Aortico-Pulmonary Glomus Tissue Distribution and Blood Supply in the Adult Cat

Abstract. *A microscopic, three-dimensional study of the aortico-pulmonary glomus tissue in the adult cat indicates a random, continuous aggregation of glomus tissue extending from the left coronary artery to the ligamentum arteriosum. It was not possible to demonstrate unequivocally specific glomera. Serial section and the injection of the pulmonary artery with India ink failed to show a vessel of supply to glomeric tissue.*

The presence of glomus tissue between the ascending aorta and pulmonary artery (herein termed aortico-pulmonary glomus tissue) is well documented (*1*). The distribution of this "non-chromaffin paraganglionic" tissue microscopically similar to that in the carotid body has been investigated, and attempts have been made to classify and name particular regional aggregations. This problem of classification has been accentuated by the recent observations of Krahl (*2*) who has defined an aggregation of glomus tissue, the "glomus pulmonale," in the adventitia dorsal to the pulmonary artery and caudal to the bifurcation. Evidence was presented from embryological reasoning for the existence of such tissue at this site. The demonstration of a blood supply from the pulmonary artery to the glomus pulmonale is of fundamental importance if this chemoreceptor tissue is to monitor mixed venous blood, a proposal postulated by Armstrong (*3*) and Duke (*4*).

A three-dimensional microscopic study of the distribution of glomus tissue was made in aortico-pulmonary complexes removed as a unit from three adult cats. The tissue was fixed and perfused with 10 percent formalin. Before the tissue was embedded the architectural relationship of the two major vessels was noted. A detailed reconstruction of the vascular complex was made from serial sections (20 μ thick) routinely stained with hematoxylin and eosin.

In 20 other adult cats, India ink (*5*) was injected into the pulmonary artery at variable pressures up to 50 mm-Hg by way of a catheter tied into the right ventricle. The deeply anesthetized animal had been heparinized and perfused with warm physiological saline containing glyceryl trinitrate (0.3 mg/100 ml). The lung roots were ligated, and a cannula was inserted into a lobar artery to act as a vent. After injection, the pulmonary artery was ligated at the pulmonary valve. It was removed and examined under a binocular dissecting microscope (maximum magnification 30), or was divided into anterior and posterior segments, and each was fixed, dehydrated, cleared, and mounted.

Histologically, the aortico-pulmonary glomus tissue was very similar to that of the carotid body. While there was an obvious variation in the size, amount, and distribution of aortico-pulmonary glomus tissue in the three animals (Fig. 1, *a–c*), certain consistent features were recognized. The glomera varied in size from single lobules containing a few cells, to large, vascular, multilobular masses completely surrounding arteries and arterioles.

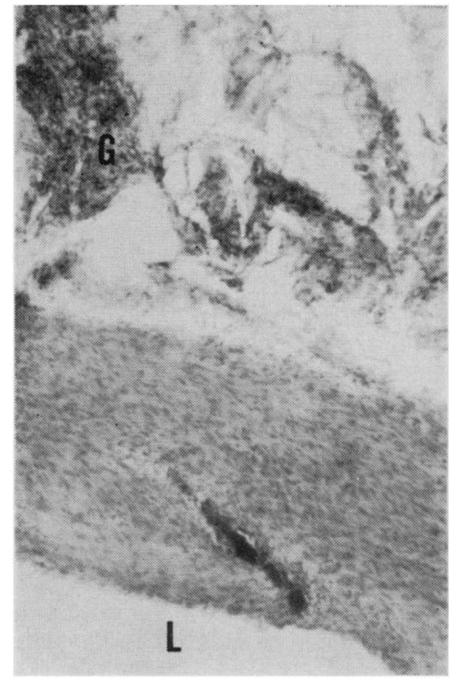

Fig. 2. Vessel traversing the media and adventitia of the posterior aspect of the pulmonary artery caudal to the bifurcation. Glomeric tissue is noted within the adventitia. Multiple sections failed to demonstrate entry of the vessel into the pulmonary artery lumen. *G*, Adventitial glomus tissue. *L*, Pulmonary artery lumen. (Hematoxylin and eosin, × 56)

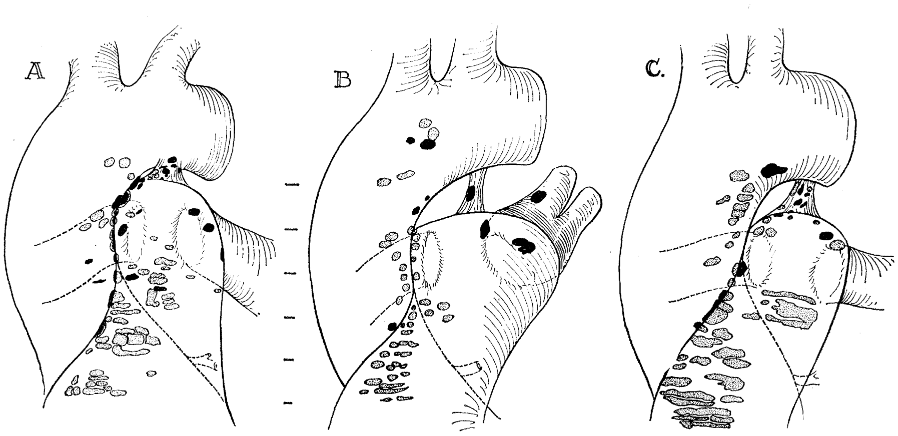

Fig. 1. Three-dimensional diagrammatic representations, viewed from the anterior aspect, of the distribution of glomus tissue in the aortico-pulmonary region of three adult cats (*A*, *B*, and *C*). The ascending aorta emerges from behind the right side of the pulmonary trunk to cover the right pulmonary artery. Glomera hidden behind vessels are shaded whereas tissue on the anterior surface is black. The ligamentum arteriosum and left coronary artery are shown.

The greater part of the tissue occupied the area between the pulmonary artery and the ascending aorta and continued into the concavity of the arch of the aorta, to surround the ligamentum arteriosum. Glomera were also observed over the anterior and posterior aspects of the ascending aorta and pulmonary artery. This distribution appeared continuous, and it was impossible to differentiate the masses of tissue to which specific names have been given. The glomera appeared to be distributed along the blood vessels rather than localized to particular areas.

The India-ink injection failed to reveal the presence of a vessel penetrating the pulmonary artery wall to supply it or the adventitial glomus tissue. This observation was confirmed in the serially sectioned tissue, and also on numerous pulmonary arteries stained to demonstrate the pattern of innervation. However, on one occasion, a large, patent muscular artery was seen to cross the media obliquely (Fig. 2). Serial sections demonstrated that this vessel did not enter the pulmonary artery lumen, but ended blindly before reaching the intima.

These observations, which confirm the presence of glomus tissue associated with the aortico-pulmonary region indicate that the magnitude and continuity of such a system in the adult animal make any attempt at specific localization futile. Previously, Palme (*6*) had noted this diffuse distribution but drew attention to the organization of large glomera in specific locales, whereas Hollinshead (*1*) found a distribution of glomera from the left coronary artery to the ligamentum arteriosum confined to the region between the pulmonary artery and the ascending aorta.

The distribution appears to be so random that to give different names to the aggregations of glomus tissue found in arbitrary areas of this region is of little value unless, or until, significant anatomical or physiologic differences become apparent. Krahl (*2*) maintained that the glomus pulmonale was different by virtue of its position and blood supply. Our results in the adult animal have not confirmed these observations. The right and left coronary arteries have been shown to supply the aortico-pulmonic glomera in the adult animal (*1, 7*). The functional significance of this supply, or the role played by the vasa vasorum of the pulmonary trunk or ascending aorta is unknown. The vessel, deep in the media, which ended blindly, in one animal would appear to be a vestige of a vessel previously described and probably functionally significant in fetal and newborn animals. The proximal part of this vessel appears to close after birth in the same way as the ductus arteriosus (*1, 3, 8*).

What we see in the adult cat is the mature pattern in which no direct pulmonic arterial blood supply to glomus tissue exists. The rare occurrence of partially obliterated vessels (and perhaps even patent vessels) is a vestigial manifestation of an organization of greater significance to the fetus and neonate. Aortico-pulmonary glomera seems to be the most appropriate name until it is decided whether their predominant physiological role in the adult animal lies with the pulmonary artery or with the aorta.

M. ANTHONY VERITY
TREVOR HUGHES
JOHN A. BEVAN

Departments of Pathology and Pharmacology, University of California, Center for the Health Sciences, Los Angeles 24

References and Notes

1. W. H. Hollinshead, *J. Comp. Neurol.* **73**, 37 (1940); W. S. Hammond, *Am. J. Anat.* **69**, 265 (1941); J. D. Boyd, *Brit. Med. Bull.* **17**, 127 (1961).
2. V. E. Krahl, in *Ciba Foundation Symposium on Pulmonary Structure and Function*, A. V. S. de Reuck and M. O'Conner, Eds. (Churchill, London, 1962), p. 53.
3. B. W. Armstrong, H. H. Hort, R. W. Blide, J. M. Workman, *Science* **133**, 1897 (1961).
4. H. N. Duke, J. H. Green, P. F. Heffron, V. W. J. Stubbens, *Quart. J. Exptl. Physiol.* **48**, 164 (1963).
5. G. W. Harris, *J. Anat.* **81**, 343 (1947).
6. F. Palme, *Z. Mikroskop. Anat. Forsch.* **36**, 391 (1934).
7. J. H. Comroe, Jr., *Am. J. Physiol.* **127**, 176 (1939); B. E. Gernandt, *Acta Physiol. Scand.* **11**, Suppl. 35 (1946); E. Neil, *ibid.* **22**, 54 (1951).
8. N. Goormahtigh and R. Pannier, *Arch. Biol. Paris* **50**, 455, 1939; J. F. Nonidez, *Anat. Rec.* **69**, 299 (1937).
9. Partially supported by USPHS grant H.E.-08359.

23 March 1964

A Primitive Heart in the Echinoid Strongylocentrotus purpuratus

Abstract. *A pulsating vessel and a compartmented contractile chamber have been found to move coelomic fluid from the perivisceral cavity into and throughout the hemal system of the sea urchin,* Strongylocentrotus purpuratus.

The question of whether echinoderms have a circulatory system has been disputed for nearly 150 years. Our study demonstrates the existence of a true circulatory system.

The axial gland, a little understood structure in echinoderms, is an elongated soft body, generally brownish or purplish in color, found near the stone canal. It has been referred to by a variety of names including heart (*1*), kidney (*2*), brown gland (*3*), ovoid gland (*4*), dorsal organ (*5, 6*), and septal gland (*6*), indicative of the considerable disagreement about its structural relationships and function. This study of the hemal system and axial gland complex of the purple sea urchin, *Strongylocentrotus purpuratus*, has yielded new information that provides a better understanding of the gland's function.

The axial gland is a hollow organ which tapers at both ends. In cross section it forms a circle, half of which consists of dense tissue and the other half is a membrane (Fig. 1).

We have found that there are two prominent and separate cavities, the axocoel and the axial gland lumen (axial sinus). The axial gland lumen is occupied by a pulsating vessel which extends the length of the axial gland with branches that form the dense spongy region. The pulsating vessel terminates aborally in an ampulla-like structure in the axocoel, directly under the madreporite. This ampullar structure is divided into two contractile chambers, which are visible in a live animal after removal of the rectum (Fig. 2). The first, a more conspicuous and opaque chamber, leads from the pulsating vessel; the second chamber, broader and thinner, extends around the inner surface of the aboral sinus.

Rhythmic contractions of the pulsating vessel were studied by time-lapse cinematography, intervals from 3 to 24 frames per second being used. Beat frequencies averaged six per minute, ranging from four to eight. Contraction of one chamber follows that of another, as in a two-chambered heart with auricular and ventricular beats. A contraction sequence begins with the second chamber, passes to the first, and continues peristaltically along the pulsating vessel within the axial gland lumen.

A connection between the stone canal of the water vascular system and lumen of the axial gland (Fig. 2), shown in serial sections, confirms earlier accounts (*3*) and clarifies confusion on this point (*7*). Separation between contractile chambers and the cavity of the axocoel is complete. The axocoel, however, communicates directly with the perivisceral coelom via a narrow slit (2 to 4 mm long) near the beginning of the stone canal. Perivisceral fluid with its contained cells can therefore move freely in and out of the axocoel.

The opening between the perivisceral coelom and axocoel forms a pathway in which coelomic fluid moves throughout the hemal system and to other tissues of the body, notably gonads and alimentary tract. Two percent fluorescein dye (0.01 ml) was injected into the coelomic cavity of an intact animal. After 15 minutes the animal was killed, the coelomic fluid with fluorescein dye was removed, and the exposed tissues were rinsed several times to remove excess dye. By means of ultraviolet light, the dye was shown to be distributed throughout the hemal system.

On the surfaces of the contractile chamber numerous microscopic ostia occur. These lead into an internal network of vessels of capillary dimension, the walls of which consist of numerous longitudinal contractile fibers. From the first chamber, these capillaries converge