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A Golgi study on the red nucleus in man

S. Patt[1], L. Gerhard[2] and E. Zill[1]

[1]Institute of Neuropathology, Free University of Berlin and [2]Institute for Clinical Neurosurgery, University of Witten/Herdecke, Hattingen, Germany

Summary. The different cell types comprising the human red nucleus (RN) from eight patients without neuronal diseases were investigated using the Golgi-Braitenberg method for long-stored autopsy material. No giant cells were found due to regression of the magnicellular part of the human RN. We found larger (40 - 50 µm) and smaller (30 µm perikaryon size) medium-sized multipolar neurons with long dendrites, mushroom spines and typical distal dendritic tufts. The larger medium-sized RN neurons had some brush-shaped dendritic end portions which could not be observed in the Golgi studies on various other mammals described in the literature. We additionally found small neurons with a perikaryon size of 15 µm. These cells were thought to be intrinsic neurons similar to those in animal investigations.

The neuronal types found in the normal human RN corresponded to those in the parvicellular part of the mammalian RN. Dendritic end brushes, however, are typical only for the human RN.

Key words: Red nucleus, Man, Anatomy, Golgi technique

Introduction

The red nucleus (RN) has been investigated from various species in Nissl and Golgi preparations from various species (von Monakow, 1909; Mingazzini, 1928; Otabe and Horowitz, 1970; King et al., 1971a,b, 1974; Reid et al., 1975; Sadun and Pappas, 1978; Iwahori and Nakamura, 1991). In many mammals, the RN is divided into a caudal magnicellular part (RNmc) and a rostral parvicellular part (RNpc). Various types of nerve cells have been described: giant, large, medium-sized and small cells. Giant cells are absent in man, whose magnicellular part is rudimentary (Olszewski and Baxter, 1954).

Despite the brief description given by Mingazzini (1928), there has not been to our knowledge, a detailed investigation on the human RN using the Golgi technique. The objective of the present study was to describe more comprehensively the different cell types comprising the RN by submitting material from eight patients without neuronal diseases to an investigation using the Golgi-Braitenberg method for long-stored autopsy material (Braitenberg et al., 1967).

Offprint requests to: Dr. Stephan Patt, Institut für Neuropathologie, Freie Universität Berlin, Hindenburgdamm 30, D-12200 Berlin, Germany

Materials and methods

The brains of eight adults without neurological symptoms, ranging in age from 46 to 87 (mean: 60 years), were obtained at autopsy, fixed in toto by immersion in 10% formaldehyde and stored for at least six months. In some cases, blocks were cut through the brain stem several months prior to the Golgi procedure. The time between death and autopsy was at least one day and, in two cases, up to five days.

For Golgi impregnation, the mesencephalon was cut horizontally. Blocks of at least 1 x 2 x 1 cm containing the whole RN of one side were selected for the Golgi impregnation technique and processed according to the modification proposed by Braitenberg et al. (1967). The blocks were frozen, cut at 100 µm, quickly dehydrated and mounted in synthetic resin. Approximately 15 sections were examined in each case. Well-impregnated neurons were photographed at different magnifications. Montages of photomicrographs were made at various depths of field. Some of the neurons were additionally drawn using a camera lucida.

Paraffin sections stained with H & E and Nissl from the contralateral NR were available for conventional examination.

Results

Light microscopy

While giant cells were not seen in serial frontal sections of the RN, it was possible to demonstrate medium-sized multipolar cells with Nissl bodies (Fig. 1c) as well as small cells without distinct Nissl granula.

Golgi impregnation

Medium-sized neurons

The perikarya of medium-sized neurons were 40-50 µm in size and were multipolar (Fig. 1a,b). Smaller medium-sized cells had a perikaryon size of approximately 30 µm and were more fusiform, sometimes «u»-shaped or torgued (Fig. 2). The multipolar cells put forth five or more thin dendrites which branched off dichotomously. The secondary dendrites were long and thin. Some long ones reversed their initial centrifugal course and connected with axons or other dendrites of the same cell. The dendrites remained within the confines of the RN. Short stubby somatic spines were found only exceptionally in larger medium-sized RN neurons. Smaller medium-sized neurons were devoid of somatic spines. The dendritic spine distribution was irregular. Spines were characteristically mushroom-shaped with a thin stalk and a pronounced end knob (Fig. 1b). In some cases there were trifoleate spines as well as local accumulations of mushroom spines. Spines without end knobs were also present, but only in peripheral dendritic portions, and were grouped together to form small tufts (type 1; Fig. 1b). Some distal end portions of dendrites were brush-shaped (type 2; Figs. 1a, 2). Both types of tufts were characteristic for larger medium-sized RN neurons but were absent in smaller ones.

The axons were only impregnated in their initial segments.

Small neurons

Small cells had a perikaryon diameter of approximately 15 µm. Their dendrites ran parallel to dendrites of those of medium-sized RN neurons (Fig. 3). In one case, two thin processes emerged from both poles of a very small fusiform neuron (Fig. 3a). One of the processes branched off and «located» a tertiary dendrite

Fig. 1a. Medium-sized RN neuron with characteristic mushroom spines. End brushes are also seen (type 2 tufts) x 280. **b.** Higher magnification of (a) with type 1 tufts (open arrow) and mushroom spines (arrow) x 700. **c.** Corresponding neuron in Nissl preparation with peripheral Nissl bodies. x 1,120

from a medium-sized neuron (Fig. 3b). A third thin process arising from the perikaryon of the small neuron branched off and emitted two thin processes that coursed parallel to the longer dendrites. One spine with an end knob was found (Fig. 3c).

Discussion

Though differing in their classification, most authors distinguished three to four types of RN neurons. Excluding small neurons, most of these types have been considered to be projection neurons. Small RN neurons in the opossum (King et al., 1974) and cat (Sadun and Pappas, 1978) have been shown to be intrinsic.

The neuronal types found in the human RN by examining Golgi and Nissl preparations were comparable to those in various mammals despite absence of giant neurons due to RNmc regression in man (Olszewski and Baxter, 1954). Table 1 compares RN cell types of the RN in man, where the RNmc is absent, with those in the monkey, a mammal highly advanced phylogenetically with an abrupt transition between RNpc and RNmc, and - at the other extreme - those in the rat, where there are no sharp borders between RNpc and RNmc. The Nissl characterization and the cell distinction based on Golgi impregnations are very similar excepting their designations. We termed the cells with a soma size below 15 - 20 µm «small neurons», as

Table 1. Comparison of RN neuronal cell types in man with those in monkeys and rats.

SPECIES	RNmc	RNpc
man[1]	absent	medium-sized with end brushes (40-50 µm) medium-sized (30 µm) small (15 µm)
monkey[2]	giant elongated (80-90 µm) giant multipolar (50-70 µm) medium-sized (30-50 µm) small (10-15 µm)	medium-sized (20-30 µm) small (10-15µm)
rat[3]	giant (more than 40µm) large (26-40 µm)	medium-sized (20-25µm) small (below 20 µm)

[1]: present study; [2]: King et al (1971a); [3]: Reid et al. (1975).

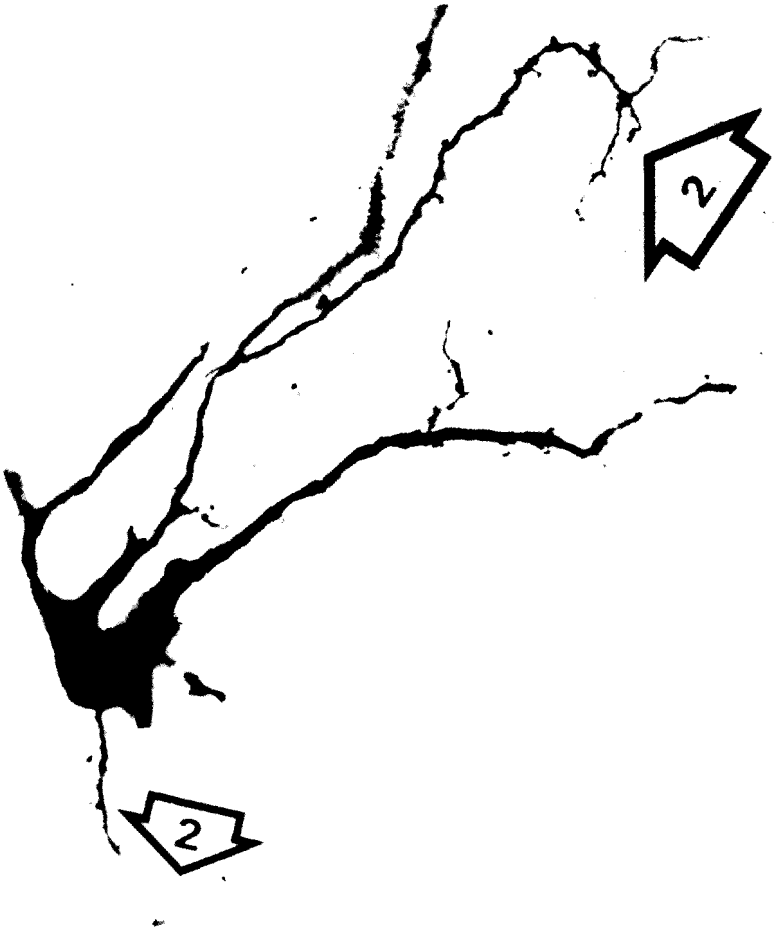

Fig. 2. Smaller medium-sized RN neuron with end brushes. x 700

Fig. 3. a. Small RN neuron (arrow) which has close contact with a dendrite of a medium-sized RN neuron (open arrow). x 700. **b.** Camera lucida drawing of a. «D» indicates the dendrite of the medium-sized RN neuron which is «located» by processes of the small RN neuron. **c.** Same cell as in a shown at a different focus. The arrow indicates a very small spine with end knob. x 700

King et al. (1971a) did in the monkey, whereas von Monakow (1909) designated them as «very small neurons». The small neurons described in animals as achromatic cells of an intrinsic nature can easily be corresponded to our «small cells», which showed the network-forming dendrites characteristic of intrinsic neurons.

Interestingly, end brushes on medium-sized neurons have only been observed in man (Mingazzini, 1928) and not in other mammals, while smaller neurons are devoid of tufts in all mammalian species. This probably reflects a higher differentiation state in man, enlargement of the dendritic surface being associated with a higher potential for synaptic contacts.

A subdivision of RN neurons based on criteria other than size, as described in the cat (Sadun and Pappas, 1978) could not be found in man.

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