Christian Kölbl
Dr. med.

A structural and functional analysis of a newly identified type of GABAergic interneuron in layer 4 of rat barrel cortex

Geboren am 15.02.1980 in Neumarkt
Staatsexamen am 27.04.2007 an der Ruprecht-Karls-Universität Heidelberg

Promotionsfach: Physiologie
Doktorvater: Prof. Dr. rer. nat. Dirk Feldmeyer

In the present study we analyzed morphological, physiological and molecular features of GABAergic L4 interneurons in rat barrel cortex. Our approach was to categorize these anatomically very heterogeneous neurons with a quantitative morphological analysis. We used complete 3D reconstructions of total axonal and dendritic domains of 45 interneurons in layer 4 of rat somatosensory (barrel) cortex, followed by cluster analysis of functionally relevant axonal features (axon home barrel ratio and axon home barrel column ratio, see Methods). Three different clusters of L4 interneurons were found based on their respective axonal morphology. We identified a new type of GABAergic L4 interneuron which was characterized by a strictly barrel-confined axonal domain and was therefore named the L4 'barrel inhibitor' interneuron. Subsequently, we focused our study on this functionally important neuron and its synaptic contacts within the barrel. 'Barrel inhibitor' interneurons could not be differentiated from anatomically distinct interneurons by any of the measured intrinsic electrophysiological features. In particular, we found that L4 interneurons of all three morphological clusters showed a steady state firing pattern consistent with the 'fast-spiking' action potential firing pattern. Our study unambiguously shows that the 'fast spiking' firing pattern does not satisfactorily describe a particular type of L4 interneuron but is a feature of several morphologically heterogeneous cells. We investigated the GABAergic synaptic connection of 'barrel inhibitor' interneurons to layer 4 spiny neurons. This connection showed a extremely high connectivity rate of 63%. Analysis of synaptic physiology revealed fast, reliable contacts with moderate efficacy and short-term depression. The reciprocal connectivity rate (from the L4 spiny neuron to the 'barrel inhibitor' interneuron) was also remarkably high with 67%. A detailed light microscopic analysis was performed to reveal the number and two-dimensional geometric distance of synaptic contacts for every individual connection. It showed that inhibitory contacts in the L4 'barrel inhibitor' interneuron to spiny neuron connection were not restricted to perisomatic areas, but also occurred at distances greater than 100 μm from the postsynaptic soma and on higher order dendrites. We conclude that an anatomically distinct L4 interneuron is characterized by dense and strictly local axonal projections. This newly identified interneuron subtype is connected to L4 spiny neurons with high convergence and divergence and thus is likely to play a major role in intra-barrel feedforward and feedback inhibition.