Blood Vascular Architecture of the Rat Parathyroid Glands: A Scanning Electron Microscopic Study of Corrosion Casts

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Summary. Blood vascular beds of the rat parathyroid glands were reproduced with a methacrylate casting medium and observed with a scanning electron microscope. The rat possesses only a single pair (one left and the other right) of parathyroid glands. Each gland was found to contain a rich capillary network which was completely isolated from the capillary plexus of the thyroid gland. Each parathyroid gland received some small afferent arteries from the superior thyroid artery and emitted a thick efferent vein continuous with the superior thyroid vein. The capillary network of the parathyroid gland consisted of freely anastomosing capillaries. The afferent arteries were divided in the superficial and deep layers of the gland. The thick efferent vein arose in the deep layer of the gland. Some small or accessory efferent veins arose in the superficial layers of the gland. These also drained into the superior thyroid vein.

It is well known that the parathyroid glands produce a hormone (parathyroid hormone or parathormone) that acts on the intestine, kidneys, bones and other target organs or tissues to maintain calcium levels in the blood and extracellular fluid (TURNER and BAGNARA, 1976; MARTIN, 1985). It is also well known that the parathyroid glands contain rich capillary networks which take up and transport this hormone to these target organs or tissues (TURNER and BAGNARA, 1976; MARTIN, 1985).

The capillary networks of the parathyroid gland have been studied in man, the monkey, dog, rat and other animals, even some lower vertebrates. Investigation has been made by light microscopy of sectioned samples, including the India ink-injected ones (PETERSEN, 1903; ROMEIS, 1926; LANDAU, 1931; KLUMPP and EGGERT, 1935; MORGAN, 1936; ISONO, 1960; GERSH cited by FAWCETT, 1986). However, this light microscopy is limited in a three-dimensional visualization of the networks, so that the finer details of these networks and their afferent and efferent vessels have not been fully elucidated or understood. The present paper demonstrates the three-dimensional vascular architecture of the rat parathyroid glands by the recently established vascular casting/scanning electron microscope method.

MATERIALS AND METHODS

Adult male Wistar rats weighing 250–300g were anesthetized with ethyl ether, and their thoracic aorta was ligated. The animals were then perfused through the ascending aorta with Ringer's solution and with a low viscosity methacrylate medium (MURAKAMI et al., 1984) until the superior vena cava was filled with the perfused methacrylate medium.

The methacrylate-perfused animals were placed for 2 hrs in a hot water bath (60°C), corroded in a hot 10% NaOH solution (60°C) overnight or longer, washed in running tap water overnight or longer, and air-dried. The blood vascular casts thus prepared were dissected with sharpened forceps, and the blood vascular beds of the parathyroid glands were isolated together with those of the thyroid gland.

The isolated specimens were sputter-coated with gold in a vacuum chamber, and observed with a scanning electron microscope (HHS-2R, Hitachi) using an acceleration voltage of 5 kV. After this observation, the specimens were microdissected with sharpened needles and observed again with the scanning electron microscope. This series of dissection and scanning electron microscopy of the parathyroid vascular casts was repeated several times for thorough elucidation of the inner structures.

RESULTS

Thorough perfusion of the low viscosity methacrylate medium through the ascending aorta after ligation of the thoracic aorta allowed a good casting of the blood vascular beds of the parathyroid glands as well as the thyroid gland (Fig. 1). Few leakages of the perfused medium were noted.

The rats were found to possess only one pair of parathyroid glands (left and right). Each gland was ovoid in shape and located at the latero-cranial aspect of the thyroid gland (Fig. 1). The capillary bed of each parathyroid gland was islanded, and its capillaries were finer than the sinusoidal capillaries of the thyroid gland (Fig. 2, 3). No direct capillary connection between the parathyroid and thyroid glands was observed (Fig. 2, 3).

The capillary beds of the parathyroid and thyroid glands were surrounded by a very coarse meshwork of fine capillaries, which were derived from the superior and inferior thyroid arteries and collected into the superior and inferior thyroid veins (Fig. 2, 3). This capsular meshwork had no direct connection with the capillary beds of the parathyroid and thyroid glands.

The capillary bed of each parathyroid gland received some (4–5) small afferent arteries from the superior thyroid artery (Fig. 2, 3). These afferent vessels took on various branchings in the superficial and deep layers of the parathyroid gland and formed a true network of freely anastomosing capillaries with an isotropical and homogeneous distribution (Fig. 1–3). The branches of the afferent vessels could usually be grouped into superficial and deep ones. The superficial branches were almost always thicker than the deep branches and supplied the outer two thirds of the network, the remaining inner one third of the network being supplied by the deep branches (Fig. 3).

The capillary network of each parathyroid gland was rather dense and compact, converging into the venules at various levels in the superficial and deep layers of the

parathyroid gland. The venules or venous twigs further converged into a few collecting venous branches (initial efferent veins), which were located in the deep layer of the parathyroid gland and confluent into a thick efferent vein (or venous trunk) within

Fig. 1. A survey scanning electron micrograph of the methacrylate-cast blood vascular beds of the rat parathyroid (*P*) and thyroid (*T*) glands (adult male rat, viewed from the left side). The capsular capillary meshwork of the thyroid and parathyroid glands were removed together with the capillary networks of the adjacent connective tissues. Capillary beds of the constrictor pharyngeal (*C*) and laryngeal (cricothyroideus) (*L*) muscles were partially removed. Note that the capillary bed of the parathyroid gland (*P*) is islanded, and also that the parathyroid vein (*PV*) receives a venous twig (superficial venous twig of the parathyroid gland) on the surface of the parathyroid gland (arrowhead). *IA* and *IV* inferior thyroid artery and vein, *SA* and *SV* superior thyroid artery and vein. $\times 40$

of the capillary network, the remaining outer one third of the capillary network being collected into the superficial venous twigs (Fig. 3). The superficial venous twigs ran on the surface of the gland, but finally crept into the deep layer to continue into the collecting venous branches (initial efferent veins) or the thick efferent vein (or venous trunk) (Fig. 2, 3). In aberrant form, a few superficial venous twigs located near the thick efferent vein directly continued into this vein on the surface of the parathyroid gland (Fig. 1).

The thick efferent vein of the parathyroid gland appeared as the parathyroid vein on the lateral surface of the parathyroid gland, ran for a short distance on the lateral surface of the parathyroid gland, and drained into an adjacent vein which collected the venous branches of the thyroid gland (Fig. 1-3). In addition to this, some (6-7) accessory venous twigs arose in the superficial layer of the parathyroid gland and drained into the adjacent veins collecting the venous branches of the thyroid gland (Fig. 2, 3). On rare occasions, the accessory venous twigs were as fine as the capillaries, and anastomosed with each other on the surface of the parathyroid gland (Fig. 2). These anastomosed and capillary-like efferent twigs almost always received one or two thin or capillary-like efferent vessels from the adjacent thyroid follicle or follicles, and drained into the adjacent veins collecting the venous branches of the thyroid gland (Fig. 2). Thus, the efferent veins of the parathyroid gland, including the accessory ones and also rare thin ones, emptied into the superior thyroid vein (Fig. 1).

The findings described above are schematically diagrammed in Figure 4.

DISCUSSION

The present study, together with our preliminary scanning observation of cast samples (KIKUTA et al., 1984), confirms that the rat parathyroid gland contains rich capillary networks which drain into the thyroid vein. This finding coincides with those obtained in man, the monkey, dog and other mammals by light microscopy of tissue sections, including sections of India ink-injected specimens (PETERSEN, 1903; LANDAU, 1931; GERSH cited by FAWCETT, 1986).

The present study clearly shows that the capillary networks of the rat parathyroid glands are completely isolated from the basket-like capillary plexus surrounding the follicles of the thyroid gland (FUJITA and MURAKAMI, 1974). It also indicates that the capillary networks of the rat parathyroid glands consist of freely anastomosing capillaries with an isotropical and homogeneous distribution. PETERSEN (1903) described the capillary networks of the human parathyroid glands as being characterized by the capillaries, with antler-like branchings (*hirschgeweihartige Verzweigung*). LANDAU (1931) reported that the capillary networks of the dog parathyroid glands often contained some special capillaries with loop-like endings (*wiederkehrendes Capillarverlauf*). In the present study, however, neither capillaries with antlered branchings nor capillaries with loop-like endings were reproduced. Even in a light micrograph of an India ink-injected section of the monkey parathyroid gland prepared by GERSH (cited by FAWCETT, 1986), no special capillaries with antler-like or loop-like patterns were observed. LANDAU (1931) and MORGAN (1936) wrote that the human parathyroid capillaries were sinusoidal and as wide as the splenic sinuses. In the present study, however, all capillaries of the rat parathyroid gland were thin, and no sinusoidal capillaries were reproduced.

HABERFELD (1911) described a few venous valves in the human parathyroid glands.

However, cast surfaces of the rat parathyroid veins studied here were smooth and no valvular impression was noted in any venous branch. Neither was any valvular impression noted in any venous branch of the thyroid gland. No marked constriction was found in the afferent vessels of the parathyroid glands. The afferent vessels of the

Fig. 3. Legend on the opposite page.

thyroid gland also failed to show any constriction. From these cast data, it is concluded the parathyroid glands receive the blood without interruptions—such as endothelial cushions—and that the blood in the parathyroid glands flows smoothly into the venous branches of the superior thyroid vein. In the rat samples studied here, the superior thyroid vein as well as the inferior thyroid vein showed no valvular impression. Thus, it is hardly likely that the blood in the parathyroid glands flows into the thyroid gland or that the blood in the thyroid gland flows into the parathyroid glands.

The accessory parathyroid glands have been described as common in the rat, being usually located within the thymus or in the dorso-lateral areas of the esophagus at the

Fig. 4. A schematic diagram showing the vascular arrangement of the rat parathyroid gland. Abbreviations: see Fig. 1-3.

Fig. 3. A microdissected form of the parathyroid capillary network (*P*) shown in Figure 2. Note that the capillary network of the parathyroid gland (*P*) receives some afferent arteries (*PA*) from the adjacent superior thyroid artery branch (*SA*). Also note that the main efferent vein (parathyroid vein) (*PV*) arises in the deep layer of the gland. Thick and thin arrows indicate the opening sites of the *sv1* and *sv2* superficial venous twigs shown in Figure 2. *T* thyroid gland, *cv* dissected remnant of the capsular capillaries, *da* deep branches of the parathyroid arteries, *dv* deep venous twigs, *iv* collecting venous branches, *pv* accessory efferent veins of the parathyroid gland, *sa* superficial branches of the parathyroid arteries, *sv3* (see Figure 2), *zz* dissected fragments of the cast. $\times 180$

level of larynx (HOSKINS and CHANDLER, 1925; DYKE, 1959). We also found these accessory parathyroid glands, confirming their vascular architecture to be similar to that of the main glands described above; the capillary networks of the accessory glands, like the main glands, consisted of freely anastomosing capillaries with an isotropical and homogeneous distribution, and received their afferent vessels from the superior thyroid arteries while emitting several (3-4) efferent vessels continuous with the branches of the superior thyroid veins (data not shown). Even in the accessory glands, main efferent veins arose deep in the gland. It has been reported in the rat that the main parathyroid glands are occasionally located near the middle or near the caudal pole of the thyroid gland (HEBEL and STROMBERG, 1976). We encountered this anomaly only in two cases, and confirmed that the microvascularization of these parathyroid glands with unusual positions is also similar to that of the glands with usual or latero-cranial positions of the thyroid gland (see above), the only difference being that the parathyroid glands near the caudal pole of the thyroid gland receive their afferent vessels from the interior thyroid artery and emit their efferent vessels continuous with the inferior thyroid vein. The parathyroid glands near the middle pole of the thyroid gland receive their afferent vessels from either the superior or inferior thyroid artery and emit their efferent vessels continuous with either the superior or inferior thyroid vein.

In the rats studied here, the superior thyroid arteries were almost always more developed than the inferior thyroid arteries. The superior thyroid veins were also almost always more developed than the inferior thyroid veins. Thus, the upper two thirds of the thyroid gland was supplied by the superior thyroid arteries and veins, and the lower one third was supplied by the inferior thyroid arteries and veins. Some insignificant anastomoses were observed between the superior and inferior thyroid veins within the thyroid gland. No marked anastomosis was noted between the superior and inferior thyroid arteries.

It has been described in the rat that the total volume of the parathyroid glands is twice as great in females as in males of equal age (BLUMENFELD and RICE, 1938). We have confirmed this in our preliminary experiments in this study. We have also confirmed that the vascular architecture of the female parathyroid glands is similar to that of the male ones (data not shown).

In lower vertebrates such as anurans and urodeles, some light microscopic studies of tissue sections, including India ink-injected ones, have shown that the vessels of the parathyroid glands are divided into two groups, the subcapsular capillary network and the intraparenchymal vessels (ROMEIS, 1926; KLUMPP and EGGERT, 1935; ISONO, 1960). In particular, ROMEIS (1926) showed that the subcapsular capillary network of *Rana temporaria* is a true network consisting of freely anastomosing capillaries which receive the afferent vessels from the superficial aspect (see also BARGMANN, 1939). It is presumed that the intraparenchymal vessels of the lower vertebrates may be efferent vessels. In fact, the vascular wall of an intraparenchymal vessel illustrated in *Ichthyophis glutinosus* by KLUMPP and EGGERT (1935) is thicker than that of the subcapsular capillaries, and apparently a venule or vein (also see: BARGMANN, 1939). ROMEIS (1926) also described an efferent vein in the deep layer of the parathyroid gland of *Rana temporaria*.

It may be interesting that the newt, frog and rat parathyroid glands have a common characteristic: the deep origin of the efferent vessel. In the newt and frog, such accessory veins as observed in the rat have not been reported (ROMEIS, 1926; KLUMPP and EGGERT, 1935). This may mean that the accessory efferent veins of the rat

parathyroid glands are acquired at a later stage of phylogenetic development. It is unknown whether or not the parathyroid glands of still higher vertebrates, including man, are provided with the accessory efferent veins.

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