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The distribution of thoracic glomus tissue (aortic bodies) in the rat

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Summary. An inventory of the distribution of thoracic glomus tissue (thoracic chemoreceptor tissue, aortic bodies) has been derived from serial sections in foetal, newborn and adult rats. In contrast to other common experimental species, such as the cat and dog, aortic bodies are an inconstant feature and, on the whole, are scarce in the rat. These morphological findings correlate well with experimental studies, indicating an absence or paucity of thoracic chemoreceptor activity in the rat. The results are discussed in terms of their physiological and pathophysiological implications and a revised model of the peripheral arterial chemoreceptor system is presented.

Key words: Aortic bodies (rat) – Thoracic chemoreceptors – Glomus tissue – Vagus nerve

It is generally considered that the peripheral arterial chemoreceptors constitute two sets of 'glomus' tissue: the bilateral carotid bodies and a number of similar cell groups distributed around the main thoracic arteries and collectively referred to as the aortic bodies (see Biscoe 1971; Howe and Neil 1972; Böck 1982, for reviews). Additional minute aggregations of glomus tissue ('mini-glomera') have also been described by Matsuura (1973) in the cat along the course of the common carotid artery and experimentally shown to be functional chemoreceptors.

Whether or not this pattern of distribution is common to all mammalian species is, however, uncertain. While the carotid bodies appear to be a constant feature of mammals, the aortic bodies may not always be represented. The rabbit, for example, seems to be poorly endowed with thoracic chemoreceptors (Schmidt 1932; Gernandt 1946; Neil et al. 1949; d'Agostini

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1954, 1955, 1959; Douglas and Ritchie 1956; Douglas et al. 1956; Howe 1957; Chalmers et al. 1967; Wiemer 1974) and in the rat (and mouse) also there is similar histological and experimental evidence that indicates a paucity of aortic bodies (Hollinshead 1941; Daly et al. 1965; Sapru and Krieger 1977a, b; Dhillon 1980).

Moreover, it is now becoming clear that the arterial chemoreceptors are involved more extensively in physiological systems, and not simply in those concerned with respiratory and cardiovascular control (Harris 1979). Hence, with the increasing use of small mammals, particularly rats, as experimental animals, it becomes important to know the precise location of vascular chemoreceptors in such species. Accordingly, the distribution of thoracic 'glomus tissue' in the rat was charted histologically. Some of these results have been reported already in a preliminary communication (Barker et al. 1980).

Materials and methods

The study was carried out on 19 rats of the Wistar strain, varying in sex and age and drawn from several different colonies. They comprised 3 foetal animals (16–21 days gestation) and 16 post-natal animals (newborn to adult). Some of the adult animals were killed by domestic gas or an overdose of sodium pentobarbitone, neonatal and foetal animals by decapitation. The chest and abdomen were opened and the animal immersed in fixative (10% Helly-formol or Regaud) for 24 h. Five of the adult rats were subjected to a period of chronic hypoxia (10% O_2 in N_2) in a chamber for 16–17 days (made available by courtesy of Dr. G. Barer, Department of Medicine, University of Sheffield), a procedure known to cause enlargement of the carotid body and hyperplasia of its glomus tissue (Barer et al. 1976; Barer and Walsh 1979). These animals were then anaesthetised with urethane (i.p.) and the trachea cannulated. The chest was opened under artificial ventilation and the animal fixed by vascular perfusion. A cannula was inserted into the aorta via a slit made in the left ventricle and a small volume of heparin saline infused. This was followed by 3% glutaraldehyde in phosphate buffer (pH 7.4, Millonig 1961), until the effluent from the punctured right atrium was reasonably free from blood and the animal was judged to be successfully fixed (as indicated by muscular spasm and the colour of its paws). The carcass was immersed in the same fixative for a further 24 h before processing. In all cases, following decalcification in ethylenediaminetetra-acetic acid (EDTA), serial longitudinal paraffin sections (10–15 μm) were cut of a block of tissue extending from the level of the medulla oblongata to the diaphragm. All sections were stained routinely with haematoxylin and orange G-erythrosin and scrutinized by two persons, working independently. The location of any glomus tissue was charted. Recognition of glomus tissue was facilitated by comparison with sections of established chemoreceptor tissue, derived from earlier studies in the cat, dog and rat (see Howe 1956; Coleridge et al. 1967, 1970; Deane et al. 1975).

Results

Only 7 of the 19 rats studied exhibited any histologically demonstrable thoracic glomus tissue (aortic bodies). The distribution of aortic body tissue in these animals is given in Table 1. Only 2 of the 7 showed the full complement of aortic bodies (4 groups) in the 'classical' locations, as described for the cat and dog (Howe 1956, 1957; Coleridge et al. 1967, 1970), and these were adult animals. Two others (one foetal and one 5 day old) showed solitary aggregations of glomus tissue in these recognised thoracic positions

Table 1. Incidence of glomus tissue (aortic bodies) in the rat

Animal/ages	Thoracic glomus tissue locations				Caudal common carotid region (clavicular)
	Group 1	2	3	4	
16–21 days Foetal	−	+	−	−	−
16–21 days Foetal	−	−	−	−	−
19 days Foetal	−	−	−	−	+
3 days Post-Natal	−	−	−	−	−
5 days Post-Natal	+	−	−	−	−
7 days Post-Natal	−	−	−	−	−
11 days Post-Natal	−	−	−	−	−
14 days Post-Ntal	−	−	−	−	−
26 days Post-Natal	+	−	−	+	−
40 days Post-Natal	−	−	−	−	−
Adult	+	+	+	+	+
Adult	+	+	+	+	−
Adult	−	−	−	−	+
Adult	−	−	−	−	−
Adult[a]	−	−	−	−	−
Adult[a]	−	−	−	−	−
Adult[a]	−	−	−	−	−
Adult[a]	−	−	−	−	−
Adult[a]	−	−	−	−	−
Total 19			7		

+ represents positive finding; − represents negative finding

[a] Indicates animals subjected to hypoxia

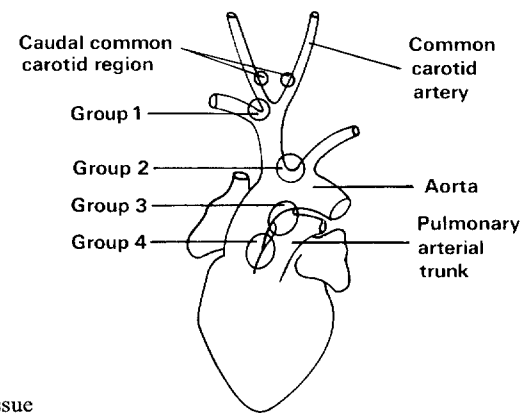

Fig. 1. Location of the thoracic glomus tissue

and one animal (26 day old) exhibited two such groups. Of the 2 remaining animals (1 foetal and 1 adult), each possessed only one small group of glomus tissue in a previously undescribed position, namely at the caudal end of the common carotid artery (at the level of the mediastinum where the vagus nerves pass under the clavicle to enter the thorax). One of the adult rats exhibiting a full complement of aortic bodies also had a single

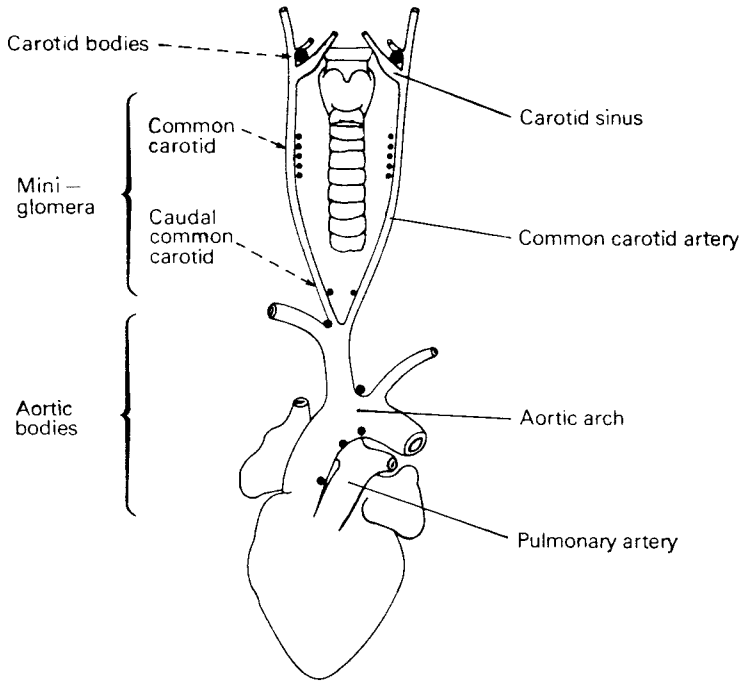

Fig. 2. Generalized diagram to show the potential distribution of glomus tissue (peripheral arterial chemoreceptor system) in mammals

group in this unusual position. No such glomus tissue was found in any of the rats (all adults) that had been exposed to chronic hypoxia.

The morphology of the glomus tissue showed considerably variation, ranging from compact ovoid structures of some 200 μm down to simply a few glomus cells embedded within branches of the vagal nerve trunks. In the larger aggregations, the glomus cells were arranged in the characteristic whorl-like groups, interspersed with fine blood vessels and nerve fibres (Fig. 3). Nerve cells, singly, in groups, or sometimes forming microganglia, were often found in close association with the glomus tissue and nerve trunks. Such arrangement and variation has been reported previously in the cat and dog (Coleridge et al. 1967, 1970).

Discussion

In view of the relatively small number of animals examined, it cannot be asserted that the results are necessarily representative of the species as a whole. Nevertheless, since each animal was examined serially and the animals came from diverse colonies, it is possible to draw a number of conclusions from this study.

It is clear that thoracic glomus (aortic body) tissue is an inconstant feature and, on the whole, is scarce in this strain of rat. From this sample, the results suggest that only a small proportion of animals (perhaps only

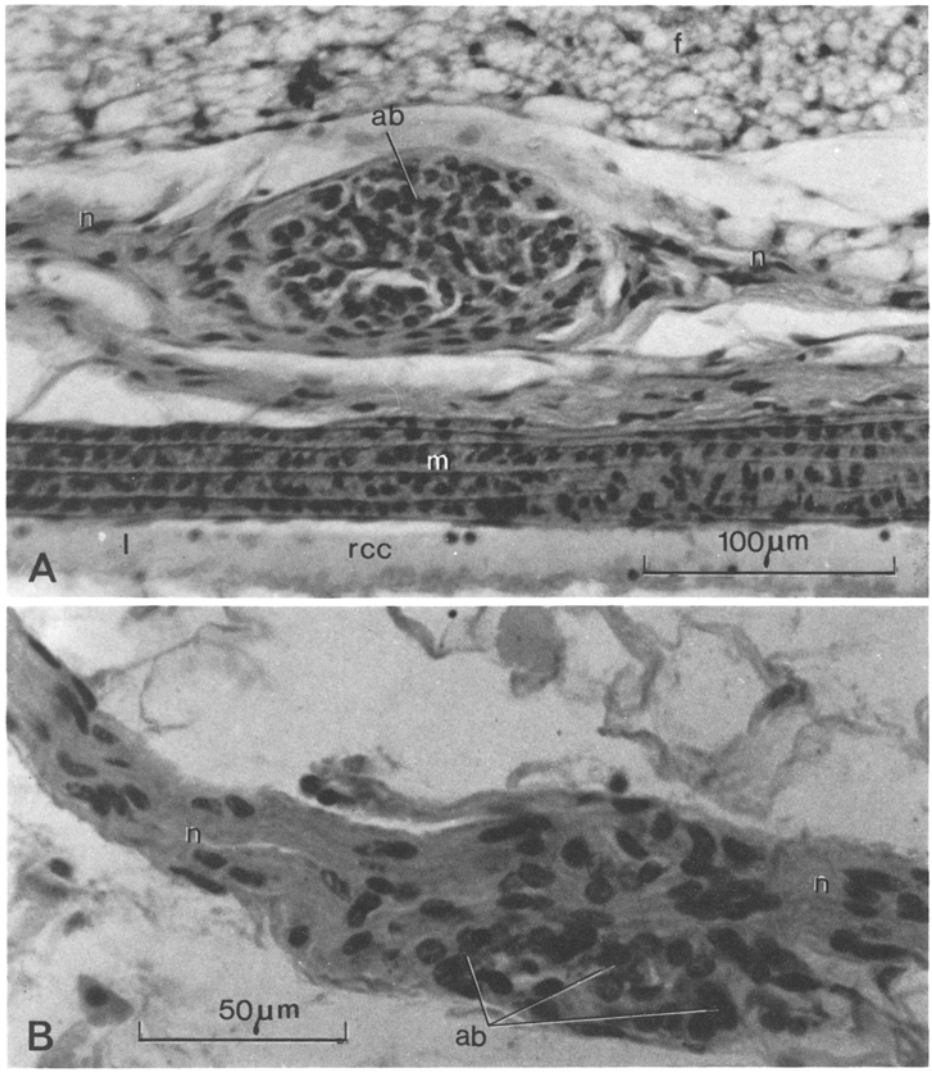

Fig. 3A, B. Photomicrographs of 10 -μm sections of thoracic glomus tissue, stained with haematoxylin and orange G-erythrosin; *ab* aortic body (glomus tissue); *f* fatty tissue; *l* lumen of artery; *m* media; *n* vagal nerve branches; *rcc* right common carotid artery. **A** A compact aortic body from the caudal carotid region, situated in the adventitial fatty tissue of the common carotid artery and embedded within vagal nerve branches. Bar represents 100 μm. The 'whorl-like' arrangement of the glomus cell groups, characteristic of peripheral arterial chemoreceptor tissue, can be seen. **B** A small aortic body, represented by a few glomus cells embedded within the vagus nerve trunk. Bar represents 50 μm

some 10%) exhibit the full complement of aortic bodies, as described in the cat and dog; the majority (some 63%) exhibit no aortic glomera at all; while a lesser proportion (some 26%) have only one or two groups of glomus tissue.

The inclusion of 5 animals that had been subjected to a period of chronic

hypoxia, sufficient to cause hypertrophy of their carotid bodies, adds weight to these conclusions. If it is assumed that this hypertrophic response to chronic hypoxia (Barer et al. 1976; Barer and Walsh 1979) is a feature of vascular chemoreceptor tissue generally, then, under such conditions, one might expect any groups of aortic bodies present to undergo a similar hypertrophy and so be more easily discernible. That no thoracic glomus tissue whatsoever was apparent in these animals strongly suggests that aortic bodies were, in fact, absent and had not simply been overlooked. An alternative conclusion, that aortic bodies atrophy and disappear during chronic hypoxia, while the homologous carotid bodies hypertrophy, has not been seriously entertained as an explanation in the absence of any evidence for that possibility. Similarly, since thoracic glomus tissue was rare in the foetal and neonatal specimens, it is reasonable to conclude that postnatal regression of thoracic glomus tissue, as has been reported by D'Agostini (1954, 1955, 1959) in the rabbit, is not a likely explanation for the scantiness of aortic body tissue in the rat. From this survey, therefore, it would appear that paucity or absence of thoracic glomera is the rule, rather than the exception, in the rat. (It should be mentioned that these conclusions are not in accord with the reports of Hansen (1981) or McDonald and Blewett (1981), who appear to have found aortic bodies to be more plentiful than this in the rat).

The present findings confirm earlier limited histological studies in the rat (Hollinshead 1941; Daly et al. 1965). They correlate well with the observations of Sapru and Krieger (1977a, b), who, from electrophysiological and reflex studies, were unable to find any evidence of thoracic chemoreceptor activity in the rat. They are also in keeping with the recent results of Dhillon (1980). Using the respiratory stimulant S2620 (Servier Laboratories), a drug that is believed to exert its effect solely via its peripheral chemoreceptor excitatory properties, this author concluded that, in the rat, such responses were mediated entirely by the carotid bodies via the glossopharyngeal nerves. Contribution from the vagus was negligible and, by inference, aortic bodies were considered to be either non-existent, non-functional or unconnected with respiratory control in the rat.

The present study, taken in conjuction with the findings of Matsuura (1973) and with the accounts of the distribution of chemodectomas (see Glenner and Grimley 1974), suggests that the current view of the peripheral arterial chemoreceptor system needs reappraising. Rather than two relatively discrete groups of receptors, one in the neck (carotid bodies) and the other in the thorax (aortic bodies), the system would appear to be composed of an extensive receptor chain distributed along the course of the IX and X cranial nerves. This extends from the level of the carotid sinus region (or perhaps even more rostral) to the aortic arch, and includes the carotid bodies, mini-glomera of the mid-cervical and caudal carotid levels, and the thoracic groups (Fig. 2). The recent findings of Clarke and Daly (1981, 1982), that the carotid body of the rabbit is, in fact, not a compact structure but extends as strands or islands of tissue around the carotid bifurcation, is in keeping with this view. Furthermore, it may be that groups of glomus

tissue in other locations will eventually be identified as part of the chemoreceptor system (see Kjaergaard 1973; Lattes 1950; Le Compte 1951; Glenner and Grimley 1974) and it is of interest that Böck (1982), in his recent extensive review of the paraganglia, suggests a number of additional sites for chemoreceptors, such as the tympanic, jugular and laryngeal regions.

Such suggestions, together with the postulated existence of abdominal chemoreceptors (Andrews et al. 1972; Howe et al. 1978, 1981), await further experimental evidence for their substantiation.

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