The H-reflex in experimental spinal cord trauma

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The H-reflex, the electrical correlate of the monosynaptic stretch reflex, recorded from the median nerve was monitored in cats sustaining controlled impact injuries to the eighth cervical segment of the spinal cord. The H-wave was unchanged in cats that showed only scattered gray matter petechial hemorrhages, whereas the H-wave could not be recorded in cats with central hematoma formation and central cavitation. With intermediate impact injuries that produced a coalescence of gray matter hemorrhages, the H-wave, although initially present, gradually diminished in amplitude and disappeared completely in approximately 2 hours.

KEY WORDS  H-reflex  stretch reflex  monosynaptic reflex  evoked potentials  spinal cord  spinal cord injuries

Changes in the averaged cortical evoked response (CER) following peripheral nerve stimulation can be correlated with the pathological damage produced by controlled impact injuries to the cat spinal cord. The initial negative deflection of the CER as used in this investigation appears to determine the functional integrity of the ipsilateral posterior column, and possibly the spinocervical tract. Since the pathological changes that occur following controlled trauma to the spinal cord first appear in the gray matter, it was decided to study the “H-reflex” as a possible monitor of gray matter function following controlled spinal cord trauma.

Since its description in 1918 by Hoffman, the physiology and clinical significance of the H-reflex have been discussed in great detail by many investigators. Essentially, the H-reflex is the electrically induced equivalent of the myotactic or stretch reflex. The central input consists of impulses arising from direct stimulation of afferent nerve fibers which have their origin in muscle spindles. These afferent impulses enter the spinal cord over the dorsal root and synapse with anterior horn nuclei whose excitability is affected by the segmental internuncial pool. The central delay is so brief that the reflex was considered to be monosynaptic when originally described by Hoffman. The monosynaptic nature of the reflex has been confirmed in cats by Lloyd, and in man, by Magladery, et al. Efferent conduction in the motor portion of the mixed nerve produces the H-wave. Since the H-reflex is monosynaptic and its afferent and efferent limbs enter and leave the spinal cord over a three- or four-segment portion.
of the cord, changes in this central gray segment should be reflected in changes in the H-wave.

Materials and Methods

Fifteen cats weighing between 3 and 3.5 kg were anesthetized with nitrous oxide and halothane. Respirations were controlled with a Harvard small animal respirator after muscle paralysis with intravenous succinyl choline. After placing the cat in a stereotaxic frame, a midline scalp incision was made and the coronal suture identified. A screw electrode was placed in the right frontal bone of the skull over the primary somatosensory area. Location of the recording electrode was verified by opening the skull at the completion of the experiment. A reference electrode was placed in the frontal sinus.

The left median nerve was exposed in the forelimb distal and proximal to the severed pronator teres muscle. After the median nerve had been severed distally, bipolar stimulating electrodes were placed on the proximal median nerve and recording electrodes on the distal portion. The exposed nerve was kept moist with a mineral oil-vaseline mixture. A three-level laminectomy was performed to expose the eighth cervical segment of the spinal cord. After the dura was exposed, the halothane was discontinued and the animals carried on 75% nitrous oxide and 25% oxygen. The proximal median nerve was stimulated with a 0.1 msec pulse of 2 V every 2 sec. The "M-wave" and "H-wave" were monitored on a Tektronix type R564B oscilloscope. Sixteen successive transients of these waves were averaged with a Biomac 1000 computer. Analysis time was 40 msec. To determine that the early and late waves recorded were the M and H waves respectively, these waves were studied in four cats. Following section of the left C6-T1 dorsal roots, the late wave (H-wave) disappeared, but the early wave (M-wave), which is produced by centrifugally conducted nerve action potentials generated by the stimulus, remained unchanged. Similar observations were made when the exposed spinal cord segment was bathed in 1% xylocaine. Furthermore, as reported by many investigators working with the H-wave, a supramaximal stimulus that produced a maximum M-wave was associated with a disappearance of the late wave (H-wave).

The cortical activity was monitored on a Grass model 6 electroencephalograph and a separate beam of the Tektronix oscilloscope. Sixty-four successive cortical transients were averaged. The analysis time was 160 msec. Cortical activity and distal median nerve activity were averaged before and after surgical exposure of the spinal cord in each animal and served as a control.

By using the technique of Albin, et al., tapered weights weighing 5, 15, and 25 gm were dropped from a height of 20 cm onto the eighth cervical segment of the spinal cord to produce 100, 300, and 500 gm-cm injuries. The CER and the H-reflex were averaged immediately and at 5-min intervals up to 1 hour following trauma. After 1 hour, the responses were averaged at 30-min intervals up to 4 hours following trauma. At 4 hours the animals were sacrificed with intravenous barbiturates. The vascular system was flushed with saline, and a five-segment cord specimen was prepared for pathological examination.

The temperature of all animals was kept between 98-99° F rectally by an external nonconductive heat source. End expiratory pCO₂ and blood pressure were monitored throughout the recordings and kept at 2.5 ± .5% and between 100-120 mm Hg respectively by appropriate alterations of the respirator and fluid infusions.

Results

In all three impact categories the M-wave, or the direct nerve action potential produced by the stimulation recorded from the severed distal median nerve, did not change significantly throughout the 4 hours of recording.

100 gm-cm Injuries

Immediately following an impact injury of 100 gm-cm, neither the H-wave nor the cortical evoked response (CER) could be recorded (Fig. 1 upper left). By 5 min after injury, both the H-wave and the CER were present at the pretrauma amplitude and remained unchanged throughout the 4 hours.
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FIG. 1. Responses to posterior impact injuries to C-8. Upper Left: 100 gm-cm force. After an initial brief disappearance, both the H-wave and cortical evoked potential (CER) return and remain unchanged. Time after impact is listed on left, and a C-8 section shown on the right (H & E). ++ indicates response of pretrauma amplitude; + indicates response present but decreased in amplitude; — indicates no response. Upper Right: 300 gm-cm force. The H-wave diminishes in amplitude and disappears by 2 hours after impact. The CER, which is initially absent, returns between 1 and 2 hours after impact. Lower Right: 500 gm-cm force. Neither the H-wave nor CER could be recorded.

300 gm-cm Injuries

As in the 100 gm-cm group, the H-wave and CER disappeared immediately following 300 gm-cm impact to the eighth cervical segment and the H-wave also reappeared within 5 min (Fig. 1 upper right). However, during the first 2 hours following injury, the amplitude of the H-wave became smaller and finally disappeared altogether at 1½ to 2 hours following impact. The CER disappeared immediately after injury. The primary component returned in a blunted form between 1 hr 45 min and 3 hrs. In all cats, the CER had returned to the pretrauma amplitude and contour by 4 hours. Microscopically the eighth cervical segment showed multiple coalescent hemorrhages in the central gray matter. There was also
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Fig. 2. H-wave and CER after 300 gm-cm injury. Computer averages of 16 successive M and H-waves and 64 successive CER’s following median nerve stimulation. The left column shows 30 msec of peripheral nerve recordings and the right column shows 150 msec of CER sweeps. Stimulus artifact initiates sweep. In the left column the first deflection is the M-wave. The deflection near center of sweep is the H-wave.

hemorrhage and cavitation at the base of the posterior columns.

500 gm-cm Injuries

Following 500 gm-cm impacts, both the H-wave and CER disappeared and did not return during the 4 hours of recording (Fig. 1 lower right). Microscopically there was coalescence of the central gray matter and dorsal horn hemorrhages and central cavitation. There was also fragmentation of the posterior columns.

Discussion

In our study the proximal portion of the median nerve was stimulated. Immediately following stimulation the centrifugal action potential, due to direct stimulation of the median nerve, was recorded. Approximately 9 msec after stimulation, the H-wave was recorded. Since, in the cat, the median nerve arises from spinal nerves C-7, C-8, and T-1, the H-wave must be due to impulses entering and/or leaving the spinal cord at these segments. Consequently, pathophysiological changes in the C7-T1 gray matter of the cat spinal cord should be reflected in changes in the H-wave as recorded in the median nerve. Our results suggest that this is the case, and like the CER, changes in the H-wave following spinal cord trauma can be correlated with the pathological changes in the spinal cord.

The transient absence of the H-wave in the first 2 min following impacts of 100, 300, or 500 gm-cm perhaps can be attributed to spinal shock, although Weaver et al., have recorded the H-wave in later stages of spinal shock in man. Except for the transient absence immediately following impact, there was no change in the H-wave in injuries producing only petechial hemorrhages in the gray matter of the eighth cervical segment. The central gray matter was essentially intact and so was the H-wave. However, impacts that produced central cavitation, central hematoma, and posterior column fragmentation totally abolished the H-wave during our recording period. The entire central cord was destroyed, and consequently the H-wave disappeared.

With 300 gm-cm impacts, the central gray matter was almost obliterated by the coalescence of hemorrhages at the site of impact. However, the major portions of the posterior columns were intact as indicated by the return of the CER and the microscopic sections of the spinal cord segment. In this group the H-wave appeared normal after transiently disappearing after impact. However, 45 min to 1 hour after impact the H-wave began to diminish in amplitude and finally disappeared at approximately 2 hours. The return of the H-wave followed by its gradual disappearance is of significance when correlated with the findings of Ducker, et al., and Osterholm and Mathews who respectively have shown a progressive increase in central gray hemorrhage and norepinephrine content during the first 2 hours following injury.
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In summary, changes in the H-wave can be correlated with pathological changes in the gray matter, and therefore may be useful in predicting the extent of gray matter damage following spinal cord trauma in cats. When used with the CER, predictions of both gray and white matter damage possibly can be made. Although this technique needs to be evaluated in humans sustaining spinal cord injuries, it promises at this time to be a useful technique since in man the H-reflex as recorded from the median nerve could monitor gray matter function at the C5-T1 spinal cord segments, the site of most traumatic injuries to the spinal cord.

Summary

Changes in the H-reflex can be correlated with the extent of pathological damage in the gray matter of the cervical spinal cord following controlled impact injuries in cats. Since the reflex is dependent on segmental gray matter function, these studies suggest its usefulness as a monitor of segmental gray matter function in the spinal cord of cats following trauma.

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References


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