Electrodiagnostic Study of Brainstem Strokes

BY JUN KIMURA, M.D.

Abstract: Electrodiagnostic Study of Brainstem Strokes

The orbicularis oculi reflex elicited by electrical stimulation of the supraorbital nerve was studied in 39 cases with vascular lesions of the brainstem (four mesencephalic, 14 pontine, 13 medullary and eight multilevel), six cases following severe anoxic episodes and two cases of traumatic brainstem lesions. The early reflex (normal latency: 10.6 ± 2.5 msec) was delayed in 20 out of 22 cases with pontine or multilevel brainstem strokes and in all the eight cases of anoxic or traumatic brainstem lesions. The direct (31 ± 10 msec) and consensual (32 ± 11 msec) late reflexes, analogously to the pupillary light reflex, were useful in distinguishing afferent, efferent, and other blocks. In all the seven comatose patients, the late reflex was virtually absent. However, a relatively normal early reflex was present in four of these. The findings of this study indicate that the brainstem conduction altered by vascular and anoxic lesions can be measured simply and objectively by the orbicularis oculi reflex. A delay of the early reflex is relatively specific to pontine lesions. The late reflex is not only altered by brainstem lesions but is also totally depressed in coma, presumably reflecting diffuse suppression in multisynaptic reticular system.

ADDITIONAL KEY WORDS: brainstem conduction, brainstem reflex, blink reflex, trigemino-facial reflex, pontine lesions, coma, reticular activating system.

Introduction

Kugelberg studied the response of the orbicularis oculi muscle to a tap over the brow and recognized two separate responses, an early ipsilateral reflex and a late bilateral reflex. The use of electrical stimulation to the supraorbital nerve instead of a mechanical tap has led to the standardization of the technique. Practical usefulness of this method for evaluation of the facial nerve, trigeminal nerve, and of polyneuropathy has been recognized. More recently, we have become interested in central delay of the reflex and have demonstrated the alterations of brainstem conduction in multiple sclerosis and in syringes and a variety of posterior fossa tumors. Alteration of the orbicularis oculi reflex in multiple sclerosis has also been shown by others.

The use of this technique as a diagnostic method for brainstem strokes is of special interest because the localization of a lesion to the brainstem has been almost exclusively dependent upon clinical findings.

Method and Criteria

Using the technique previously described, percutaneous stimulations with a shock of 0.1 msec duration and 10 to 40 mamp were applied to the...
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**TABLE 1**

Latency of Motor Response, and Early and Late Reflex in 30 Normal Subjects (msec) (Kimura et al., 1969)

<table>
<thead>
<tr>
<th></th>
<th>Direct motor response</th>
<th>Early reflex</th>
<th>Late reflex</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>3.15</td>
<td>10.6</td>
</tr>
<tr>
<td></td>
<td>S.D.</td>
<td>0.28</td>
<td>0.82</td>
</tr>
<tr>
<td>Normal range</td>
<td>Right and left (Difference)</td>
<td>3.2 ± 0.8</td>
<td>10.6 ± 2.5</td>
</tr>
<tr>
<td>Mean</td>
<td>Right and left (Difference)</td>
<td>&lt;0.6</td>
<td>&lt;1.2</td>
</tr>
<tr>
<td></td>
<td>Right and left (Difference)</td>
<td>&lt;8†</td>
<td></td>
</tr>
</tbody>
</table>

*Right (left) direct late reflex compared to simultaneously recorded left (right) consensual late reflex.
†Right (left) direct late reflex compared to subsequently recorded right (left) consensual late reflex.

Facial nerve in the area just anterior to the mastoid process and to the supraorbital nerve at the supraorbital foramen. The responses were recorded with surface electrodes placed over the right and left orbicularis oculi muscles and the latencies were compared to the normal values (table 1).

The right direct motor response (latency: 3.2 ± 0.8 msec), represented the contraction of the right orbicularis oculi muscle to a direct stimulation of the right facial nerve. The right early reflex (latency: 10.6 ± 2.5 msec) represented the unilateral reflex contraction of the right orbicularis oculi muscle to a stimulation of the right supraorbital nerve. The right direct (latency: 31 ± 10 msec) and the left consensual (latency: 32 ± 11 msec) late reflex were obtained in analogy with the pupillary light reflex, bilaterally synchronous reflex contractions of the right and left orbicularis oculi muscle respectively to a stimulation of the right supraorbital nerve.

The amplitude of the early reflex was less valuable as a criterion since it varied considerably from one individual to another and in some normals from time to time. When the early reflex was difficult to obtain, a paired stimulation with a five-millisecond interval was a very effective way to facilitate the evoked response.

As the late reflex was more variable than the early reflex, several trials were necessary in order to select the maximal response with the shortest latency and the largest amplitude. A comparison of a right (left) direct late reflex to a simultaneously recorded left (right) consensual late reflex was most meaningful, although a comparison of a right (left) direct late reflex to a subsequently recorded right (left) consensual late reflex was also useful (see Discussion).

Materials and Results

Of 47 cases included in this study (table 2), 39 had vascular lesions of the brainstem (four mesencephalic, 14 pontine, 13 medullary and eight multilevel), six had anoxic lesions of the brainstem (and cortex) and two had traumatic lesions of the brainstem. The cases of lateral medullary syndrome discussed elsewhere were excluded from medullary lesions in this study. The reflex study was performed in most cases when the patient was alert, but in seven cases (one pontine and one multilevel vascular, four anoxic, and one traumatic), the patient was in coma. In six cases the test was repeated serially. Only two patients (cases 7 and 10) came to autopsy. In the rest, clinical signs were compared to the result of the reflex study. The reflex responses in ten representative cases will be illustrated in figure 1 (cases 1 to 6), figure 2 (case 7), figure 3 (case 8), figure 4 (case 9), and figure 5 (case 10). Of these, the clinical history will be briefly described in cases 7 to 10.

As shown in table 2, the early reflex was abnormal either bilaterally or unilaterally on the side of vascular lesions (figs. 1 and 6) in 12 out of 14 cases with pontine lesions (cases 2, 3, 8, and 9) and in all the eight cases with multilevel brainstem lesions (cases 1, 4, 5, 6, and 7). On the other hand, it was normal in three out of four cases of mesencephalic and 11 out of 13 cases of medullary vascular lesions. The early reflex was bilaterally abnormal in all the six cases of anoxia (fig. 6). It was also abnormal bilaterally in one and unilaterally in the other case of traumatic brainstem lesions (fig. 6).

The late reflex (table 2) was abnormal in 10 out of 14 cases of pontine and five out of...
eight cases of multilevel brainstem vascular lesions. Of these an efferent block (see Discussion) was found in seven cases of pontine lesions (case 2), and an afferent block in one case of pontine and one case of multilevel brainstem vascular lesions (case 5). All the others (case 7) were compatible with neither pure efferent nor afferent block. The late reflex was normal in three out of four cases of mesencephalic and 11 out of 13 medullary vascular lesions. In the other patient with mesencephalic involvement, the right-sided lesion was associated with a delay of the left direct and the right consensual late reflex (40 msec) when compared to the right direct and the left consensual late reflex (30 msec), suggesting an afferent block on the side contralateral to the lesion (see Discussion). The late reflex was abnormal in all but one case of anoxia and in both cases of brainstem trauma. In all the seven patients in coma (one pontine and one multilevel vascular, four anoxic, and one traumatic) the late reflex was either totally absent (cases 1, 8 and 10) or at best minimal in amplitude even when a stimulus shock of very high intensity was used. The early reflex, however, was present bilaterally in one patient and unilaterally in three. Of these four patients it was bilaterally delayed in case 1, unilaterally normal in cases 8 and 10, and unilaterally present and delayed in the fourth. In the remaining three patients the early reflex was bilaterally absent. The late reflex reappeared as the patients recovered from coma in two cases (cases 1 and 8). The late reflex was also absent in two alert but immobile patients (cases 6 and 7) with encephalomalacia of the brainstem.

The direct motor response (table 2) was normal in all but three cases with pontine dysfunction who showed electromyographical evidence of facial nerve degeneration, presumably due to involvement of the facial nucleus. All three of these patients showed a delayed, or absent, early reflex on the involved side, together with an efferent block of the late reflex.

**Case Reports**

**Case 7 (L.K.)**

A 60-year-old diabetic man developed slurred speech and right hemiparesis at the end of April, 1969. On May 30 he suddenly became pale and unable to talk or move, but remained alert and
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EARLY REFLEX IN BRAINSTEM LESIONS

Bilaterally abnormal early reflexes (two successive recordings in each frame to show consistency) in pontine (cases 2 and 3) and multilevel brainstem (cases 1, 4, 5, and 6) vascular lesions. The top tracings are normal control with barred areas indicating normal range (mean ± 3 SD in 30 normal subjects). Note a marked delay of the reflex on the right in case 4 and on the left in cases 1 and 5, and the absence of the reflex on the right in cases 2 and 5. The others were either slightly delayed or borderline in latency but abnormally irregular in shape. A paired stimulation with a five-millisecond interval was required to evoke the early reflex on either side in case 6.

CASE 8 (F.Z.)
A hypertensive 40-year-old man suddenly collapsed unconscious on December 29, 1970. When seen on January 7, 1971, he was comatose. There was left spastic hemiparesis with right facial paresis, but was able to wrinkle his forehead. There was nystagmus on lateral gaze to either side. Upward gaze was normal. The early reflex on June 3 (fig. 2) was much delayed bilaterally (17.0 msec). The late reflex was absent or at best minimal. He became apnic and expired on June 9. At autopsy, encephalomalacia (fig. 7) of the mesencephalon, pons, right and left cerebellar hemispheres and right occipital lobe attributable to occlusion of the dominant vertebral artery was found.
CASE 7. Top to bottom, the direct motor response and the early reflex with a faster sweep speed, and a pair of the direct and the consensual late reflexes recorded simultaneously at a slower sweep speed. Note a much delayed and irregular early reflex (17.0 msec) on either side, although a small component of the evoked potential on the left appeared at a shorter latency (14.2 msec). The late reflex was absent or at best minimal. The direct motor response was normal (3.1 msec on right, 3.8 msec on left).

weakness. The right early reflex (fig. 3) was absent. The left early reflex was elicited with much difficulty and was very irregular in shape with a small component beginning at a normal latency (11.0 msec). The late reflex was absent. On January 11, 1971, when he became alert, sensory examination revealed right hemihypesthesia and hypalgesia including the face. He had internuclear ophthalmoplegia manifest on left lateral gaze. Right lateral gaze was absent. Vertical nystagmus was present on up and down gaze. The left early reflex was still irregular in shape but normal in latency (12.0 msec). He continued to improve. On January 21, 1971, the right early reflex was obtained for the first time although delayed (15.0 msec). On January 29, the right direct (35 msec) and the left consensual (33 msec) as well as the left direct (39 msec) and the right consensual (50 msec) late reflexes were noted but with minimal amplitude. On February 17, he was able to sit up. Right facial weakness was improved, but neurological status was unchanged otherwise. The early reflex was still delayed (15.0 msec) on the right but normal in latency (11.5 msec) as well as in shape on the left. The right direct and the left consensual late reflexes were normal (33 msec) but the left direct (49 msec) and the right consensual (47 msec) late reflexes were delayed, suggesting an afferent block on the left.

CASE 9 (C.D.)
A 57-year-old man suddenly felt a tingling sensation of the right arm and the right leg on January 25, 1971. His speech was transiently slurred. He was alert and ambulatory. Examination revealed mild hemiparesis, hemiataxia, and hemihypesthesia on the right. There was slight horizontal nystagmus on right lateral gaze. On January 28, and February 2, the early reflex (fig. 4) was normal in latency (11.1 msec on right, 11.0 msec on left), but the shape of the evoked
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PONTINE HEMORRHAGE

F. Z.

Case 8. Four top tracings on each side show the early reflex (two successive recordings in each frame to show consistency) at a faster sweep speed, and the bottom tracing shows the direct and the consensual late reflexes recorded simultaneously at a slower sweep speed. Note a multiphasic left early reflex on January 7, and its progressive change to normal (11.5 msec) on February 17, and an absent right early reflex on January 7 and its appearance with a delayed latency (15.0 msec) on January 21 and thereafter. Also note a delayed left direct (49 msec) and a right consensual (47 msec) late reflex and a normal (33 msec) right direct and a left consensual late reflex on February 17, suggesting an afferent block on the left.

Case 10 (H.P.)

A 21-year-old man was injured in an auto accident on July 12, 1970. On admission he was unconscious with only minimal response to painful stimulation. The right pupil was dilated but sluggishly reactive to light. Oculocephalic and ciliospinal reflexes were absent. There was no change in his neurological status until July 16. The early reflex (Fig. 5) on July 16 was normal (10.5 msec) on the right and absent on the left in the morning and again in the afternoon. The late reflex was totally absent on both occasions. His condition deteriorated on July 17 and spontaneous respiration stopped. The pupils were dilated and fixed. He was areflexic. An electroencephalogram was iso-electric. The early and late reflexes were absent bilaterally in the morning. He expired in the afternoon. Autopsy revealed bilateral contusion of the cerebral hemispheres and gross
KIMURA

PONTINE INFARCT

C.D.

LEFT

<table>
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<tr>
<th>Date</th>
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<th>Tracings</th>
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<tbody>
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<td>Jan 28-71</td>
<td>Lt</td>
<td>E (multiphasic)</td>
</tr>
<tr>
<td>Feb. 2</td>
<td>Lt</td>
<td>E (multiphasic)</td>
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<tr>
<td>Feb. 10</td>
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<td>Feb 26</td>
<td>Lt</td>
<td>E (multiphasic)</td>
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RIGHT

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<td>E (multiphasic)</td>
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<td></td>
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<td>E (multiphasic)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>E (multiphasic)</td>
</tr>
</tbody>
</table>

Stimulation left supraorbital nerve

Stimulation right supraorbital nerve

E = early reflex
L = bilateral late reflex
* = simultaneous recording

FIGURE 4

Case 9. The same arrangement of the tracings as in figure 3. Note a multiphasic early reflex with a normal latency (11.1 msec on right, 11.0 msec on left) bilaterally on January 28 and February 2 and its progressive change in shape to normal on the left and to near normal on the right on February 26. The late reflex was normal throughout (36 msec to 38 msec).

Discussion

It has been shown previously that a unilateral delay of the right early reflex, for example, may be due to a lesion of the right trigeminal nerve, of the right facial nerve or of the right side of the pons, while a bilateral delay of the early reflex suggests a pontine lesion provided polyneuropathy and rare multiple peripheral lesions can be excluded.

As discussed elsewhere, it is possible to analyze the alteration of the late reflex in analogy with the pupillary light reflex and distinguish a right afferent block characterized by a delay of the right direct and the left consensual late reflex and a right efferent block characterized by a delay of the right direct and consensual late reflex. An afferent or an efferent block may be central due to lesions in the brainstem or peripheral due to lesions in the trigeminal or facial nerve. A change of the late reflex compatible with neither afferent nor efferent block may be considered central (provided multiple lesions of the trigeminal and/or facial nerves are excluded).

The alteration of the early reflex as well as of the late reflex noted in a majority of cases with pontine involvement either as a selective lesion (pontine vascular) or as a part of a diffuse brainstem involvement (multilevel vascular, anoxia, or traumatic) is in good contrast to the sparing of these reflexes in a majority of

hemorrhage in the mesencephalon and the pons (fig. 8).

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ELECTRODIAGNOSTIC STUDY OF BRAINSTEM STROKES

COMA (HEAD INJURY)

H. P.

July 16 AM 1970

July 16 PM 1970

July 17 AM 1970

Stimulation

Rt Facial N

Rt Supra Orbital N

Rt Supra Orbital N.

D - direct response
E - early reflex
L - bilateral late reflex (absent in this case)
* - simultaneous recording

FIGURE 5

Case 10. Top to bottom, the right direct motor response and the right early reflex with a faster sweep speed and a pair of the right direct and the left consensual late reflexes recorded simultaneously at a slower sweep speed. Note a normal right early reflex (10.5 msec) on July 16 in the morning as well as in the afternoon, and its absence on July 17, the day of the patient’s death. The late reflex was totally absent throughout. The left early reflex (not shown) was also absent. The direct motor response was normal (3.0 msec) bilaterally. The right early reflex seen with a slower sweep in the upper tracing of the bottom pair on July 16 swayed across the lower tracing due to stimulus artifact, because a shock of very high intensity was used in search for the late reflex.

Consistent absence of the late reflex or its minimal amplitude in all the comatose patients studied is noteworthy. The brainstem involvement alone does not seem to account for this finding in view of the presence of a normal or nearly normal early reflex in some of these patients, as the latter ordinarily is much more susceptible to brainstem lesions. In addition, the late reflex may reappear as the patient recovers from coma. Thus it is more likely that the absent late reflex simply reflects the inability of these patients to respond to painful stimuli presumably due to diffuse suppression in multisynaptic reticular system.2,3 It seems that the presence of a normal late reflex with a shock of ordinary intensity is incompatible with a comatose state. However, total absence of this reflex is also found in alert but immobile patients with extensive brainstem lesions. These patients seem to have features of the “locked-in” syndrome.13

While detailed anatomical and physiological parameters of the orbicularis oculi reflex remain unknown, the elicitation of this reflex is of practical clinical value in identifying the presence of brainstem stroke and improving the accuracy of its localization. Serial testing of the reflex is a useful addition to clinical observations in assessment of progressive changes of
brainstem function as no other laboratory method is available for this purpose.

Acknowledgment
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References

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Figure 6
Distribution of latency of the direct motor response and the early reflex in 30 normal subjects (60 responses considering the right and the left sides in each)—and 30 patients (60 responses) with pontine involvement either as a selective lesion (14 pontine vascular) or as a part of a diffuse brainstem involvement (eight multilevel vascular, six anoxic, and two traumatic). Note that the early reflex is considerably delayed or absent while the direct motor response is essentially normal in cases with pontine involvement.
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Case 7. Weil's myelin stain showing extensive demyelination due to encephalomalacia of the pons at the level of the trigeminal nerve. Courtesy of Dr. W. F. McCormick, Iowa City.

and in other lesions of the trigeminal nerve. Neurology 20: 574-583 (June) 1970


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Case 10. Gross hemorrhage in the mesencephalon and the tegmentum of the pons more prominent on the right side.

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