Intracellular recordings from Deiters' neurons in response to saccular and oculomotor nucleus stimulations

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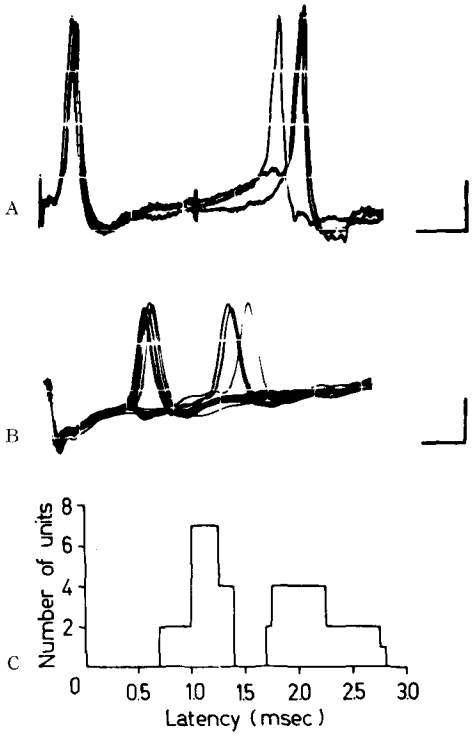
Summary. 2 populations of cells were found in the Deiters' nucleus responsive to direct electrical stimulation of the ipsilateral saccule. Only those Deiters' neurons activated monosynaptically from the saccule could be driven antidromically from the oculomotor nucleus. Such an intracellular study provides strong evidence for a tri-neuronal arc in the sacculo-ocular reflex for vertical eye movements.

In mammals, movements of the head elicit definite reflexes of balance, involving the antigravity and the extraocular muscles[3]. The position of the head is detected by the vestibular labyrinths which are known to be connected with the oculomotor system and the spinal motor apparatus by way of the vestibular nuclei in the brain stem[4–7]. Ito et al. first succeeded in recording intracellularly from the Deiters' neurons as identified by antidromic activation through the vestibulospinal tract[8]. Using similar techniques, Wilson et al. have since revealed a disynaptic connection between the labyrinth and neck motoneurons, but a tri-synaptic connection between the labyrinth and the limb motoneurons[5,6]. In so far as the vestibulo-ocular reflex is concerned, most studies were focussed on the effects of stimulation of the semicircular canals[9–11]. In cats, the otolith organs have been shown to exert strong excitatory influence on the eye muscles[12] and direct electrical stimulation of the utricular macula resulted in eye movements[13]. Information on the saccular influence on eye movements is scanty. Fluur and Mellstrom reported vertical eye movements induced by electrical stimulation of the superior area of the saccular maculae[14]. Recently, by selective stimulation of the saccule in cats, Hwang and Poon[15] provided supporting evidence for a tri-neuronal arc of the sacculo-ocular reflex first proposed by Lorente de Nó[16]. By recording intracellularly from the Deiters' neurons as identified by antidromic activation of the medial longitudinal fasciculus via the third nuclear area and selectively stimulating the superior area of the saccular maculae orthodromically, this report substantiates the trineuronal nature of the sacculo-ocular reflex responsible for the vertical eye movements.

Materials and methods. Cats were anaesthetized with Ketamine hydrochloride, a dissociative anaesthetic. The saccule was exposed after the technique developed by Hwang and Poon[15]. The superior area of the saccule responsible for vertical eye movements was selectively stimulated monopolarly by tungsten microelectrode with tip diameter around 1 μm, using single pulses < 1 V at 0.2 μA. Recordings were made from the Deiters' neurons with glass micropipettes filled with 3 M KCl. A dorsal approach (30° posterior) was employed after partial removal of the cerebellum by suction. Bipolar concentric electrodes were advanced into the oculomotor (third) nucleus responsible for upward eye movements. Accurate placements of the recording electrodes in the Deiters'



A Antidromic and orthodromic action potentials elicited from Deiters' neuron by stimulating the oculomotor nucleus and the superior area of the ipsilateral saccular macula. (Calibration: 15 mV, 1 msec.) *B* A Deiters' neuron responding monosynaptically (first response) or disynaptically (second response) to ipsilateral saccular stimulation. (Calibration: 20 mV, 0.5 msec.) *C* Histogram showing 2 populations of Deiters' neurons responding either monosynaptically or disynaptically to selective electrical stimulation of the saccule.

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neurons was identified by characteristic field potentials evoked by orthodromic and antidromic stimulations. Successful penetrations were indicated by resting membrane potentials exceeding – 45 mV.

Results and discussion. Intracellular recordings were made from the Deiters' neurons as identified by characteristic field potentials. Figure A shows an example of a Deiters' neuron which could be driven antidromically from the oculomotor nucleus as well as orthodromically from the saccule. Latency for the EPSP was 0.8 msec and the orthodromic action potential could be triggered as early as 1.2 msec after the onset of stimulus. The antidromic spike was initiated after a delay of 0.3 msec. Such records provide further evidence that some of the Deiters' neurons are connected monosynaptically with the primary afferents from the saccule and project directly to the ipsilateral oculomotor nucleus. Figure B shows, however, that some Deiters' neurons could be connected both monosynaptically (1.0 msec) and disynaptically (1.8 msec) with the saccule. Figure C depicts that among 33 Deiters' neurons so recorded, 2 populations of cells could be distinguished. The first population (n = 14) responded monosynaptically to saccular stimulation with a mean latency of 1.14 ± 0.05 msec (SEM) but the second population (n = 19) responded with a mean latency of 2.14 ± 0.08 msec (SEM), and therefore probably driven disynaptically. In no case did any of the disynaptically driven cells respond to antidromic stimulation. The tri-neuronal nature of the sacculo-ocular reflex therefore remains unchallenged at least in so far as the vertical eye movements are concerned. Experiments are in progress to study the specific connections between the different vestibular nuclei and the extra-ocular motoneurons in the sacculo-ocular pathways.

Hypoxic tachycardia in the rat[1]

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Summary. Awake, freely breathing rats subjected to moderate hypoxia (10% O_2) manifest prompt tachycardia which is essentially unaffected by atropine and is blocked by propranolol, and is thus apparently mainly of sympathetic origin.

When exposed to moderate hypoxia, freely breathing dogs generally manifest tachycardia[2], while bradycardia is commonly observed in cats[3] and rabbits[4]. The present experiments were designed to characterize the change in heart rate (HR) in unanesthetized laboratory rats breathing 10% O_2, and to assess the roles of vagal and sympathetic influences in the response.

Methods. Under brief halothane (Fluothane, Ayerst) anesthesia, 5 male Sprague-Dawley rats (370–470 g) were each implanted with 3 Michel nickel-silver wound clips, widely spaced along the dorsal midline, for use as active electrocardiographic (ECG) and ground leads. At least 1 day intervened between the anesthesia and the first experimentation. At each recording session, the Michel clips were connected to a Grass 7P1A preamplifier whose output was used to trigger a Grass 7P4A cardiotachograph for recording of HR on a Grass 7D polygraph.

Experimental trials were conducted with the rats in clear plastic boxes of a size (16.5 × 8.5 × 8.5 cm) chosen to restrict movement without discomfort, as indicated by prompt cessation of any struggling. The top of each box

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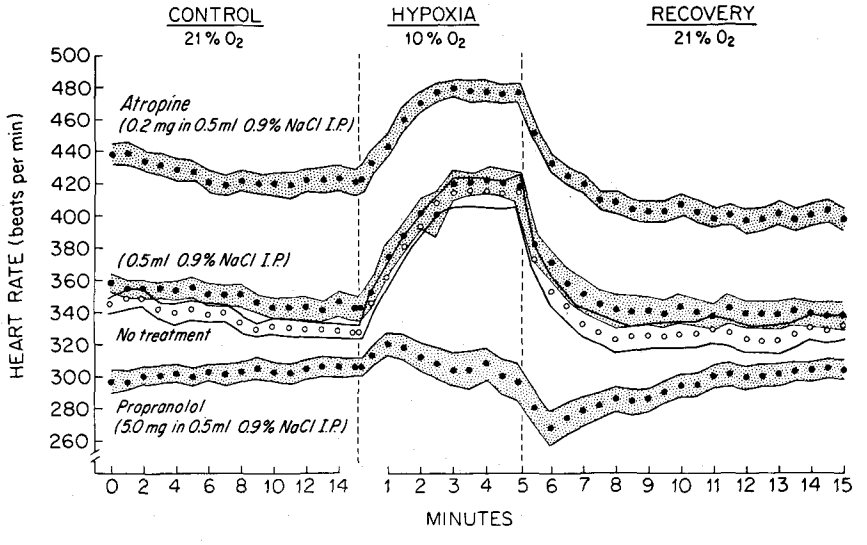

Heart rate responses to hypoxia produced by 10% O_2 in rats untreated (open circles) or injected i.p. (filled circles) with 0.5 ml of 0.9% NaCl alone, or with atropine (0.2 mg) or propanolol (5.0 mg). The circles represent the average values for all trials in all rats (numbers given in text) at each 1-min- (control) or $^1/_2$-min- (hypoxia and recovery) interval, while the accompanying lines indicate ± SE of the mean. Note that the time scale for the control period is compressed.