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A comparison of H-reflex in the triceps surae muscle group in patients with S1 radiculopathy

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ABSTRACT

Despite differences in the anatomical and physiological characteristics of the medial gastrocnemius (MG), lateral gastrocnemius (LG), and soleus (Sol) muscles, it is common practice to investigate them as single triceps surae H-reflex recordings. The aim of this study was to compare the latencies of H-reflex recordings from the Sol, MG, and LG in patients with explicit magnetic resonance imaging (MRI) evidence of unilateral S1 radiculopathy and also compare their diagnostic yield in varied clinical characteristics (i.e., symptom duration and severity of involvement). We found a significant difference between H-reflex latencies of Sol and the two others (p < 0.05 for both comparisons). Although Sol had more sensitivity in patients with positive straight leg raising (SLR) of 30°–50° and also the sub-acute phase of the disease, MG and LG had more sensitivity in the acute phase of the disease and patients with positive SLR of 50°–70°, there were no statistically significant differences between diagnostic ability of the three heads of the triceps surae in various clinical settings and they can be used interchangeably in patients with suspected S1 radiculopathies.

Introduction

The monosynaptic Hoffmann (H) reflex is an electrodiagnostic parameter that was first described in 1910 and 1918 by Paul Hoffmann; in-depth electrophysiological investigations of this late response were performed by Magladery and McDougal in the 1950s and they designated this potential the H-reflex in honor of Hoffmann (Magladery and McDougal 1950).

Perhaps the most common clinical application of the H-reflex is to evaluate the status of the peripheral nervous system with respect to proximal peripheral nerve conduction and potential entrapment of the nerve roots, for example, radiculopathies.

It has been well established that the H-reflex in the triceps surae is sensitive in the detection of S1 radiculopathy and is helpful in differentiating it from L5 radiculopathy (Braddom and Johnson 1974; Sabbahi and Khalil 1990; Oh 2003). In studying S1 radiculopathy, prolonged onset latency and/or absence of the H-reflex on the affected side are the most commonly used measures of the H-reflex (Braddom and Johnson 1974a, 1974b; Khosrawi and Fallah 2013). H-reflex latency prolongation or side-to-side differences probably indicate the neural demyelination with significant damage of the large diameter nerve axons (Alrowayeh and Sabbahi 2011).

The triceps surae consists of the medial head of the gastrocnemius (MG), lateral head of the gastrocnemius (LG), and the soleus (Sol) muscles. There are several clear differences between the gastrocnemii and the soleus. It is accepted that these muscles perform different functions (Herman 1967), differ in the structure and muscle fiber types (Johnson et al. 1973; Edgerton et al. 1975; Tucker and Turker 2004), and are innervated differently (Young et al. 1983). Their fiber type differences affect their resistance to fatigue (Ochs et al. 1977), contractile properties (Vandervoort and McComas 1983), and electromyogram (EMG) activity patterns during standing and walking (Joseph and Nightingale 1952; Campbell et al. 1973). Such differences in anatomical and physiological functions between the muscle groups may result in different activation patterns. Thus, it may be possible to record the differences in the reflex responses of the Sol, MG, and LG muscles during varied clinical characteristics. Nevertheless, it is common practice to investigate them as a single gastrocnemius–soleus H-reflex recording (Dumitru et al. 2002; Oh 2003; Alrowayeh et al. 2011). The Sol is the most commonly used muscle for H-reflex studies in humans (Tucker et al. 2005). Zheng et al. (2014) introduced biceps femoris-long head H-reflex from S1 root stimulation as an additional and reliable method for assessing the S1 spinal reflex pathway of the lower limb proximal muscles.

The aim of this study was to compare the latencies of H-reflex recordings from Sol, MG, and LG in patients with explicit magnetic resonance imaging (MRI) evidence of S1 root involvement and compare their diagnostic yield in varied clinical characteristics (i.e., symptom duration and severity of involvement). The results of this study may provide a guide for clinicians to choose the most appropriate muscle in...
order to evaluate H-reflex in patients suspected with S1 radiculopathy.

Materials and methods

Study subjects

Figure 1 is a graphic summary of the subject recruitment and study methodology. Sixty potentially eligible participants referred due to unilateral radicular low back pain were recruited from December 2016 to February 2017 in the physical medicine and rehabilitation outpatient clinic of Shahid Faghihi Teaching Hospital, Shiraz, Iran.

Inclusion criteria were the age range of 18–60 years with a history/physical examination suggesting unilateral S1 radiculopathy which includes: complaints of low back pain with pain or paresthesia radiating into the right or left lower extremity below the level of the knee, in the nerve root territory, dermatomal sensory loss, or any sign of muscle atrophy or weakness for less than 3 months. The subjects gave their informed consent and agreed to participate in the study. The ethics committee of the university approved the study.

A physiatrist took the patients’ history and performed a comprehensive and codified spinal history and physical examination. During the physical exam, a diagnostic test of straight leg raising (SLR) was performed by asking the patient to lie down on a flat examination table in a supine position. Both hips and knees of the involved leg were maintained in a neutral position neither abducted nor adducted. The patient’s head was not supported by a pillow. The examiner grasped the patient’s heel in the cup of his hand and the other hand maintained the patient’s knee in an extended position. The examiner slowly raised the tested leg up to 90° by flexing the hip while maintaining the knee in extension and keeping the limb neutral, neither externally nor internally rotated. The maneuver was positive if the patient complained of reproduction of symptoms distal to the knee joint, between 30° and 70° of hip flexion (Tarulli and Raynor2007). If the test was positive, an angular goniometer with a degree of error equal to ±1° was applied at the level of the greater trochanter to measure the value of the hip flexion. Only patients with a positive SLR test on physical examination were included in the study.

All subjects underwent a non-contrast lumbosacral spinal MRI scan (GE Signa Horizon LX; GE Medical Systems, Milwaukee, WI, USA) which was interpreted by a masked neuroradiologist. Only patients with ipsilateral S1 root involvement were included.

Other exclusion criteria in the current study were any type of neuropathy such as diabetic neuropathy, brain disorder such as cerebrovascular accident, spinal cord lesions such as spinal cord injury, previous history of spinal cord surgery, lower limb fracture, any type of nerve entrapment in the lower limb such as Piriformis syndrome, congenital deformity in the lower limb, bilateral positive SLR, bilateral absent H-reflex, and multilevel MRI finding.
Experimental procedure

All the eligible participants underwent the same standardized electrophysiological examination by a board certified physiatrist using the same instrument (Medelec Synergy; VIASYS, Woking, UK). A sweep speed of 10 ms/div, amplifier sensitivity of 500 μV/div, pulse duration of 1.0 ms, and filter bandpass of 10 Hz–10 kHz were used by a constant current stimulator. In order to record H-reflex from triceps surae of both lower limbs (symptomatic and asymptomatic), the patient was positioned comfortably in the prone position with feet off the edge of the plinth. A pillow was placed beneath the legs to cause a slight knee flexion. The cathode of Ag/AgCl surface stimulation was placed in the mid-popliteal fossa with the anode distal in a longitudinal placement along the length of the tibial nerve. The stimuli were delivered at a rate of one stimulation every 2 or 3 seconds in a consistent manner across trials. The current intensity was slowly increased until the H-reflex magnitude was maximized without concomitant activation of the motor fibers. Several responses were observed at this stimulus level to ensure a reproducible and stable response. The onset latency (measured from the stimulus artifact to the first deflection of the H-wave from baseline) and side-to-side H-reflex latencies were obtained. The upper limits of normality for side-to-side latency differences are different in various studies. In the current study, unobtainable H-reflex or side-to-side difference over 1 ms (Han et al. 1997; Tsai and Tsai 2013) and over 1.5 ms (Braddock and Johnson 1974; Dumitru et al. 2002) was used as a prediction of an S1 radiculopathy.

One centimeter disposable electrodes were used for recording. The MG, LG, and Sol H-reflexes were recorded according to the method of Sabbahi and Khalil (1990) and Alrowayeh and Sabbahi (2009), as shown in Figures 2 and 3.

A minimum room temperature of 25°C and a distal limb temperature higher than 32°C were maintained continuously throughout all electrodiagnostic studies.

The order of recordings from the muscles was randomly alternated to compensate for the potential inherent changes of the H-max recording during the course of the experiment.

Data analysis

It is indicated that the degree of limitation of SLR has a direct relationship to the size and position of the disc protrusion and to its relationship to the spinal nerve (Xin et al. 1987; Ombregt 2013). In other words, the more limited the SLR, the greater the disc protrusion (Urban 1981; Wong 2010), so we have supposed SLR degree as a clinical marker for severity of the underlying pathology. Therefore, the patients were divided into two groups: positive SLR between 30° and 50° and positive SLR between 50° and 70°.

In addition, the authors categorized the duration of the symptoms as: acute (>4 weeks) or sub-acute (4–12 weeks) to compare the diagnostic ability of different muscles’ H-reflex based on symptom duration.

For statistical analyses, SPSS for Windows (Statistical Package for Social Sciences, IBM, Armonk, NY, USA), version 21, was used. The Kolmogorov–Smirnov test was applied to test the normality of the distribution for all continuous variables. The McNemar test was used to compare the diagnostic ability for S1 radiculopathy in the MG, LG, and Sol muscles. H-reflex latencies obtained from three heads of the triceps surae muscle were compared using paired t-test. Pearson correlations were used for pairwise comparisons of the H-reflexes. We hypothesized that the related measures would have moderate ($r = 0.35–0.49$) to strong ($r \geq 0.50$) correlations.
to support their convergent utility. In all instances, we considered $p < 0.05$ as the significance level.

**Results**

**The subjects’ characteristics**

A total of 20 subjects were finally enrolled in the study. The mean (SD) age of the patients was 40.6 (8.4) years old. Among these patients, 13 were male and 7 female. Clinical characteristics are displayed in Table 1.

**H-reflex latency**

As expected, the latencies of H-reflexes from all three muscles were significantly higher on the symptomatic affected side than the non-symptomatic side ($p < 0.01$ for all paired comparisons).

As shown in Table 1 the H-reflex latency of the symptomatic leg, obtained from Sol, was significantly prolonged compared with MG ($t(20) = -2.62, p = 0.018$) and LG latencies ($t(20) = -2.06, p = 0.048$) while there was no significant difference between MG and LG latencies ($t(20) = 1.11, p = 0.282$).

In the asymptomatic leg, there was no significant difference between H-reflex latencies obtained from Sol (28.88 ± 1.9), MG (28.53 ± 1.87), and LG (28.15 ± 1.95) muscles ($p > 0.05$ for all paired comparisons).

Diagnostic criteria for S1 radiculopathy were absence of H-reflex on the affected side and side-to-side latency differences. Considering 1 ms as the upper limit of normal for H-reflex latencies.

As shown in Table 2, based on the assumed cutoff point of 1.5 ms for abnormal side-to-side latency differences, 4 patients (sensitivity 44.4%) were diagnosed as S1 radiculopathy by Sol H-reflex while MG and LG H-reflexes were diagnosed in 6 (sensitivity 66.6%) and 5 (sensitivity 55.5%) patients, respectively.

McNemar’s test showed that the differences between the MG, LG, and Sol muscles’ H-reflex latencies in the acute phase appeared to be due to chance and there were no significant differences between the paired tests ($p > 0.05$ for all).

In the sub-acute phase of the disease, 9 (sensitivity 81.8%) patients were diagnosed by Sol H-reflex while MG and LG H-reflexes could diagnose S1 radiculopathy in 8 (sensitivity 72.7%) and 7 (sensitivity 63.6%) patients, respectively.

Despite the differences in sensitivities of the muscles of the triceps surae in the sub-acute phase of S1 radiculopathy, McNemar’s test determined that there were no statistically significant differences in the proportion of abnormal H-reflexes in different muscles in the sub-acute phase ($p > 0.05$ for all paired proportions).

**SLR degree**

Nine (sensitivity 81.8%), 8 (sensitivity 72.7%), and 7 (sensitivity 63.6%) patients with positive SLR test of $30^\circ–50^\circ$ showed abnormality in Sol, MG, and LG H-reflexes, respectively, but McNemar’s test determined that there were no statistically significant differences in the proportion of abnormal H-reflexes in different muscles ($p > 0.05$ for all paired proportions).

**Table 1.** Clinical characteristics and measures of H-reflex in patients with unilateral S1 radiculopathy ($n = 20$).

<table>
<thead>
<tr>
<th>Sex</th>
<th>Male: 13 (65%)</th>
<th>Female: 7 (35%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>40.6 ± 8.4</td>
<td></td>
</tr>
<tr>
<td>Height (cm)</td>
<td>168.4 ± 9.25</td>
<td></td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>69.63 ± 7.91</td>
<td></td>
</tr>
<tr>
<td>Mean symptom duration (days)</td>
<td>37.05 ± 22.24</td>
<td></td>
</tr>
<tr>
<td>Acute (&gt;4 weeks)</td>
<td>9 (45%)</td>
<td></td>
</tr>
<tr>
<td>Sub-acute (4–12 weeks)</td>
<td>11 (55%)</td>
<td></td>
</tr>
<tr>
<td>Mean positive SLR</td>
<td>49.65 ± 11.64</td>
<td></td>
</tr>
<tr>
<td>$30^\circ–50^\circ$</td>
<td>11 (55%)</td>
<td></td>
</tr>
<tr>
<td>$50^\circ–70^\circ$</td>
<td>9 (45%)</td>
<td></td>
</tr>
<tr>
<td>Sol H-reflex latency (ms)</td>
<td>$30.87 ± 3.43^{ab}$</td>
<td>$28.88 ± 1.9^{cd}$</td>
</tr>
<tr>
<td>MG H-reflex latency (ms)</td>
<td>$29.75 ± 2.56^{ac}$</td>
<td>$28.53 ± 1.87^{cd}$</td>
</tr>
<tr>
<td>LG H-reflex latency (ms)</td>
<td>$29.55 ± 3^{ac}$</td>
<td>$28.15 ± 1.95^{cd}$</td>
</tr>
</tbody>
</table>

*Paired-sample test showed a statistically significant difference ($p < 0.05$).

**Table 2.** Comparison of diagnostic ability of the Sol, MG, and LG in different SLR degrees and symptom durations.

<table>
<thead>
<tr>
<th>Cut-point for side-to-side H-reflex latency differences</th>
<th>Positive SLR</th>
<th>Sol</th>
<th>MG</th>
<th>LG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Acute</td>
<td>Sub-acute</td>
<td>Acute</td>
</tr>
<tr>
<td>$&gt;1$ ms</td>
<td></td>
<td>4</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50$^\circ–70^\circ$</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>$&gt;1.5$ ms</td>
<td></td>
<td>3</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50$^\circ–70^\circ$</td>
<td>0</td>
<td>3</td>
</tr>
</tbody>
</table>
In patients who exhibited positive SLR test at 50°–70°, Sol H-reflex was abnormal in 3 (sensitivity 33.3%) patients while MG and LG H-reflexes were abnormal in 4 (sensitivity 44.4%) and 5 (sensitivity 55.5%) patients, respectively. Differences in the number of abnormal subjects were not statistically significant (McNemar’s test, p > 0.05 for all comparisons).

Results of the comparison of H-reflexes obtained from these three muscles, using >1.5 ms as the cutoff point in different clinical settings, are shown in Table 2.

### Discussion

The MG and LG, together with the Sol, are traditionally considered as one functional unit of the ankle plantar flexor muscles (i.e., the triceps surae). The present study aimed to explore the similarities and differences in the H-reflexes obtained from the three heads of the triceps surae muscle in patients with explicit evidence of S1 radiculopathy on MRI.

The latencies of the H-reflexes were shorter for the MG and LG than for the Sol which exhibited a significant difference in the symptomatic side (for the Sol, MG, and LG, H-reflex onset latencies were 30.87 ± 3.43, 29.75 ± 2.56, and 29.55 ± 3 ms, respectively). It could be due to the more proximal locations of the MG and LG electrodes compared to the Sol electrodes.

Although some previous studies suggest that the L5 nerve root supplies the lateral head of the gastrocnemius (Marinacci 1958; Fisher 1992) and hence LG H-reflex is suggested as a reliable evaluation in the examination of the L5 nerve root lesion (Alrowayeh and Sabbahi 2009; Alrowayeh et al. 2011), the positive and strong correlation between MG, Sol, and LG H-reflex latencies in the current study justifies that they are significantly related to similar concepts and they are measuring the same domain. Thus, LG can be employed in line with MG and Sol which are proven (Bobinac-Georgijevski et al. 1991; Strakowski et al. 2001) to be reliable measures in electrodiagnostic evaluation of patients with suspected S1 radiculopathy.

The total number of patients with abnormal H-reflex in the three muscles (13/20, 12/20, and 12/20 for Sol, MG, and LG, respectively) showed that despite the differences in functions, the contractile properties, structure, muscle fiber types, innervation, and even EMG activity patterns of three heads of the triceps surae, generally there was no statistically significant difference among LG, MG, and Sol in the diagnosis of S1 root involvement.

H-reflex latencies based on the symptom duration showed that although MG and Sol were the most sensitive heads in acute and sub-acute phases (diagnostic ability of 66.6% and 81.8%, respectively), there was no statistically significant difference in diagnostic utility of different heads (p > 0.05 for all). Meanwhile, although it is believed that the H-reflex changes may be the earliest abnormality of radiculopathy electrodiagnosis in the absence of other findings, we found that in all three heads of the triceps surae, the diagnostic yield increased in the sub-acute phase as compared with the acute one. Some of the previous studies have also concluded that patients with the duration of symptoms more than 1 month have more electrodiagnostic abnormalities compared to those with clinical involvement less than 1 month (Nafissi et al. 2012). Latency change in more chronic conditions is not transient because it is caused by structural changes in the neural myelination as well as axonal damage to a large extent. However, in the acute stage, the H-reflex latency changes are less likely to be detected, especially when the neural impingement compromises the axonal function before enough demyelination has occurred (Alrowayeh and Sabbahi 2011).

The H-reflex latencies based on SLR degree of limitation showed that in patients with a positive SLR test of 30°–50°, the Sol muscle exhibited the most diagnostic utility (81.8%) while LG was the most sensitive head (55.5%) in patients who had a positive SLR test of 50°–70°. Nevertheless, the difference in diagnostic utility of different heads was not statistically significant (McNemar’s test, p > 0.05 for all comparisons).

Meanwhile, we found that in all three heads of the triceps surae, diagnostic yield increased in patients with a positive SLR test of 30°–50° compared to those with a positive SLR test of 50°–70°. One possible explanation could be that there is a strong negative correlation between the degree of SLR test and various parameters that signify the severity of the patient symptoms (pain at rest, pain at night, pain upon coughing, reduction of walking capacity, and regular consumption of analgesics) (Jonsson and Stromqvist 1995). On the other hand, as the patient’s symptoms increase, a greater number of neural axons will be compromised (Fisher 1992) and due to progression of the nerve root involvement, abnormal latency will be more pronounced (Alrowayeh and Sabbahi 2011).

The limitations of our study were as follows: first, we know that the number of patients enrolled in the present survey was relatively small statistically to support a general recommendation. Therefore, our finding needs to be confirmed in a larger study. Additionally, the recommended H-reflex diagnostic criteria were side-to-side latency differences (Braddom and Johnson 1974; Fisher 1992; Han et al. 1997), but using amplitude reduction on the affected side might be helpful in differentiating the diagnostic ability of three heads of the triceps surae, especially in the acute phase of the disease (Alrowayeh and Sabbahi 2011). Third, physicians must be aware that one of the inherent problems with trying to determine the accuracy of a diagnostic test is the lack of a gold standard for the diagnosis of lumbosacral radiculopathy. Studies that used imaging as the reference standard most probably overestimated the sensitivity and underestimated the specificity due to its false-positive rate, or in other words, overestimated the number of the diseased subjects (Rubinstein et al. 2007). Therefore, further investigation is needed to gain insight into the most appropriate muscle in order to evaluate H-reflex in different clinical settings in patients suspected with S1 radiculopathy.

### Conclusion

The results of this study suggested that although the Sol muscle has more sensitivity in patients with positive SLR of
30°–50° and sub-acute phase of the disease, and MG and LG had a higher diagnostic ability in the acute phase of the disease and patients with positive SLR of 50°–70°, there were no statistically significant differences in the diagnostic ability of the three heads of the triceps surae in various clinical settings and they can be used interchangeably in patients with suspected S1 radiculopathies.

The results also suggested that the sensitivity of the muscle group (Sol, MG, and LG) H-reflexes decreases in patients with positive SLR of 50°–70° and acute stage of the disease.

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Disclosure statement

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