Brain Research Bulletin 86 (2011) 447–453

Contents lists available at ScienceDirect

Brain Research Bulletin

journal homepage: www.elsevier.com/locate/brainresbull

Research report

Effects of neck muscle activities during rhythmic jaw movements by stimulation of the medial vestibular nucleus in rats

Yoshihide Satoh[a,*], Eriko Yajima[b], Yasuhiro Nagamine[b], Ken'Ichi Ishizuka[a], Toshiki Murakami[a]

[a] Department of Physiology, The Nippon Dental University, School of Life Dentistry at Niigata, 1-8 Hamaura-cho, Chuou-ku, Niigata 951-8580, Japan
[b] Department of Orthodontics, The Nippon Dental University, School of Life Dentistry at Niigata, 1-8 Hamaura-cho, Chuou-ku, Niigata 951-8580, Japan

ARTICLE INFO

Article history:
Received 28 April 2011
Received in revised form 27 July 2011
Accepted 5 August 2011
Available online 1 September 2011

Keywords:
Medial vestibular nucleus
Jaw and neck muscle activities
Rhythmic jaw movements
Orofacial motor cortex

ABSTRACT

This study first examines whether there is rhythmic activity of the neck muscles during cortically induced rhythmic jaw movements in rats anesthetized by urethane. Rhythmic jaw movements were induced by repetitive electrical stimulation of the orofacial motor cortex. An electromyogram in the splenius muscles (spEMG) showed rhythmic bursts during the jaw-opening phase, or during the transition from the jaw-opening phase to the jaw-closing phase. In the sternomastoid (stEMG), however, the electromyogram did not show any bursts during rhythmic jaw movements. A further study then examines whether stimulation of the medial vestibular nucleus (MVN) modulates the rhythmic activity of the neck muscles. Stimuli applied in the jaw-closing phase induced a transient burst in the stEMG, and the duration of activity in the spEMG was increased. Stimuli applied in the jaw-opening phase induced a transient burst in the stEMG and an inhibitory period in the spEMG. These results imply that the MVN is involved in the modulation of neck muscle activities during rhythmic jaw movements induced by stimulating the orofacial motor cortex.

1. Introduction

The medial vestibular nucleus (MVN) receives data relating to balance and equilibrium from the semicircular canals. The medial vestibulospinal tract originates from the MVN and descends to the cervical cord [2]. The medial vestibulospinal tract is involved in control of the vestibulo-collic reflex [33]. The MVN is divided cytoarchitecturally into three parts: the parvicellular part, which consists mainly of small cells (MVNPC); the magnocellular part, which contains medium-sized and relatively large cells (MVNMC); and the caudal part [20].

Morphological studies have found reciprocal connections in rats between the MVN and the spinal trigeminal nucleus [3,6,31]. The spinal trigeminal nucleus is known to contain premotor neurons projecting to the trigeminal motor nucleus [14,18,32]. Recent studies have found that the MVN projects to motoneurons which innervate the masseter muscle [4,9]. According to physiological studies, the vestibular input elicits excitatory tonic control of masseter muscle activity [28], and activation of the vestibular afferents elicits excitatory responses in the jaw-opening motoneurons and the jaw-closing motoneurons [29]. Our previous papers showed that stimulation of the MVNPC and the MVNMC facilitate the jaw-opening reflex [24] and the masseteric monosynaptic reflex [25]. We also found that stimuli applied to the MVNPC and the MVNMC influence the rhythmic jaw movements, and influence electromyographic activity in the jaw muscles induced by stimulating the orofacial motor cortex [26]. Stimulation during the jaw-closing phase increased the amplitude of the jaw-closing movement. Activity in the electromyogram of the masseter muscle went on for longer. Stimulation during the jaw-opening phase disturbed the rhythm of jaw movements and induced a small jaw-closing movement. A transient burst and an inhibitory period was induced in the electromyogram of the masseter muscle, and in the electromyogram of the anterior belly of the digastric muscle.

Head movements are reported to occur concomitantly with jaw movements [7,10,11,30]. The presence of rhythmic movements involving the jaw and head supposedly implies coordinated muscle activities of the jaw and neck. Previous studies suggest that patterned motor activities occur in the neck and jaw muscles in humans [5,7,12,30] and rabbits [11] during jaw movement. It has been suggested that these coordinated movements occur to smooth jaw movements and balance the trunk [13]. It is therefore likely that the MVN is involved in control of head and jaw movements during rhythmic jaw movements.

This study first examines whether there is rhythmic activity of the neck muscles during cortically induced rhythmic jaw movements. If so then a further study will examine whether the MVN stimulation modulates the rhythmic activity of the neck muscles.

* Corresponding author. Tel.: +81 25 267 1500; fax: +81 25 267 1134.
E-mail address: ysatoh@ngt.ndu.ac.jp (Y. Satoh).

0361-9230/$ – see front matter © 2011 Elsevier Inc. All rights reserved.
doi:10.1016/j.brainresbull.2011.08.007

2. Methods

These experiments were performed on 12 male Sprague-Dawley rats weighing 334–408 g. Animal care protocols and surgical procedures were approved by the Laboratory Animal Committee of The Nippon Dental University School of Life Dentistry at Niigata. The rats were initially anesthetized with urethane (1 g/kg i.p.). Supplemental doses (0.2 g/kg, i.v.) were given so as to maintain anesthesia at the level at which no withdrawal reflex was evoked by noxious stimulation of the paw.

Surgical procedures and experimental protocols were similar to those described previously [26]. In summary, electromyograms were recorded from the masseter muscle (mEMG), the anterior belly of the digastric muscle (dEMG), the sternomastoid muscle (stEMG) which acts as a head flexor muscle, and the splenius muscle (spEMG) which acts as a head extensor muscle on the right or left side. Horizontal and vertical jaw movements were recorded by a photodiode transducer which tracked the displacement of a light attached to the mandibular. A bipolar concentric electrode was inserted vertically into the orofacial motor cortex (OfM: anterior cortical masticatory area) contralateral to the EMG recordings. Through it, electrical stimulation (duration 0.5 ms, 30 Hz, 10 s) was applied to the OfM. The intensity of stimulation was set at the threshold for inducing rhythmic jaw movements.

A bipolar concentric electrode was inserted stereotaxically and vertically into the MVN, ipsilateral to the OfM stimulation site. Stimulation (duration 0.3 ms, 1 Hz, 130 μA, 4 s) was applied to the MVN exactly 6 s after stimulation of the OfM had begun, once the amplitude of the jaw movements was stable. Three trials were performed.

The electromyographic responses were amplified and stored on computer disk. The EMG was full-wave rectified. As a control, the mean EMG activity and its standard deviation (S.D.) were calculated for 3 s prior to the OfM stimulation. The onset of mEMG and stEMG burst was defined as the instant when mEMG and stEMG activity exceeded 2 S.D. from the control value. Correspondingly, the offset was defined as the instant when mEMG and stEMG activity fell below 2 S.D. from the control. In fact the baseline of the dEMG and spEMG activity during the jaw-closing phase exceeded 2 S.D. from the control, so we defined the onset of dEMG and spEMG burst as the instants at which the dEMG and spEMG activity exceeded 3 S.D. from the baseline.

A jaw movement cycle was taken to begin at the moment of maximum jaw-closing (the start of the jaw-opening phase), and to end at the next maximum jaw-closing. The duration of a jaw movement cycle was taken as the control value (100%) for each rat, since there was variability between animals. We determined the range (expressed as a percentage relative to control values) in the onset of the dEMG and spEMG burst, the offset of the dEMG and spEMG burst, and the duration of the dEMG and spEMG burst.

The MVN stimulation phase in jaw movements was determined as the ratio of the delay from the moment of maximum jaw-closing (the start of the jaw-opening phase) to the duration of the immediately previous jaw movement cycle without stimulation.

The duration of the EMG burst for which the perturbation occurred as a result of stimulating the MVN is referred to as the perturbed duration. The duration of the EMG burst after the perturbed duration is termed the post-stimulus duration. The duration of the EMG burst immediately prior to the perturbed duration is referred to as the pre-stimulus duration. The mean perturbed duration and the post-stimulus duration are expressed as a percentage of the mean pre-stimulus duration (control). All data were analyzed for statistical significance.

At the end of each experiment, the animals were given a further, lethal, dose of anesthetic and the brain was perfused. Serial coronal sections were made. The stimulating sites were verified according to a standard atlas [19].

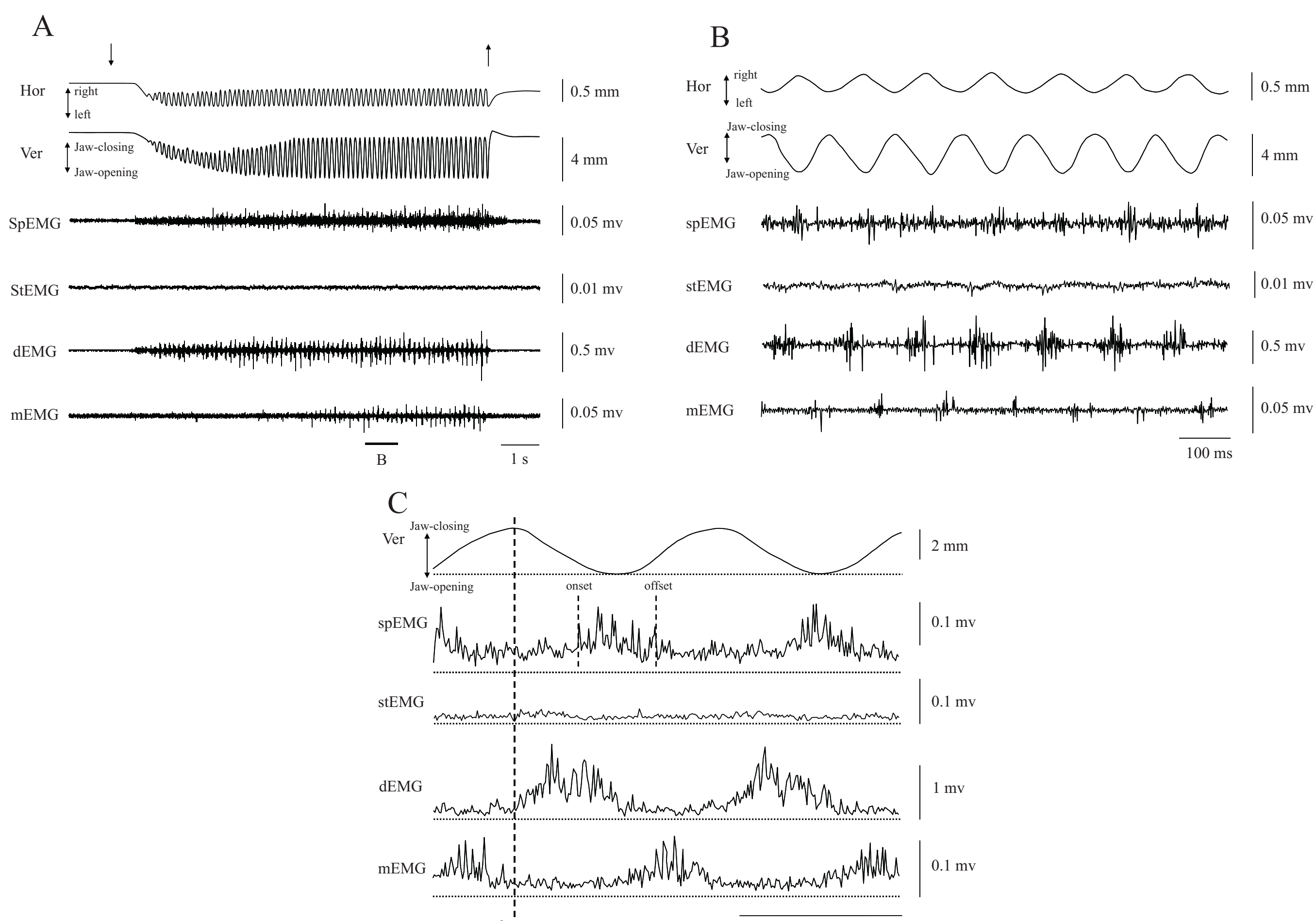

Fig. 1. Jaw movement trajectories, and neck and jaw muscle activities during rhythmic jaw movements induced by stimulating the left OfM (duration 0.5 ms, 30 Hz, 130 μA, 10 s). (A) Example of the recording. The down-pointing and upward arrows respectively indicate the onset and end of the stimulation. (B) Underlined part of (A) on an expanded time scale. (C) Temporal phase relation between jaw movements and neck and jaw muscle activities, rectified and averaged by the maximum jaw-closing position in ten jaw movement cycles. Hor: horizontal jaw movements (left down). Ver: vertical jaw movements (opening down). spEMG, stEMG, dEMG and mEMG: electromyographic activities of the splenius, the sternomastoid, the anterior belly of the digastric and masseter muscles on the right side.