Original article

Study on placing electromyography electrodes on lumbar multifidus muscles

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Abstract

Several studies have been carried out in the last decades showing that specific exercises for the multifidus muscle can aid the lumbar back pain treatment. Hence, it is very important to determine the exact location of these muscles for an electromyographic evaluation. The objective of this study is to conduct a literature review to show the different techniques used to place invasive electrodes and test a specific technique through an anatomic study in cadavers. PubMed database in the period of 1970 to 2009 was used. The results suggest that the needle should be introduced 2.5 cm laterally and 1.0 cm cranially from the most inferior point of the spinous process at a 45° medial inclination toward the vertebral laminae until reaching the periosteum. For the L5 level, the needle is inserted at the same angle, 2.5 lateral to the midline between the posterior superior iliac spines.

Keywords: multifidus, electromyography, lumbar back pain, rehabilitation, muscles.

1 Introduction

Nowadays, the rehabilitation programs in patients who suffer from recurrent lumbar back pain include electromyographic evaluation (HODGES and RICHARDSON, 1999a, b). A fundamental factor to understanding these programs is that the trunk muscles activity is necessary to stabilize the lumbar spine, and that during algic episodes this activity should be restored and optimized (MACDONALD, MOSELEY and HODGES, 2006; RICHARDSON, JULL, HODGES et al., 1999). Hence, it is important to know precisely the location of the muscles involved in the stabilization and movement of the lumbar spine (FOSTER, THOMPSON and BAXTER, 1999; HIDES, RICHARDSON and JULL, 1996, HAIG, MOFFROID and HENRY, 1991).

A number of studies have been carried out in the last decades demonstrating that specific physical exercises for the multifidus muscle can aid the lumbar back pain treatment (HODGES and RICHARDSON, 1999a, b; AROKOSKI, VALTA, AIRAKSINEM et al., 2001; HIDES, STOKES, SAIDE et al., 1994; HODGES and RICHARDSON, 1999a, b; RICHARDSON, JULL, HODGES et al., 1999; RICHARDSON, JULL, TOPPENBERG et al., 1992). These studies highlight that certain lumbar muscles promote spine stability, and that these programs aim at improving the segmental movement control (MACDONALD, MOSELEY and HODGES, 2006), the vertebral stability, muscle strength, spine orientation, or a combination of these characteristics since the muscles are altered causing pain (HIDES, STOKES, SAIDE et al., 1994).

The multifidus muscles have an important role in the stability of the lumbar spine due to their action, morphology, and innervation peculiar characteristics, and thus this group of muscles seem to be responsible for the support and segmental control (MOSELEY, HODGES and GANDEVIA, 2002; HIDES, RICHARDSON and JULL, 1996; KAY, 2000; BAJEK, BOBINAC, BAJEK et al., 2000).

Those are the most medial muscles in the lumbar spine, and they present an organized connection from one vertebra to another (MACINTOSH and BOGDUCK, 1986). Their muscle fibers present fasciculus that originate in the spinous process and lamina of each lumbar vertebra toward caudolateral of 3.4, or even 5 inferior levels (LEWIN, MOFFETT and VIIDIK, 1962, MOSELEY, HODGES and GANDEVIA, 2002). According to Lewin, Moffett and Viidik (1962), each multifidius fasciculus is innervated by the corresponding spinal nerve dorsal branch suggesting that these muscles can adjust or control a specific vertebral segment due to load application (ASPEDEN, 1992).

Several studies indicate that the multifidus muscles present superficial and deep fibers with different functions, and that the superficial fibers have more activity during the rotation and extension of the lumbar spine, whereas the deep fibers act mainly during the control of the lumbar spine stabilization (MACDONALD, MOSELEY and HODGES, 2006; RICHARDSON, JULL, HODGES et al., 1999). Moseley, Hodges and Gandevia (2002) verified the activation of the multifidus muscle during a specific arm movement, and concluded that this muscle contributes to a better motor control of the spine, and that the role of the deeper fibers is related to invertebrate control.

From the studies found in the literature, it can be said that there are several studies on focused on these muscles, which demontrate the most different methodology approaches for evaluating these muscles. It is worth to sate that among them are the studies that evaluate the muscular activity through electromyography (EMG), which is the record of the electrical activity associated with muscular contraction (HODGES, CRESSWELL and THORSTENSSON, 2001; HODGES and RICHARDSON, 1999a, b; VASSELJEN, DAHL, MORK et al., 2006; MOSELEY, HODGES and GANDEVIA, 2002; KURIYAMA and ITO, 2005; DANNEELS, COOREVITS, COOLS et al., 2002; HODGES and RICHARDSON, 1999a, b).

EMG have proved a very imporatant cinical and research ally as a tool for evaluating functions and disfunctions of the spine (HAIG, MOFFROID, and HENRY, 1991).

It can be observed that below L3 the multifidus muscles are covered only by the aponeuroses of the spine erecting muscle. Therefore, it facilitates the location of these muscles from this vertebral level. Above this vertebral level, the multifidus muscles are covered by the muscular fibers of the spine erecting and iliocostalis muscles (DANGELO and FATTINI, 2007), which makes their location and the capturing of the electrical activity of the central and deep muscles more difficult.

In order to capture electrical signals from inferior superficial muscles, surface electrodes should be placed parallel to the muscle fibers, which will be captured after cleaning the epidermis to reduce resistivity and ensure good electrical conductivity. To place those electrodes, SENIAM (Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscles) recommendations have been followed, which is a technique used in several areas such as neurology, orthopedics, ergonomics, sports, etc.

Although its principles was developed in the beginning of the 20th century and became popular quickly, in the last 10 years, surface electromyography has not been a widely used technique yet. Most of the studies worldwide are conducted by specific scientific groups and do not follow a pattern of surface electrodes placement. The majority of methodologies used by those groups are in general different, which makes difficult the wide use of this technique, therefore standardization is fundamental.

To place the electrodes on the surface of the multifidus muscles and according to the SENIAM recommendations, the subject should be in prone position with slight trunk flexion. The electrodes should be placed aligned 2 or 3 cm from the medline of the L5 spinous process (HERMES, FRERIKS, DISSELHORST-KLUG et al., 2000).

In order to capture electrical signal from deep muscles, wire electrodes can be used. Despite its difficult use, it is still the most common technique used since it can be placed deep into the muscular venter such as the multifidus muscle (BASMAJIAN and De LUCA, 1985).

Since it is a small and deep muscle, it can be expected that the insertion of a needle to place the wire electrode is not very precise due to misplacement or undesired movements after repeated contractions capturing the activity of a surrounding muscle instead. Thus, several studies describe the most adequate positioning of surface electrodes (HERMES, FRERIKS, DISSELHORST-KLUG et al.,2000), such as wire (TONG, HAIG, YAMAKAWA et al., 2005, HAIG, MOFFROID and HENRY, 2001; STEIN, BAKER and PINE, 1993) or needle electrodes (BOJADSEN, MOCHIZUKI, SERRÃO et al., 2001).

The wire electrodes have considerable advantages over surface electrodes. They are extremely thin and easily inserted and removed, and they can be placed in deep and specific muscles (BASMAJIAN and De LUCA, 1985).

According to Sutton (1962), when inserted properly, the wire electrodes register the voltage more precisely than the surface electrodes since they can register the voltage of a single motor unit. These electrodes can be easily implanted without anesthesia. If pain is experienced, it is caused by the needle that is used as a conductivity canal to the electrode and is removed after the electrode is implanted. Basmajian and De Luca, (1985) describe that the use of this kind of electrode has proved very useful in experimental studies.

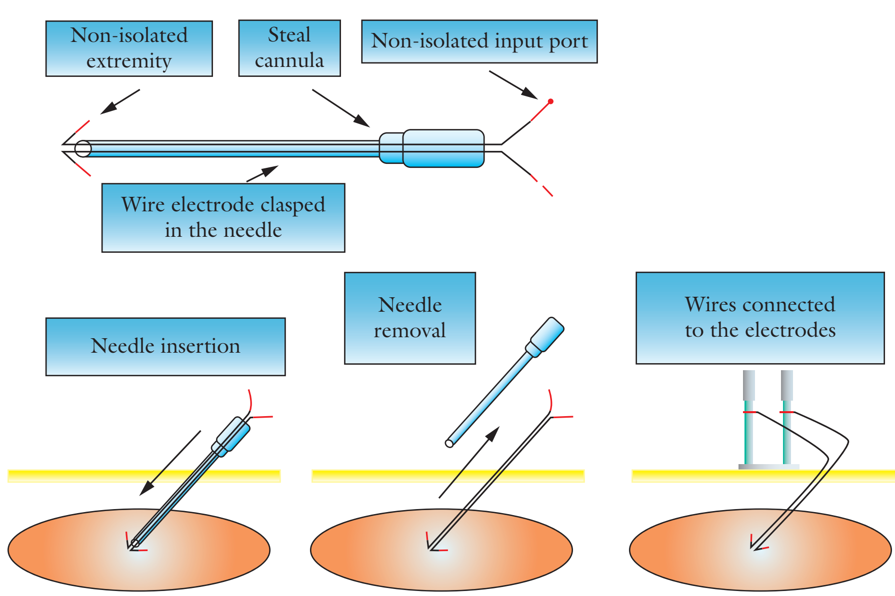

Figure 1. Wire electrode scheme (above) and its implantation (below). Adapted from Noraxon Inc USA (2005).

Jonsson and Reichaman (1970) developed a radiology technique to control the insertion of this kind of electrode. Another way to control the insertion of a needle and positioning the wire is using ultrasonography to guide the insertion (VASSELJEN, DAHL, MORK et al., 2006; MOSELEY, HODGES and GANDEVIA, 2002). Since the wire electrodes are extremely thin, they need to be inserted through a needle in order to be introduced into the muscle. The extremities of the wire are not isolated and are bent into a hook, in a way that when the needle is removed from the muscle, the wires are kept fixed implanted into the muscle (Figure 1).

Different techniques to place wire electrodes can be employed, especially in the multifidus muscle, when equipment to guide the insertion can not be used. Nevertheless, there are some divergences among the various kinds of manual techniques.

The literature studied on different techniques employed to locate the muscles highlights these divergences demonstrating the difficulties to evaluate these muscles in vivo.

The objective of this work was to contribute to solving the problem of locating multifidus muscles in vivo by:

- Conducting a literature review to show the different existing techniques and their divergences;
- Testing the Haig, Moffroid and Henry (1991) technique through a anatomical study in cadavers.

2 Material and methods

2.1 Literature review

The PubMed database from 1970 to 2009 (www.pubmed.nl) was used to conduct the literature search using the following keywords: Multifidus, invasive electromyography, low back pain, and rehabilitation.

2.2 Anatomical study

Firstly, with the cadaver in the dorsal decubitus position, the region to be studied was marked: dorsal region between L1and L5. A long pin that simulated the needle which would be used to insert the thin wire electrodes in vivo, was used in this study. It was inserted at the right side of the L1, 2.5 cm lateral and 1 cm cephalic in relation to the spinous process. The pin was inclined 45° toward the vertebral laminae, and it was inserted until it touched the periosteum guaranteeing that by using this procedure the electrodes were positioned in the muscular venter as desired (HAIG, MOFFROID and HENRY, 1991).

Next, with a longitudinal midsagittal plane incision and two horizontal incisions in the delimited region, the skin and the superficial fascia were retracted. Therefore, the lumbar fascia was exposed, which was also retracted exposing the erector spinal muscle, in which the muscles belly were progressively dissected and removed until a portion of the multifidus muscle was reached in each one of the five lumbar segments. Thus, it could be seen that the distal extremity of the pin was in fact inside the multifidus muscle.

Lastly, the trunk was dissected keeping the pin positioned in the muscle. After thorough dissection, it was verified that was inserted in the target muscular venter.

3 Results

3.1 Literature review

Several methods have been adopted focusing on finding the best way to place wire electrodes, but they were unsuccessful attempts.

According to Tong, Haig, Yamakawa et al. (2005), the exact location multifidus muscle is 2.5 cm laterally and 1.0 cm superior the most inferior aspect of the spinous process of L3, L4, and L5 at a 45° angle toward the midline focusing on inserting approximately 5 mm until reaching the spinous process. For the S1 level, the position is between the posterior superior iliac spines with 2.5 cm laterally. Lee and Coppieters (2005), who used intramuscular bipolar electrodes to locate the thoracic multifidus muscles, state that the best way is inserting the electrodes 2.0 cm laterally the midline until reaching the most dorsal aspect of the vertebral laminae. Using this technique for T5 and T11, the electrodes are inserted into the most inferior part of the transverse process, and for the T8 they are inserted at the most superior level of the transverse process.

Another important observation to place the electrodes in those muscles is the inclination that the needle should be inserted. According to Bojadsen, Mochizuki, Serrão et al. (2001), the needle should penetrate 2 cm laterally to the vertebral spinous process at a 45° angle until reaching the periosteum. The authors also concluded that in the thoracic spine the multifidus muscles are below the most superficial muscles, and thus the placement of wire electrodes is necessary. Below L3, they are superficial; therefore, surface electrodes can be used.

However, there have been controversies about the needle inclination for the electrodes placement because according to Stein, Baker and Pine (1993) the needle should be inserted into a midline between the spinous processes at a 30° cephalic angle and 10 to 15° of lateral angle, and the needle should be inserted 2 to 2.5 cm deep.

Haig, Moffroid and Henry (1991) suggest that the needle should be inserted 2.5 laterally and 1.0 cm cranially from the most inferior point of the spinous process at a 45° medial inclination toward the vertebral laminae until reaching the periosteum. For the L5 level, the needle should be introduced 2.5 cm laterally the midline between the posterior superior iliac spines. This study developed an accurate technique for the placement of needles in specific muscles of the paravertebral group. This technique has 81% accuracy proving that the needle is located in the lumbar multifidus muscles. Hence, it was the technique chosen in this study.

Table 1 shows the different techniques used for locating and placing electrodes in the multifidus muscles.

3.2 Anatomical study

It can be observed in Figure 2 that the needle extremity is located exactly in the muscular venter.

4 Discussion

The literature has improved concerning the use of EMG surface electrodes. The SENIAM has contributed for the standardization adopted by the scientific community.

Table 1. Summary of the literature review on the different methodological procedures for locating the multifidus muscles showing its controversies.

Author	Journal	Electrode	Level evaluated	Technique employed	Observation
Tong, Haig, Yamakawa et al. (2005)	Spine 30: 17, 2005	50 mm Neddle electrode	L3, L4, and L5	2.5 cm laterally and 1.0 cm superior the most inferior aspect of the spinous process of L3, L4, and L5 at a 45° angle toward the midline focusing on inserting approximately 5 mm until reaching the spinous process. For the S1 level, the position is between the posterior superior iliac spines with 2.5 cm laterally.	IF abnormal signals such as fibrilation occur after the placement of the electrodes, they should be removed and placed again.
Lee and Coppieters (2005)	Spine 30:08, 2005	Intramuscular Bipolar	T5, T8, and T11	2.0 cm laterally the midline until reaching the most dorsal aspect of the vertebral laminae. Using this technique for T5 and T11, the electrodes are inserted into the most inferior part of the transverse process, and for the T8 they are inserted at the most superior level of the transverse process.	
Bojadsen, Mochizuki, Serrão et al. (2001)	Brazilian Journal of Biomechanics 2(2): 2001	Intramuscular wire electrodes	Thoracic	The needle should penetrate 2 cm laterally to the vertebral spinous process at a 45° angle until reaching the periosteum.	In the thoracic spine the multifidus muscles are below the most superficial muscles, and thus the placement of wire electrodes is necessary. Below L3, they are superficial; therefore, surface electrodes can be used.
Haig, Moffroid and Henry (1991)	Muscle Nerve 14:1991	Intramuscular wire electrodes	L1 to L5	The needle should be inserted 2.5 laterally and 1.0 cm cranially from the most inferior point of the spinous process at a 45° medial inclination toward the vertebral laminae until reaching the periosteum. For the L5 level, the needle should be introduced 2.5cm laterally the midline between the posterior superior iliac spines.	
Stein, Baker and Pine (1993)	Arch Phys Med Rehabil 74: 1993	Intramuscular wire electrodes		The needle should be inserted into a midline between the spinous processes at a 30° cephalic angle and 10 to 15° of lateral angle, and the needle should be inserted 2 to 2.5 cm deep.	

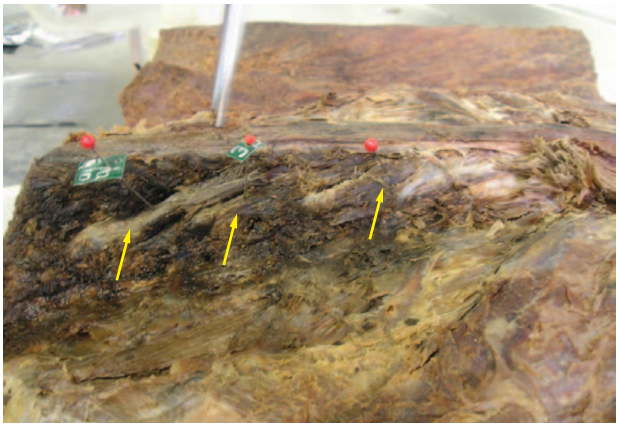

Figure 2. Cadaver piece showing the dissected dorsal region and the needles inserted into the multifidus muscles of L3, L4, and L5 (arrows).

Nevertheless, for studies that include the evaluation of the multifidus muscles above L3, the use of invasive electrodes is necessary. According to Jonsson and Reichamann (1970), touching the trunk structures does not provide enough information to guide the insertion of wire electrodes into the individual muscles of the paravertebral group.

The results of the present study are in accordance with Haig, Moffroid and Henry (1991), who suggest that the needle should be inserted 2.5 laterally and 1.0 cm cranially from the most inferior point of the spinous process at a 45° medial inclination toward the vertebral laminae until reaching the periosteum. For the L5 level, the needle should be introduced 2.5 cm laterally the midline between the posterior superior iliac spines.

5 Conclusion

Further research should use the needle electrodes and/or wire electrodes placement procedures described in this study.

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