Comparative Fine Structure of the Trigeminal Ganglia, Including Human Autopsy Studies*

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BEFORE we undertook an electron microscopic study of semilunar ganglia from patients with trigeminal neuralgia,6 we investigated the normal ultrastructure of this ganglion.5,12,22 Although we could obtain biopsies from patients with diseased trigeminal ganglia, the surgical removal of normal ganglia was of course not feasible. Autopsy material, on the other hand, was available, but could not be evaluated without previous knowledge of the unautolyzed architecture of the ganglion. We therefore turned to the experimental animal. We found that previous electron microscopic studies of trigeminal ganglia provided an inadequate basis for our study, primarily because of concentration on a particular structure in the ganglion to the exclusion of others51–53 or because of a lack of illustrations of normal tissue.29 In addition, these investigations were all of trigeminal ganglia from the rat. For these reasons, we made a comparative study of several species of animals121,122 in conjunction with an autopsy study of human ganglia.5 We felt that if the trigeminal ganglia in specific animals showed a structural pattern comparable to that in man, we would have a basis for subsequent interpretation of human surgical specimens.

We examined trigeminal ganglia from guinea pigs, rabbits, Cebus monkeys, and rhesus monkeys, in addition to human ganglia from 21 random autopsies. Four of each of the different experimental animals were used. The guinea pigs ranged in age from 8 weeks to 2 years and the rabbits from 15 weeks to 3 years. The monkeys were all estimated to be young or middle-aged adults. We removed ganglia from the experimental animals immediately after lethal doses of pentobarbital or after decapitation without administration of an anesthetic agent. Human ganglia were collected at autopsy as soon as possible after death (1 to 8 hours).

To compare the different fixatives and evaluate the effect of mincing the tissue prior to fixation, we cut some autopsy ganglia into small blocks, fixing them in both Dalton's fluid and in glutaraldehyde. We fixed the whole contralateral ganglion from the same case in glutaraldehyde and then cut it into tiny cubes before post fixation. We also compared whole ganglia fixed in glutaraldehyde with bits of ganglion removed with a pituitary rongeur, as is done surgically.

For further comparison, several guinea pigs were killed with intraperitoneal sodium pentobarbital and the ganglia removed at 2, 4, and 8 hours postmortem. These ganglia were processed in the same ways already described. To determine the effect of handling tissue following biopsy, we placed pieces of guinea pig ganglia, which had been removed immediately after or before death, on dry cottonoids saturated with distilled water, and cottonoids saturated with normal saline solution. These specimens stood for 10 minutes before fixation in Dalton's fluid. After fixation, we handled all tissues in the same manner. The details of this methodology have been presented elsewhere.5,122

Although we noted a slight variation in the distribution and size of the ganglion cells from one species to another, the human and simian neurons being largest, the nature and amount of neuronal cytoplasmic pigments seemed to be the chief species difference. By light microscopy, the 2- to 3-year-old guinea pigs and rabbits showed a moderate amount of yellow lipofuscin pigment which stained with oil blue N, whereas the young adult animals showed no pigment in paraffin sections. Ganglia of Cebus monkeys revealed prominent amounts of the oil blue N-positive lipofuscin-like material and, rarely, widely-scattered pigment granules which stained dark purple to black with the diamin silver stain for melanin. Rhesus monkey and human trigeminal ganglia likewise contained large amounts of the lipofuscin pigment, in addition to relatively greater amounts of dark brown neuromelanin pigment16 that appeared sparsely distributed.

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throughout the cytoplasm or arranged in clumps adjacent to the neuron nucleus. The lipofuscin was more abundant in older humans and tended to be arranged in clumps scattered about the ganglion cell cytoplasm. In the satellite cell cytoplasm we occasionally noted dark brown pigment granules which picked up melanin stain.

Under the electron microscope, the trigeminal ganglia from guinea pigs, rabbits, monkeys, and man all showed neurons of varying size surrounded by satellite cells (Figs. 4 and 5). The cell bodies of the neurons tended to be grouped in clusters, which were easily recognized by their large size and typical architecture. A varying assortment of myelinated and unmyelinated fibers, capillaries, fibroblasts, and collagen fibrils occupied the area between the neurons (Fig. 4). Although occasionally we saw "light" and "dark" neurons, most of the cells were intermediate in appearance. Lighter neurons differed from the darker variety only in cytoplasmic density. The density of the neuronal cytoplasm seemed to be related to a fluid shift between the neuron and the extracellular space, which in the area around darker cells was widened and more prominent. This was also borne out experimentally, in that the animal ganglia from the dry cottonoids were composed predominantly of darker cells, while those that had been on cottonoids saturated with distilled water were light and vacuolated, the vacuolization being due primarily to mitochondrial swelling. On the other hand, ganglia from the cottonoids saturated with normal saline solution were virtually indistinguishable from those that had been fixed immediately.

The nuclei of ganglion cells were usually central in position and occupied from one-fifth to one-fourth the total volume of the perikaryon (Figs. 4 and 5). The nuclear membrane, instead of being smooth, generally was irregular and sinuate (Fig. 4). In sectioned cells, we noted one and rarely two prominent nucleoli. Nucleoli of all species were composed of two basic parts, but there were apparent species differences in the arrangement and distribution of the components. Simian ganglia often had a distinct intranucleolar

Fig. 4. Representative human ganglion cell with centrally placed nucleus and large nucleolus. Note the sinuate contour of the nuclear membrane and the small ring-like structures to the left of the nucleolus. Clumps of Nissl substance are evenly dispersed throughout the cytoplasm. An accumulation of pigment granules lies to the right of the nucleus. Portions of adjacent ganglion cells (G) may also be seen. Chrome-osmium fixation; ×3,000. Insert: A higher magnification of the nuclear ring-like structures; ×15,000.