A new approach for estimation of the number of synapse(s) included in the H-reflex

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Abstract:

Background:

The main clinical application of the H-reflex is the evaluation of the S1 nerve root such as radiculopathy. An attempt has been made to reduce the pathway over which H-reflex can be obtained in the hope for localizing a lesion to the S1 nerve root, so S1 central loop has been suggested. The main goal of this study is the estimation of H-reflex number of synapse for better understanding the physiology of this practical reflex.

Methods:

Forty healthy adult volunteers (22 males, 18 females) with mean age of (37.7±10.2) years participated in this study. They were positioned comfortably in the prone position, with the feet off the edge of the plinth. Recording electrodes were positioned at the mid point of a line connecting the mid popliteal crease to the proximal flare of the medial malleolus. Stimulation was applied at the tibial nerve in the popliteal fossa and H, F and M waves were recorded. Without any change in the location of recording electrodes, a monopolar needle was inserted as cathode at a point 1 cm medial to the posterior superior iliac spine, perpendicular to the frontal plane. The anode electrode was placed over the anterior superior iliac spine, and then M and H waves of the central loop were recorded. After processing the data, sacral cord conduction delay was determined by this formula:

* Sacral cord conduction delay = central loop of H-reflex – (delays of the proximal motor and sensory fibers in central loop).
Results:

Central loop of H-reflex was (6.77 ± 0.28) msec and sacral cord conduction delay was (1.09 ± 0.06)msec.

Conclusion:

This study is in accordance with previous investigations indicative of one synapse at the S1 cord level of H-reflex, because sacral cord conduction time was estimated to be about 1.09 msec, so it was sufficient for only one synapse.

Key words: H-reflex, central loop of H-reflex, sacral cord conduction delay, monosynaptic reflex, synapse.

Background:

The H-reflex was first described by Hoffmann in 1918. The major clinical application is evaluating the status of the peripheral nervous system with respect to proximal peripheral nerve conduction and potential entrapment of the S1 nerve root. The traditionally performed H-reflex has a very long pathway reducing its ability to localize a lesion to the S1 nerve root. To overcome this obstacle, H-reflex study was devised by stimulating the S1 nerve near the first sacral intervertebral foramen by Pease and coworkers [1,2] and was further investigated by others [3,4,5].

Despite the agreement on its usefulness, there is controversy regarding the synapses involved in its reflex arc. Many authors believe that this is a monosynaptic reflex [6,7]. However, some investigators have hypothesized that the reflex is mainly oligosynaptic [8,9,10].

In this study, we have tried to estimate the number of involved synapse(s) in this reflex with calculating the conduction time across the sacral cord with using F-wave and the peripheral and central components of H-reflex.
Methods:

The study was performed on 40 asymptomatic volunteers. The study group consisted of 22 men (55%) and 18 women (45%).

They had no low back pain and no previous history of neurologic problems, intervertebral disc problem, rheumatic diseases, diabetes and renal or metabolic diseases. It was assured that they had normal symmetrical plantar and Achilles tendon reflexes, normal muscle strength, able to tiptoe and heel walking, no sensory deficit and negative straight leg raising (SLR) test.

After obtaining informed consent, the subjects were examined relaxed in prone position. Examination was performed in room temperature with skin warmed to reach normal, if cold.

Dantec 2000C equipment was used. Recording electrodes were surface electrodes with 0.5 cm diameter. The active electrode was placed at the middle of the line connecting the popliteal crease to the medial malleolus. The reference electrode was placed 2 cm distal to it. The ground electrode was placed near the active pick-up electrode over the calves. Stimulator electrodes for stimulation at the popliteal fossa were surface electrodes with 0.5 cm in diameter and cathode-anode distance of 2 cm. Direct rectangular current pulses were used with a duration of stimulation of 1msec for H-reflex and 0.2 msec for F and M waves. Stimulation frequency was 0.5 Hz for H-reflex and 1 Hz for F-wave. The monitor had a filter frequency of 2 Hz to 10 KHz, sweep speed of 5 msec/division and voltage sensitivity of (0.1-2) mv/division.

The soleus H-reflex was obtained with submaximal stimulation of the tibial nerve at the popliteal fossa. Then peak latency and base to peak amplitude of the H-wave were recorded.

After that, with supramaximal stimulation, F and M waves were recorded, than an averaged F-wave latency, onset latency and base to peak amplitude of M-wave were determined.

For determination of averaged F-wave latency, at least 10 F-waves were recorded.

To obtain central H-reflex, stimulation was done using monopolar needle electrode for cathode and disc surface electrode with 0.5 cm diameter for anode. The cathode electrode was inserted at a point 1 cm medial to the posterior superior
iliac spine, perpendicular to the frontal plane. After the needle touched the sacrum, it was slightly retracted. The anode electrode was placed over the anterior superior iliac spine. Pickup electrodes were not changed; then stimulation was applied and increased until the largest H-wave could be seen. After that, peak latencies and base to peak amplitudes of M and H waves were recorded.

Finally, the distances were measured:
- Popliteal crease to the needle.
- Needle to the T12 spinous process.
- Popliteal crease to the T12 spinous process (via greater trochanter)

Then processing of the data was done as outlined below:
First, conduction velocity of proximal motor and sensory fibers were measured by these formulas:

\[
\text{Motor NCV} = \frac{2 \times (\text{distance between popliteal crease to T12 spinous process})}{F^* - M^{**} - 1}
\]

\[F^* : \text{mean of F onset latencies (ms)}\]
\[M^{**} : \text{onset latency of M-wave (ms)}\]

\[
\text{Sensory NCV} = \frac{\text{Distance between popliteal crease to the needle (mm)}}{\text{Peak H (peripheral) - Peak H (central)}}
\]

\[
\text{Conduction time} = \frac{\text{distance between needle to T12 spinous process (mm)}}{\text{NCV (motor or sensory) (m/s)}}
\]

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We considered the above distance equal to the length of S1 nerve root since the 12th thoracic spine is opposite the first sacral segment [11].

Afterwards, sacral cord conduction time was calculated:
Sacral cord conduction time = central loop of H-reflex – (delays of the proximal motor & sensory fibers in central loop).

The analyses were performed using SPSS 10.0 software. Independent t-test has been applied for statistical analysis of the data. P<0.05 was considered significant.

Results:

The study group consisted of 22 men (55%) and 18 women (45%) with the mean age of (37.7±10.2) and the range of (21-62) years.

You are provided with the results of stimulation of the tibial nerve in the popliteal fossa in Table 1.

The results of direct stimulation of the S1 nerve root and recording from the soleus are shown in Table 2. The mean central loop of the H-reflex was obtained as (6.77 ± 0.28) msec.

The results of distances between landmarks are summarized in Table 3.

Finally, after calculation (as discussed previously), sacral cord conduction time in H-reflex was obtained as (1.09 ± 0.06) msec (Table 4).

Discussion:

There is controversy regarding the synapses involved in the H-reflex. Many authors believe that this is a monosynaptic reflex arc [6,7]. However, some investigators have hypothesized that the reflex is mainly oligosynaptic [8,9,10].

Ertekin and coworkers stimulated the tibial nerve at the popliteal fossa and recorded from different lumbar epidural intervertebral levels. The time interval between the negative peaks of the ventral and dorsal root potentials was used to calculate the approximate sacral cord conduction time, which was found to be 1.3
msec, so they suggested the reflex is exclusively monosynaptic [7]. In another study, Ertekin and coworker stimulated the tibial nerve and epidurally recorded the potentials and proposed that the central conduction time of the soleus H-reflex could be about 1.1 msec[12]. The values of 1.3 and 1.1 msec that were obtained are close to the our value of 1.09 msec.

In contrast with some investigators that have hypothesized there could be some oligosynaptic contributions to the H-reflex [8,9,10], it can be concluded that the soleus H-reflex is for the most part a monosynaptic reflex, composed of a single synapse between the group Ia fibers and the soleus motor neurons. Because in this study, mean sacral cord conduction time was estimated to be about 1.09 msec, so it was sufficient for only one synapse.

As stated earlier, studying the central loop of H-reflex is an important tool to differentiate central from peripheral lesions of the S1 spinal nerve, the normal value of which was (6.77 ± 0.28) msec in this study. This result is in line with the results of previous studies by Pease and coworkers showing a normal value of (7 ± 0.3) msec[2], by Ghavanini and coworkers with normal value of (6.9 ± 0.4) msec [3], by Zhu and coworkers with normal value of (6.88 ± 0.33) msec [4] and by Sadeghi and coworkers with normal value of (6.78±0.3) msec [5].

Conduction time in the afferent fibers of the central loop H-reflex, (2.69 ± 0.13) msec, and in efferent fibers, (2.99 ± 0.15) msec, were similar to estimations provided by Zhu and coworkers that showed 2.6 msec and 3.2 msec for afferent and efferent fibers, respectively [4].

The estimated length of S1 nerve root was (174 ± 8) mm. The resulting value is similar to estimation of Zhu and coworkers in 15 cadavers, that was (175 ± 3) mm [4].

Mean conduction velocity of the afferent (Ia) and the efferent fibers of the H-reflex was (64.9) m/s and (58.3) m/s, respectively. There was no significant difference between men and women in this regard. Its cause seems to be a) longer lower extremity in men and b) more time for proximal sensory and motor fibers conduction in men. (see Tables 3 and 4). Our results are similar to estimations provided by other methods[4,13].

Best necessary stimulation to obtain the central H-reflex was significantly higher than necessary stimulation to obtain the peripheral H-reflex. This more intense stimulation may be due to the fact that the S1 spinal nerve emerges from the sacrum at
the anterior aspect. Thus, the needle cannot approach it well from the posterior aspect. Furthermore, the large distance between cathode and anode causes current diffusion increasing the best necessary stimulation.

**Conclusion:**

This study, as many previous investigations, showed that the H-reflex is a monosynaptic reflex arc.

**-Competing interests:** none

**- Author’s contributions:**

- M.R.A.G : Suggesting the research, supervision and helping with calculation.
- A.A. : examining the cases, calculation of data, writing the paper.
- S.S. : examining the cases, calculation of data.
- M.R. E : examining the cases, calculation of data.

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**References:**


Table 1: M, H&F waves in the tibial nerve stimulation at the popliteal fossa.

<table>
<thead>
<tr>
<th>Wave</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Onset latency (msec)</td>
<td>4.3</td>
<td>0.5</td>
</tr>
<tr>
<td>Amplitude (mv)</td>
<td>4</td>
<td>1.6</td>
</tr>
<tr>
<td>H</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak latency (msec)</td>
<td>34.4</td>
<td>2.5</td>
</tr>
<tr>
<td>Amplitude (mv)</td>
<td>1.3</td>
<td>0.7</td>
</tr>
<tr>
<td>F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Onset latency (msec)</td>
<td>30.7</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Table 2: The characteristics of the central loop H-reflex.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>M-wave</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak latency (msec)</td>
<td>19.1</td>
<td>1.7</td>
</tr>
<tr>
<td>Amplitude (mv)</td>
<td>1.4</td>
<td>0.8</td>
</tr>
<tr>
<td>H-wave</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak latency (msec)</td>
<td>25.9</td>
<td>1.8</td>
</tr>
<tr>
<td>Amplitude (mv)</td>
<td>0.9</td>
<td>0.6</td>
</tr>
<tr>
<td>Central loop of H-reflex (msec)</td>
<td>6.77</td>
<td>0.22</td>
</tr>
<tr>
<td>Amount of stimulation</td>
<td>41.9</td>
<td>8.5</td>
</tr>
</tbody>
</table>
Table 3: Distances between landmarks.

<table>
<thead>
<tr>
<th>Distance</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monopolar needle to T12 spinous process (mm)</td>
<td>174*</td>
<td>8</td>
</tr>
<tr>
<td>Monopolar needle to popliteal crease (mm)</td>
<td>567*</td>
<td>26</td>
</tr>
<tr>
<td>Popliteal crease to T12 spinous process (mm)</td>
<td>742*</td>
<td>32</td>
</tr>
</tbody>
</table>

* Significant difference between men & women (p<0.0001).

Table 4: Conduction times and velocities in central loop of H-reflex.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Motor fiber</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conduction time (ms)</td>
<td>2.99*</td>
<td>0.15</td>
</tr>
<tr>
<td>Velocity (m/s)</td>
<td>58.3</td>
<td>2.8</td>
</tr>
<tr>
<td><strong>Sensory fiber</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conduction time (ms)</td>
<td>2.69*</td>
<td>0.13</td>
</tr>
<tr>
<td>Velocity (m/s)</td>
<td>64.9</td>
<td>2.3</td>
</tr>
<tr>
<td><strong>Sacral cord conduction delay (ms)</strong></td>
<td>1.09</td>
<td>0.06</td>
</tr>
</tbody>
</table>

* Significant difference between men & women (P<0.05).