Implementation of Listing’s Law in Patients with Unilateral Sixth Nerve Palsy

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INTRODUCTION

During fixation and saccades, human eye movements obey Listing’s law, which specifies the torsional eye position for each combination of horizontal and vertical eye position.1,2 To study the mechanisms that implement Listing’s law, we investigated whether it was violated in peripheral and central unilateral sixth nerve palsy.

METHODS

Twenty-seven patients with unilateral sixth nerve palsy and 10 normal subjects were studied. Informed consent was obtained from each subject. Patients with diplopia of less than 4 weeks’ duration were classified as having acute palsy; all others were designated here as having chronic palsy.

MRI with enhancement was performed for patients under 50 years of age and for those with neurologic signs. CT with contrast was obtained in patients with ischemic risk factors and those over 50 years of age. If the CT was normal, patients were followed at about 3 months. Those without improvement at 3 months and those with an abnormal CT were further investigated with MRI.

Eye positions were measured with magnetic search coils while patients followed a laser target at 1 m with one eye covered. The laser was programmed to appear in nine different target positions, arranged in a 3 × 3 square. With head immobile, subjects made saccades to a target that moved between straight ahead and 8 eccentric positions. At each target position, fixation was maintained for 3 seconds before the next saccade.

Using fitted functions, we quantified violations of Listing’s law by comparing the ocular torsion in each recorded eye position to the torsion predicted by the law. The standard deviation of the differences between the predicted and measured torsion was called Listing deviation.

In all 27 patients, Listing deviation in both the paretic and non-paretic eyes did not differ during paretic or non-paretic eye viewing. In what follows, we report only Listing deviation during non-paretic eye viewing; deviations during paretic eye viewing were similar. Statistical analysis was performed using analysis of variance. Values were defined as significant when $p < 0.05$.

**RESULTS**

Patients with central sixth nerve palsy had abnormal ocular torsion in both the paretic and non-paretic eyes, violating Listing’s law (Fig. 1). During fixation, List-
ing deviation averaged 2.4° in the paretic eye, and 1.7° in the non-paretic eye, compared to 0.8° in normal controls \((p < 0.05)\). During saccades, Listing deviation averaged 2.7° in the paretic eye, and 1.6° in the non-paretic eye, compared to 0.8° abnormal ocular torsion only in the paretic eye, but not the non-paretic eye (Fig. 1). Listing deviation of the paretic eye averaged 2.3° during fixation and 3.2° during saccades \((p < 0.05)\). Patients with chronic peripheral sixth nerve palsy obeyed Listing’s law during both fixation and saccades (Fig. 1).

**DISCUSSION**

In acute peripheral sixth nerve palsy, Listing’s law was violated in the paretic eye, presumably because the lateral rectus muscle was paretic and perhaps also because its pulley was abnormally positioned. In chronic peripheral palsy, both eyes obeyed Listing’s law, even though the lateral rectus was still markedly weak. This recovery shows that the neural circuitry underlying Listing’s law is adaptive, restoring the law despite a palsied muscle and possibly a disrupted pulley system. Neural adaptation must work by readjusting the innervations to the remaining extraocular muscles; it may also adjust their pulleys, though theoretically Listing’s law could be restored with or without a new pattern of pulley placement and motion.

All patients with central fascicular sixth nerve palsy caused by brainstem lesions had abnormal ocular torsion in both the paretic and non-paretic eyes. Evidently the neural adaptive mechanisms underlying Listing’s law are unable to restore it after brainstem lesions. Our results also indicate that the pontomedullary region is an element of the neural pathway that enforces Listing’s law.

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**REFERENCES**