The characteristics of slowly adapting mechanical sensory neurons in the trigeminal ganglia of crotaline snakes

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Abstract—Mechanical pressure (P) and touch (M) neurons, two types of slowly adapting neurons, can be distinguished in the trigeminal ganglion of crotaline snakes, *Trimeresurus flavoviridis*, by their electrophysiological membrane properties. Intracellular stimulation and the recording of the responses from P and M neurons *in vivo* was performed with microelectrodes. The characteristics of the receptive field (RF) of both types of neurons were examined. P neurons had a much larger RF size and a higher mechanical threshold than those of M neurons. Both of them responded with discharges to mechanical stimulation. The active and passive electrophysiological membrane properties were measured from nine P and 18 M neurons. The active membrane properties of P neurons showed a larger amplitude and longer duration of action potential, a larger after-hyperpolarization with a longer duration to half-decay, and a higher electric threshold in response to intracellularly injected depolarizing current than M neurons. The passive membrane properties of P neurons showed a higher input resistance, much longer time constant, and larger capacitance than M neurons. The rebound spike which responded to injecting sufficient hyperpolarizing current was sometimes observed, and had a longer latency in P neurons than M neurons. These results indicated that some electrophysiological membrane properties of primary sensory neurons are dependent on their sensory modalities.

Keywords: Trigeminal ganglion; sensory neuron; intracellular recording; membrane characteristics.

1. INTRODUCTION

Recently, the active and passive electrophysiological membrane properties of neurons in sensory ganglia have attracted the attention of many investigators. Their studies reported a close relationship between somal action potential (AP) form and sensory modalities (lamprey, Matthews and Wickelgren, 1978; rat, Rose *et al.*, 1986; cat, Koerber *et al.*, 1988; Traub and Mendell, 1988). Further investigations have also revealed that the primary sensory neurons of different sensory modalities have different characteristics of cellular properties, that are due to a variety of ionic channels distributed on the soma-fiber membrane in the dorsal root ganglion (DRG) or the

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trigeminal ganglion (TRG) (mouse, Yoshida et al., 1978; cat, Koerber et al., 1988; guinea pig, Spigelman and Puil, 1989; rat, Ritter and Mendell, 1992). Anatomical features of the crotaline snake (in which the TRG is not covered by cerebellum and the heart is far from the brain) made conditions for intracellular recording easier and more stable. Terashima and Liang (1993) reported the characteristics of various modality neurons of crotaline snakes in terms of active electrophysiological and morphological properties with intracellular recording and horseradish peroxidase (HRP) injection techniques, but not in terms of their passive membrane properties that represent the membrane ionic characteristics. Terashima and Zhu (1997) reported the difference in passive membrane properties and response patterns to depolarizing current identifying touch (M) and vibrotactile (V + M) neurons in the TRG, both of which are A-beta mechanical neurons with low thresholds. Christenson et al. (1988) showed the possibility of separating the primary sensory neurons into M and pressure (P) neurons in the lamprey using an intracellularly stimulating method. They further proved that the different electrophysiological properties were due to the different distribution of the ionic channels in the neurons (Christenson et al., 1993). In addition, the existence of distinctive differences in passive membrane properties was shown between these two types (Martin and Wickelgren, 1971). In the TRG of crotaline snakes, we found two kinds of different mechanical threshold neurons. We called them P (Terashima and Zhu, 1996) and M neurons (Terashima and Liang, 1993, 1994; Terashima and Zhu, 1997), respectively. Both of them were slowly adapting neurons which responded to a sustained mechanical stimulation of the receptive field (RF) with a train of discharges. The naming of P and M neurons is historical and does not refer to different adaptation rates. The differences in the sensory and electrophysiological properties of P and M neurons have not been reported except in the lamprey. The purpose of this research is to investigate the relation of sensory modality and electrophysiological characteristics. It is difficult to find RFs because the intrasomally recorded neuron escapes easily when skin or mucosa is stimulated by applying force. If there are differences in the electrophysiological characteristics between P and M neurons it will also help us to distinguish them. Preliminary results have been published in an abstract form (Terashima and Zhu, 1996).

2. MATERIALS AND METHODS

2.1. Animal preparation

Crotaline snakes, Trimeresurus flavoviridis, of either sex weighing 200–500 g were anesthetized with halothane followed by pancuronium immobilization (2 mg/kg, i.m.). Pancuronium and ketamine injection (30–40 mg/kg, i.m.) was continued every 4–5 h during the procedure. Artificial respiration was applied by an aquarium air pump with a unidirectional airflow moistened prior by passing through a water bottle. The air flux was kept at 0.5 l/min. Hypodermic needles were inserted into the posterior air sac of the lung for outflow of the air. This system avoids respiratory movement which affects intrasomal recording. The animals were fixed with two pairs of snake head