THE ARTERIAL SUPPLY AND VENOUS DRAINAGE OF THE VERTEBRAL COLUMN OF THE DOG

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In recent years orthopaedic surgeons have become increasingly aware of the importance of comparative anatomy and pathology. Because of this renewed interest, the dog is being used more frequently for experimental work on the vertebral column and hip joints by surgeons and veterinarians alike. It would seem timely, therefore, to reassess the work on the blood supply of the dog's vertebrae.

Apart from a general anatomical description of the arteries supplying the spine, the standard reference works provide inadequate detail on the intraosseous distribution of the vessels (Miller, 1948; Bradley & Grahame, 1959).

The interest aroused in the vertebral venous system in man by the work of Batson (1940) has been extended to the dog by Worthman (1956). His papers on the anatomy and functional aspects of the longitudinal vertebral venous sinuses of the dog do not, however, contain a full account of the arrangement of veins within the vertebrae.

This paper is designed primarily to describe the anatomy of the arteries and veins as they are found within the vertebrae of the dog.

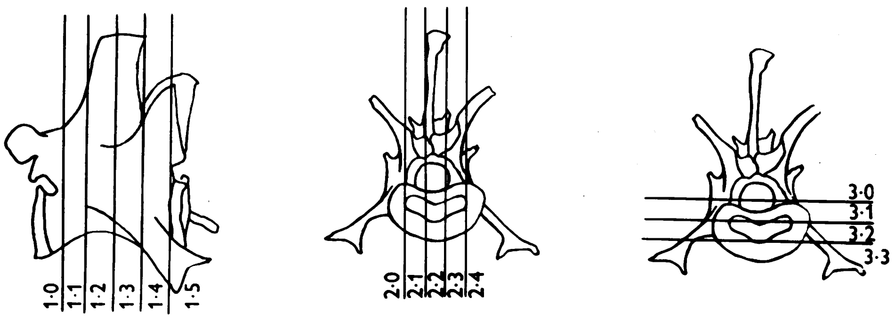
MATERIALS AND METHODS

Specimens were obtained from the cervical, thoracic and lumbar vertebrae of fifteen normal dogs. The arterial supply to the vertebral column was studied in ten dogs, and the venous drainage in five. These animals varied in age from 8 weeks to 12 years. The group was made up of different breeds, and included two adult cocker spaniels, four greyhound racing dogs, one bull terrier cross breed and eight mongrel dogs. They were all killed with intravenous doses of pentothal sodium, and injected with a suspension of barium sulphate (Micropaque), alone or mixed with 10 % Berlin Blue, within a few minutes of death, by the following technique:

The thorax was opened between the fourth and fifth ribs on the left side. A polythene cannula was then inserted in a caudal direction into the thoracic aorta and tied in place. In addition, a cannula was also placed in the common carotid artery on one side of the neck, directed cranially. For the venous specimens, a similar cannula was inserted into the caudal vena cava from the right side of the chest or passed upwards into it from the femoral vein.

The injection medium was then delivered through the cannula under constant pressure (7–10 lb./sq. in. arterial, 5–7 lb./sq. in. venous), from an oxygen cylinder source. The apparatus used was of simple construction, as recommended by Tompsett (1957). The volume of Micropaque injected varied according to the size of the animal. It is extremely difficult to obtain uniformly good filling of the intraosseous veins of the vertebrae. The large clots which appear in the caudal vena cava soon after death are broken up into small fragments by the barium injection mass.

Consequently, the veins in many specimens may become obstructed and they fill only partly with the barium suspension. In order to overcome these difficulties a large dose of anticoagulant (Pularin Heparin) was administered to one dog while under anaethesia, and this was allowed to circulate for a few minutes before the lethal dose of pentothal was administered. The injection of the vertebral veins obtained in this case was of a high standard. Notwithstanding the difficulty produced by clot fragmentation, good specimens may be obtained in most cases if two conditions are observed while making the injection. The first is to ensure flow of the medium under a constant adequate pressure, and the second, to allow the fluid to flow into the body until its delivery comes to a halt.



Text-fig. 1. Key A, Key B, Key C. (For explanation see text.)

After the injection of Micropaque, the vertebral columns were removed and fixed in formol saline for at least 5 days. Then they were decalcified in 15 % nitric acid, or 10 % formic acid if histological sections were to be made. The vertebrae were then divided into slices, longitudinal, horizontal and transverse sections being made. These were radiographed, using a water-cooled low voltage medical X-ray unit with a beryllium window and a fine grain emulsion film. Some of the specimens were subsequently cleared by the Spalteholz technique, and examined under the dissecting microscope. In this way it was possible to supplement the information obtained from the radiographs which were otherwise difficult to interpret.

In the legend accompanying the illustrations made from the radiographs of these specimens, each figure is followed by a key number. The key number, taken from the three line drawings reproduced in this paper (Text-fig. 1), shows the precise origin of the section of the vertebra which has been radiographed.

THE ARTERIAL SUPPLY

The lumbar spine of the dog is the most readily accessible area for experimental work on vertebral bodies. Because it is used most frequently for this purpose the salient features of the gross anatomy of the lumbar arteries will be described. That aspect of the thoracic and cervical vertebral blood supply will be dealt with more briefly, but equal attention will be focused on the intraosseous distribution of arteries in these three areas of the spine.

THE GROSS ANATOMY OF THE LUMBAR ARTERIES

The lumbar vertebrae are supplied by seven pairs of vessels arising from the dorsal aspect of the thoracic and abdominal aorta and from the internal iliac arteries.

The first pair are quite small and arise from the thoracic aorta above the diaphragm.

The second pair are larger and arise from the abdominal aorta between the crura of the diaphragm at the level of the disc between the first and second lumbar vertebrae.

The third pair of vessels arise at the level of the disc between the second and third lumbar vertebrae, at the same level as the site of origin of the right renal artery from the aorta (Pl. 1, fig. 1).

The fourth pair of lumbar arteries arise at the level of the disc between the third and fourth lumbar vertebrae, and they pass laterally over the attachments of the long tendons of the diaphragm to proceed obliquely across the body of the fourth lumbar vertebra.

The fifth pair arise just below the fourth at the level of the middle of the fourth vertebral body. The vessels proceed downwards in the mid-line of the spinal column, running parallel to each other, wedged between the psoas muscles (Pl. 2, fig. 2). After crossing the disc between the fourth and fifth lumbar vertebrae, they run across the body of the fifth lumbar vertebra.

The sixth pair of vessels arise at the level of the bifurcation of the aorta, over the middle of the body of the fifth lumbar vertebra. These are slender vessels and they diverge slowly from each other at the level of the disc between the fifth and sixth lumbar vertebrae to cross obliquely the body of the sixth lumbar vertebra.

The seventh pair are the most slender of all the lumbar arteries. They arise at the level of the middle of the sixth vertebral body, in common with the origin of the median sacral artery, or from the hypogastric arteries (Bradley & Grahame, 1959).

Each lumbar artery, therefore, eventually passes obliquely across its corresponding vertebral body, being crossed laterally by the sympathetic trunk. The main trunk proceeds towards the caudal and medial part of the intertransverse aponeurosis, which it pierces. Between its origin from the aorta and its passage through this aponeurosis, the vessel gives off a series of small branches. One branch enters the bone where a basivertebral vein emerges on the abdominal surface; this supplies the centrum. Others penetrate the ventro-lateral aspects of the vertebral body cranially and caudally to supply the epiphyses (Pl. 2, fig. 2). In addition, a number of slender branching vessels are given off and these enter the deep surface of the psoas muscle.

Where the main lumbar artery penetrates the intertransverse aponeurosis, it is lying on the dorso-lateral aspect of the intervertebral disc. It divides there into two main branches. One passes laterally along the transverse process, and from it large branching vessels pass into the sacrospinalis muscle mass laterally. The other crosses the intervertebral foramen, passing dorsal to the emerging nerve root, and it proceeds caudally and backwards in close relation to the mamillary process and the lateral side of the zygapophyseal joint of the caudal vertebra. It winds around this structure to pass on to the lamina, and thence medially and farther backwards to its termination in fine branches along the side of the spinous process of this adjacent caudal vertebra. It is from this major branch of the lumbar artery, in the region of the intervertebral foramen, that a number of fine branches arises which will supply the posterior aspects of the vertebral bodies. In its course across the dorsal elements of the vertebrae, many branches are given off to supply the bulk of the sacrospinalis muscles and many small vessels pass into the bones. Consequently each lumbar artery is seen to supply branches not only to its corresponding vertebral body on its ventral aspect, but to the neural elements of its own and those of the vertebra immediately caudal to it after its passage through the intertransverse aponeurosis.

THE INTERCOSTAL ARTERIES

The intercostal arteries give off branches to the centrum and epiphyseal areas in the same way as do the lumbar arteries, between their origin from the aorta and their point of division at the intervertebral foramen.

THE VERTEBRAL ARTERIES

In the cervical spine the vertebral arteries give off small ventral branches at each intervertebral foramen. These curve around the ventro-lateral sides of the vertebral bodies, giving off extraspinal epiphyseal arteries. The main trunks of these fine arteries then converge towards the centre of the vertebral body, breaking up into a multitude of branches, some of which enter the vertebra, while the remainder enter the overlying ventral cervical muscles (Pl. 2, fig. 3).

Using standard methods of dissection, it is possible to demonstrate only a few of the vessels which are to supply the vertebral body, after the arteries have been injected with latex rubber (Pl. 2, fig. 2). They are all, without exception, very fine branches. Using the barium suspension, Micropaque, the vessel patterns within the vertebrae can be demonstrated clearly after injection, in decalcified sections submitted to X-ray examination.

THE ARTERIES OF THE VERTEBRAL BODY

The arteries supplying the body of the growing vertebra are distributed in a similar manner to those seen in a growing long bone (Morgan, 1959), with the difference that more than one nutrient artery always enters the centrum (Pl. 2, fig. 4). Likewise, while the epiphyseal plates remain open there is no anastomosis between metaphyseal loops and the arteries of the epiphyses (Pl. 2, fig. 5, 6).

THE EPIPHYSEAL BRANCHES

The vertebral bodies are penetrated by arteries on their spinal and ventro-lateral aspects. The origins of the extraspinal epiphyseal arteries have been described above (Pl. 2, fig. 2)

These vessels penetrate the ventro-lateral aspects of the vertebral body. They course centrally in the transverse plane, breaking up into many small branches as they proceed (Pl. 2, fig. 7). The contributing branches of arteries supplying the epiphysis from its spinal and extraspinal surfaces anastomose with each other (Pl. 2, fig. 8).

The intraspinal epiphyseal arteries spring directly from the arterial arcades found on the dorsal surfaces of the vertebral bodies (Pl. 2, fig. 9). These arcades will be described in more detail below.

Within the growing epiphysis there is a complex pattern of distribution of the main arteries. Adjacent to the disc surface, beneath the thin cartilage end-plate of the vertebra, there is a densely woven arteriolar network (Pl. 2, fig. 5). On the growth plate side of the epiphysis, there are numerous fine arteriolar branches given off from the parent stems of the epiphyseal arteries. However, the concentration of arterial loops over this area is much lower than that beneath the end plate or at the metaphyseal side of the epiphyseal plate (Pl. 2, fig. 5).

When the growth plates of the vertebral body close, the concentration of arterial loops in the metaphyseal zone falls and loosely knit anastomoses are established between the arteries of the two regions (Pl. 2, fig. 10).

THE ARTERIES OF THE CENTRUM

(a) *Extra-spinal branches*

The pattern of distribution of the arterial supply to the centrum is essentially the same in typical vertebrae from the lumbar, thoracic and cervical regions of the spine in dogs of all ages and of differing breeds. Assessed on the calibre of the injected vessels, the main contribution appears to come from arteries entering the ventral surface of the vertebrae, in most cases (Pl. 2, figs. 6, 10; Pl. 3, fig. 11), but occasionally the main vessel enters the centrum from behind (Pl. 3, fig. 12). Irrespective of the site of origin of this main parent trunk, once it has entered the centrum it breaks up into a tree-like pattern, its branches spreading out in all directions. In longitudinal sections, these vessels can be seen passing out towards the metaphyseal ends of the vertebral bodies (Pl. 2, fig. 10). The three-dimensional perspective of this arterial pattern is completed by examining horizontal and transverse sections taken through the centre of vertebral bodies (Pl. 2, fig. 4; Pl. 3, fig. 13). It will be noted that the main arterial supply to the centrum runs into the vertebra along the basivertebral canals (Pl. 3, fig. 11).

(b) *Intraspinal branches*

At the level of the intervertebral foramina, the lumbar and intercostal arteries and the vertebral arteries in the cervical spine, all give off a small branch which enters the spinal canal and further subdivides. One branch breaks up to supply the nerve roots and spinal cord.

Another passes dorsally, dividing into a variable number of branches, which enter the pedicles and laminae, being distributed within the bone to the various elements which make up the neural arch (Pl. 3, figs. 14, 15). A small main vessel passes into each separate element and runs a straight course towards its termination. For example, a main stem artery runs from the centre of the pedicle across the lamina and up into the corresponding zygapophyseal process. Small branches are given off from each side of it along its whole course (Pl. 3, fig. 14).

The spinous process contains a similar vessel running centrally within it. Each of these arterial branches is closely related to a venous channel (Pl. 3, fig. 16).

The anastomoses within the bone, between these vessels from within the spinal canal and those from outside it are shown in Pl. 2, fig. 4.

The third of these main branches entering the spinal canal at the intervertebral foramen courses on to the dorsal surface of the vertebral body, and joining with branches from foramina above and below, helps to form arterial arcades on each side. These vessels are arranged in arcs converging on the centre of the vertebral body from each side. They mirror the pattern of the longitudinal vertebral venous sinuses which actually overlie them (Pl. 2, fig. 9; Pl. 3, fig. 17). From these arcs, branches pass into the transverse processes and the bases of the pedicles laterally, into the epiphyseal zones and via the basivertebral canals, into the centres of the bodies of the vertebrae. Delicate branches spring from the convexities of adjacent arcs in the regions of the intervertebral discs. These contribute to the rich anastomosis between the intraspinal arteries which supply the vertebral bodies. Fine irregularly arranged branches also form a network around the longitudinal vertebral venous sinuses. These minute vessels are destined to supply the soft tissues around the spinal theca. They will not be considered in any further detail.

With advancing age, the contribution of the intraspinal arteries to the blood supply of the vertebral body in the dog appears to diminish. The calibre of these vessels is certainly very small compared with the size of those which enter from the ventral aspects of the vertebral bodies. This difference is seen when Pl. 2, fig. 10, and Pl. 3, fig. 11, are compared.

THE VENOUS DRAINAGE

(*a*) *The longitudinal vertebral venous sinuses*

The venous drainage of the dog's vertebra centres around the longitudinal vertebral venous sinuses, which lie on the dorsal aspects of the vertebral bodies. These are vessels of large calibre (2–4 mm. in diameter), arranged segmentally in arcs, the right and left convexities of which approach each other in the mid-line of each vertebral segment (Pl. 3, fig. 17). Worthman (1956) has described their extravertebral connexions in considerable detail. The present study confirms the findings recorded in his papers, but provides more information on the intraosseous distribution of the vertebral veins.

At each intervertebral foramen, where one arch joins the next in the arcade, intervertebral veins connect the sinus of the side with veins outside the vertebral canal (Pl. 3, figs. 17, 18). The course taken by veins draining the spinal cord and theca will not be considered in this paper.

Worthman (1956) stated that there were connexions between the convexities of the right and left sinuses in the middle of each vertebra, in close relation to the dorsal longitudinal ligament. Basivertebral veins make connexions between these anastomoses and extravertebral veins on the ventral surfaces of the vertebrae.

(*b*) *Basivertebral veins*

In the present series of vertebrae, the basivertebral veins frequently joined the dorsal longitudinal sinuses directly. However, deeper within the vertebral bodies, the basivertebral veins, if they were paired, always anastomosed with each other (Pl. 3, fig. 19; Pl. 4, fig. 20). In the case of the single basivertebral vein, Worthman's description always applied, with the exception that the single basivertebral vein sometimes divided into two branches just before emerging from the ventral aspect of the vertebral body (Pl. 4, fig. 21).

(*c*) *The veins of the centrum*

The tributaries of the basivertebral vein within the centrum were arranged predominantly at right angles to its main axis. This is clearly shown in longitudinal sections (Pl. 4, figs. 22, 23). The arrangements are shown to be somewhat more complex than this when specimens are viewed in horizontal sections (Pl. 4, figs. 24, 25). It is apparent then, that the basivertebral vein is the centre of a rosette, but its largest branches are still directed in the long axis of the vertebra. These branches appear to originate within a short distance of the metaphyseal zones of the vertebra, from whence they course centrally towards the basivertebral vein or veins. It is evident, therefore, that the venous drainage of the centrum follows a regular basic pattern, but it is subject to minor variations, depending on the arrangements of the basivertebral veins (Pl. 3, fig. 19; Pl. 4, figs. 20, 21).

(*d*) *The epiphyseal veins*

There was one constant feature noted in vertebrae from any region of the vertebral column, both in growing and adult dogs, of different breeds. This was the striking pattern of the veins draining the epiphyseal zones of the vertebrae. Fine arborizing veins, which were bilaterally symmetrical, drained by slender stems directly into the longitudinal vertebral venous sinuses. These veins appeared to have no connexion with extravertebral veins (Pl. 3, fig. 18, Pl. 4, figs. 22, 26). This same basic pattern was seen in the vertebrae of an 8-week-old dog examined in this series. The accompanying illustration shows the outline of the main epiphyseal veins, behind which the brush-like pattern of the veins draining the centrum is seen (Pl. 4, fig. 27). In contrast to the findings in the adult dogs, many fine veins are arranged radially around the outside of the epiphysis, draining directly into extravertebral veins.

(*e*) *The neural element veins*

The various features of the venous drainage of the neural elements of the vertebrae and of the transverse processes are illustrated in Pl. 3, fig. 18; Pl. 4, figs. 21, 22, 24 and 28. The spinous processes are drained by a large vein which traverses the length of the process, lying within the bone adjacent to its cranial edge. It is intimately related to the accompanying artery (Pl. 3, fig. 16; Pl. 5, fig. 29). The tributaries which join this main channel at varying levels along its length are connected across the periosteum with extravertebral veins in the surrounding soft tissues.

On reaching the lamina this central spinous vein bifurcates (Pl. 4, fig. 21, 28), crosses the lamina and enters the pedicle. In the pedicle, veins from the transverse processes and from the neural elements finally come together. A short pedicle vein is thus formed, running parallel to the dorsal surface of the vertebral body in the base of the pedicle. It finally emerges from each end of the pedicle at the intervertebral foramina bounded by it, to join the confluence of intraspinal and extraspinal veins.

In addition, a few small venous radicles emerge from the spinal surfaces of the laminae and drain into veins around the spinal theca. These are inconstant.

In the vertebrae of the 8-week-old puppy examined, there was another significant deviation from the findings on the venous drainage of the vertebrae in the adult dogs; that concerned the tributaries of the larger calibre vessels such as the basivertebral veins. These tributaties were of extremely fine calibre and their concentration in a given area was high. In the radiographs, the outlines of the main vessels are shown lying in a more or less homogeneous grey background, made up of these numerous delicate venous channels. The orientation of these tributaries is identical with the much larger analogues in the adult. It will be noted in Pl. 5, fig. 30, for example, that the centrum veins course towards the basivertebral vein and enter it at right angles.

DISCUSSION

During the preparatory planning of an experimental investigation on the dog's vertebral column it was found that the detailed information on the anatomy of the arterial supply and venous drainage of the spine was deficient. Standard veterinary anatomical texts provided descriptions only of the larger vessels related to vertebrae. Likewise, a thorough search of the literature published on the anatomy of the dog confirmed the fact that there was a hiatus in the knowledge of intraosseous vessel patterns in vertebrae.

This study was designed to fill the hiatus so that the details it provided, taken with information already available, would permit one to have an integrated and more complete knowledge of this anatomy.

Certain points have emerged from this work which have a potential practical importance for those interested in experimental surgery on the dog's vertebral column.

Definitive patterns of the arterial supply and venous drainage of the dog's vertebrae were present soon after birth. During the period of growth there were only two significant differences in intraosseous vessel patterns from the findings in adult dogs. The first concerned the arterial arrangements in relation to the epiphyses of the vertebral bodies. Attention was drawn to the complete absence of anastomoses between epiphyseal and metaphyseal vessels in the vertebral bodies of growing dogs. In recent years, following the work of Rubaschewa & Priwes (1932) and Trueta (1957), such findings have come to be recognized as the normal arterial patterns adjacent to all growth plates. The same findings have been recorded in the vertebral bodies of growing rabbits (Amato & Bombelli, 1959).

The second point of difference between the young and adult dogs concerned the over-all concentration of fine branches of both arteries and veins. Although the basic definitive patterns of main branches were present in very young dogs and remained constant throughout adult life, the concentration of fine branches of the arteries and of the tributaries of major veins was far higher in the young dogs. Throughout the growth period there appeared to be a gradual decrease in the number of branches of the vascular trees until the final adult patterns emerged after fusion of the epiphyses of the vertebral bodies.

For reasons already mentioned in this paper it would seem important to draw particular attention to the distribution of the lumbar arteries. Although these vessels are of large calibre only small branches pass from them into the lumbar vertebrae. This is almost certainly true in the case of the human lumbar vertebrae too, yet the possibility that such is the case does not appear to be widely appreciated (Prignacchi, 1956).

In the dog, it appears that the neural elements of a particular lumbar vertebra receive their arterial supply from branches of two lumbar arteries on each side. The blood supply of the vertebral body contrasts markedly with this finding. The ventral aspect of an individual lumbar vertebra is penetrated by a small series of branches derived solely from the two lumbar arteries which cross it. The dorsal surface of the vertebral body is supplied with branches derived from an arterial arcade with rather extensive cranial and caudal anastomoses. Despite these anastomoses, which have been illustrated in this paper (Pl. 2, fig. 9) the calibres of the branches entering the dorsal aspects of the vertebral bodies have been shown to be smaller than those of corresponding branches which enter from the ventral surface of the vertebral body. This applies only to the adult dog. It may well be, therefore, that in the adult dog the neural elements of the lumbar vertebrae have a richer arterial supply than the vertebral bodies. This finding has been of great interest to us because of its possible implications in relation to the study of spinal fusion techniques in the dog.

Finally, the arrangements of the epiphyseal veins have been studied in considerable detail in this paper. We have been unable to find any published work which shows similar radiographs of these veins.

SUMMARY

1. The intraosseous blood supply of typical cervical, thoracic and lumbar vertebrae from dogs has been studied. Specimens were obtained from fifteen animals of varying ages and different breeds.

2. The techniques of radiography and clearing of some specimens (Spalteholz), following the injection of a barium sulphate suspension (Micropaque) alone or mixed with 10% Berlin Blue, have provided detailed information of the vessel patterns within the vertebrae.

3. Findings recorded supplement the available published accounts of the anatomy of the arterial supply and venous drainage of the dog's vertebrae.

I wish to thank Prof. J. Trueta for granting me the facilities to carry out this work and for his constant encouragement. I am indebted to Prof. E. C. Amoroso, F.R.S., for the most useful suggestions he made during the preparation of this paper.

My veterinary colleagues, Mr L. C. Vaughan of the University of London and Mr Heather of Oxford, gave me invaluable assistance in obtaining the animals used in this study. Mr D. W. Charles helped at every stage in the preparation of the specimens and produced the illustrations. Miss M. Litchfield prepared the histological sections. I am most grateful to all of them.

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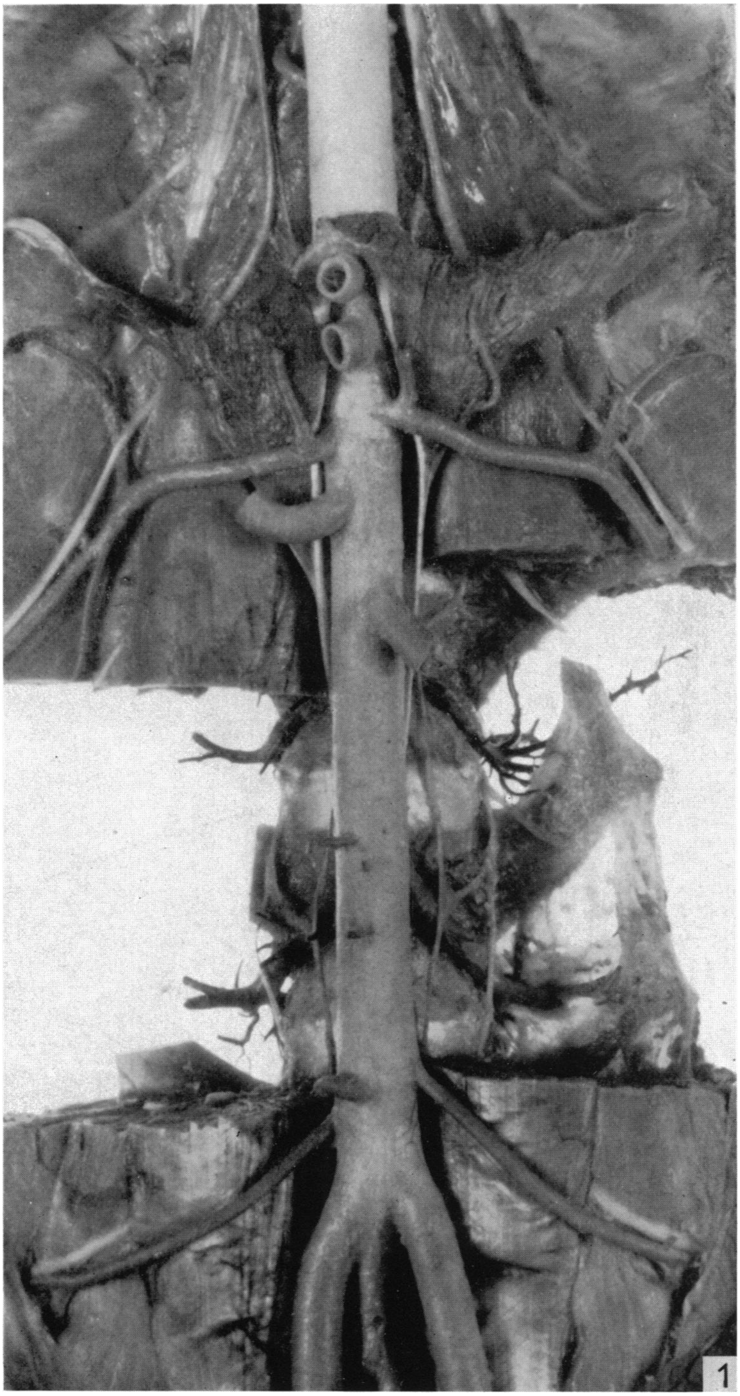

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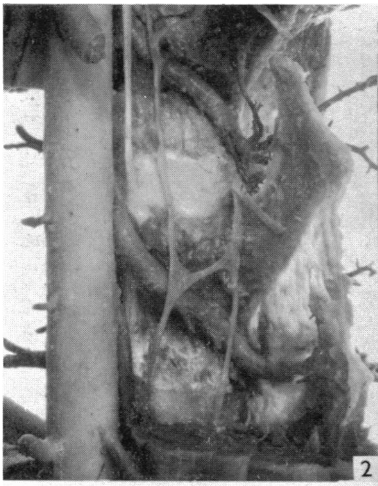

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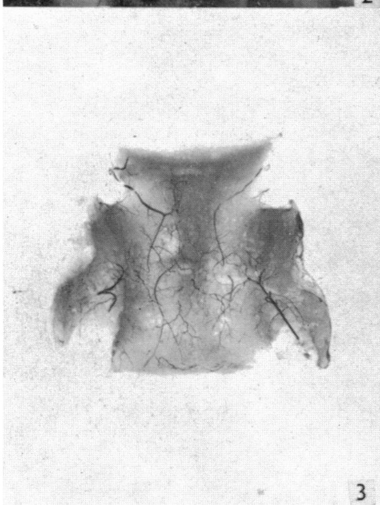

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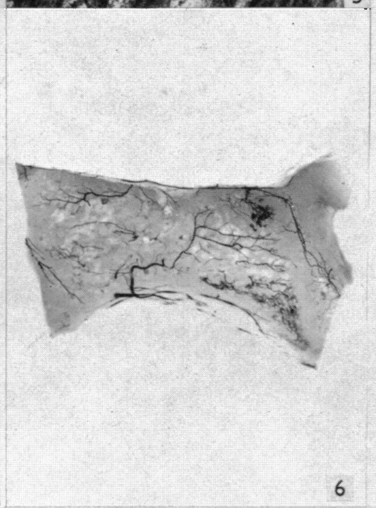

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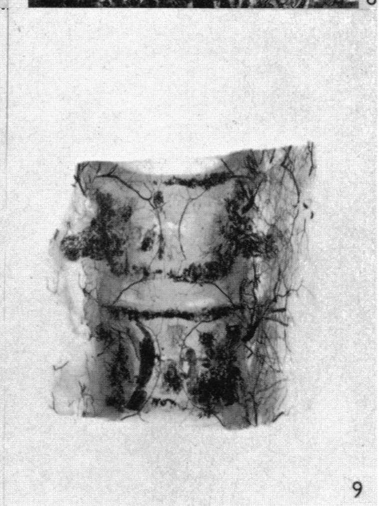

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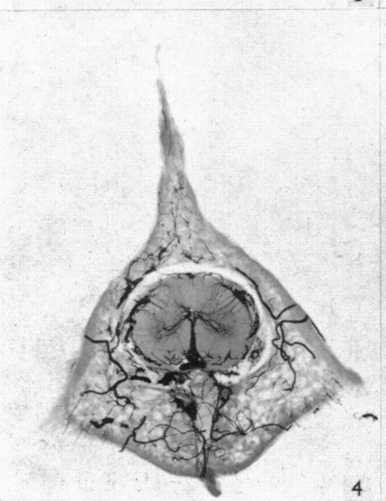

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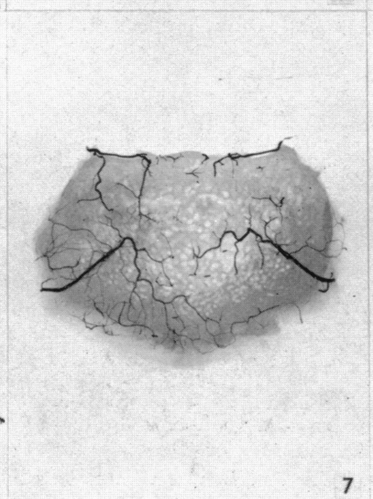

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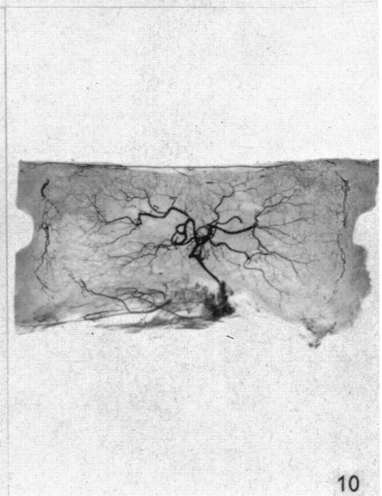

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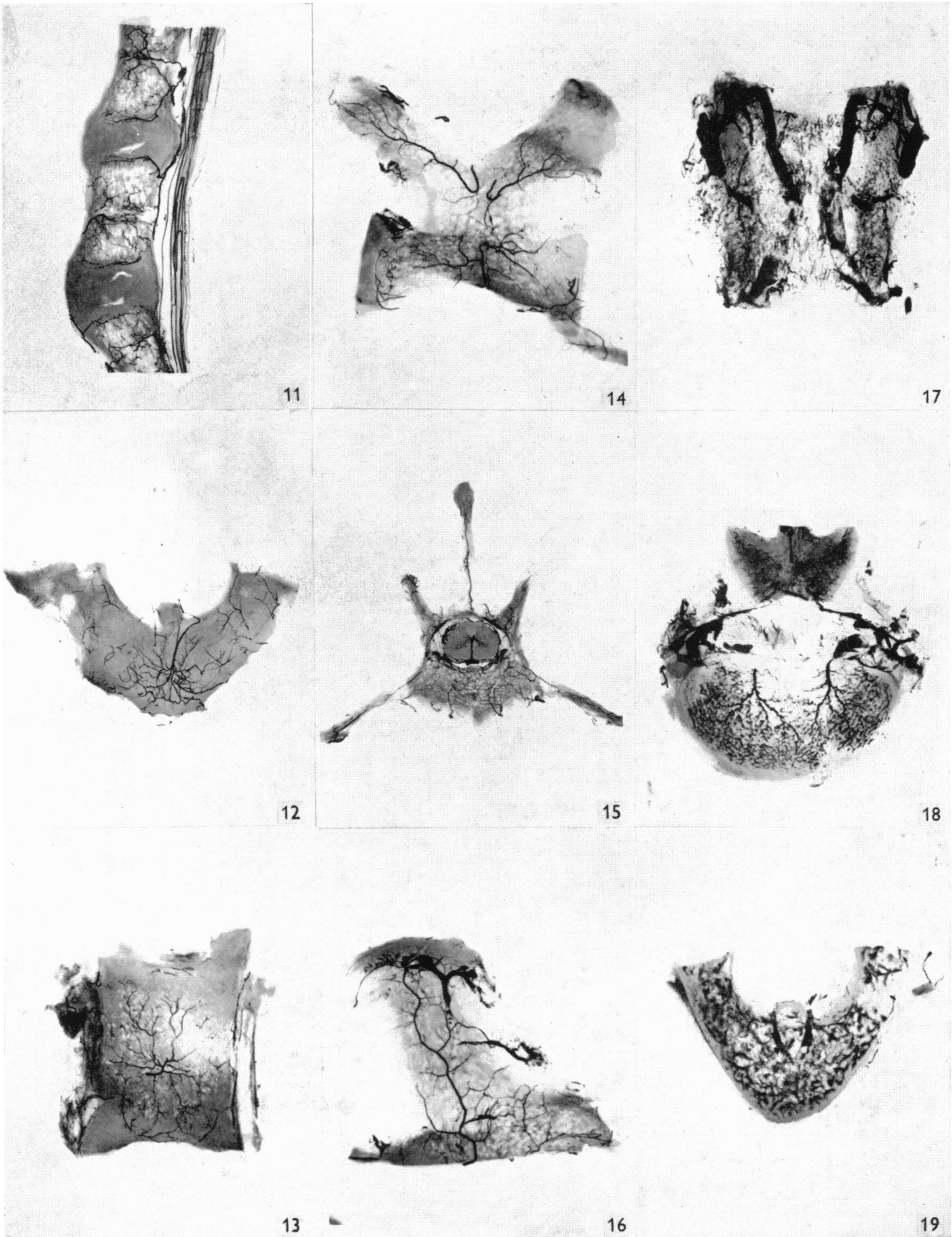

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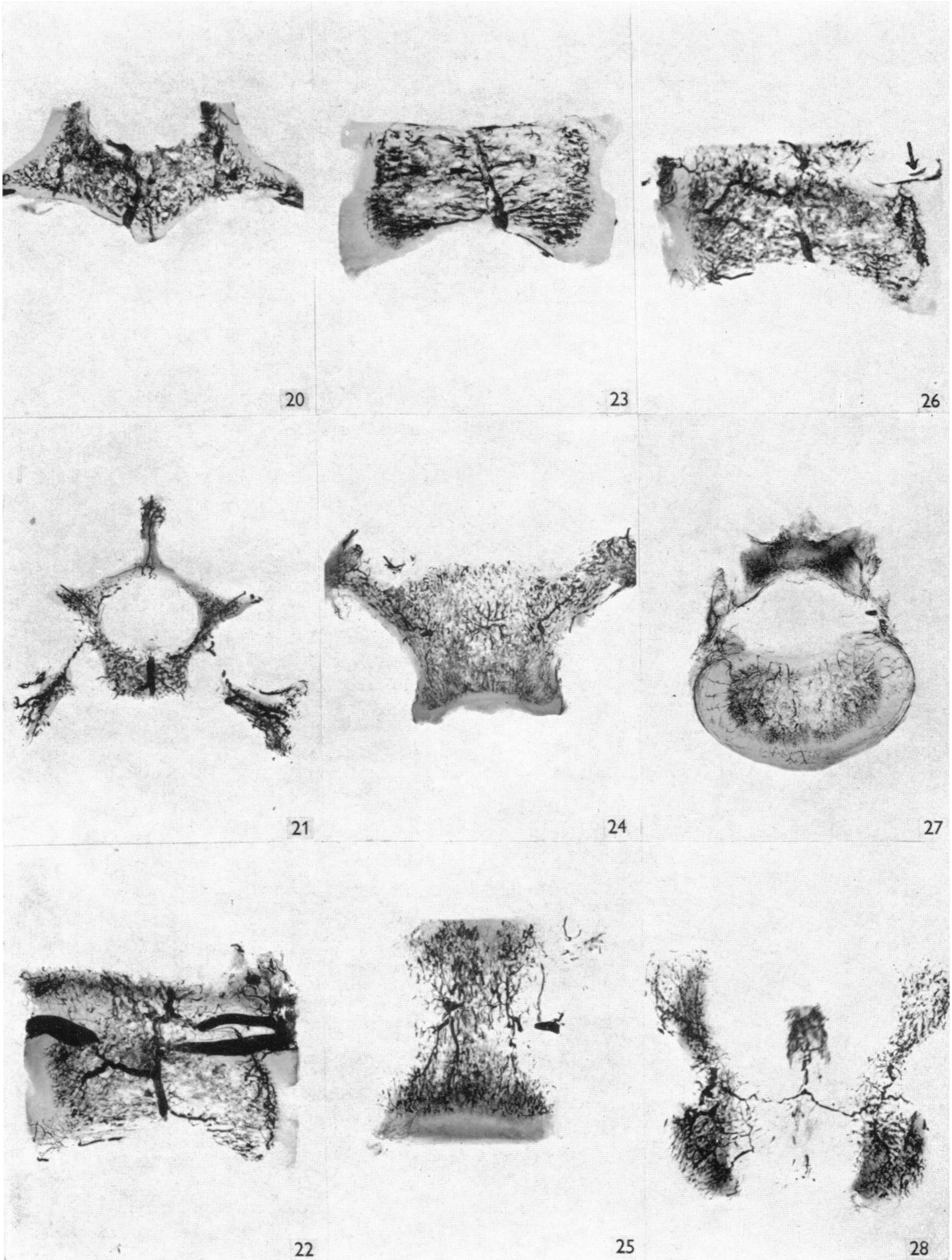

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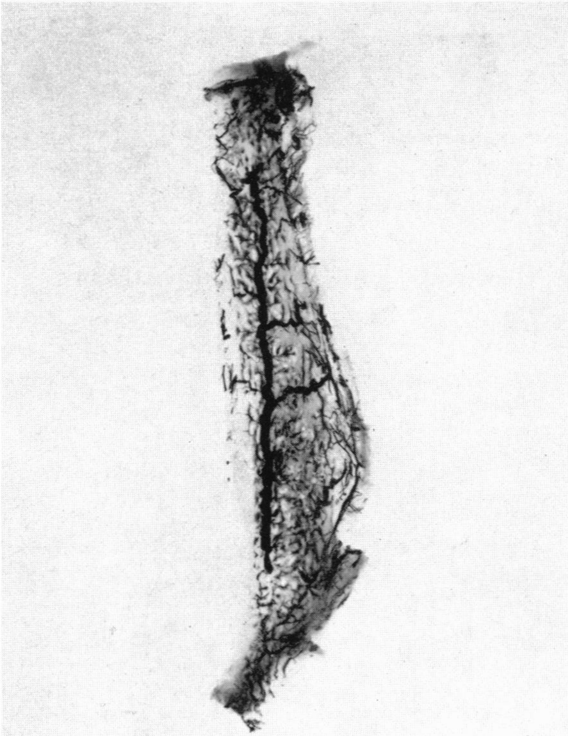

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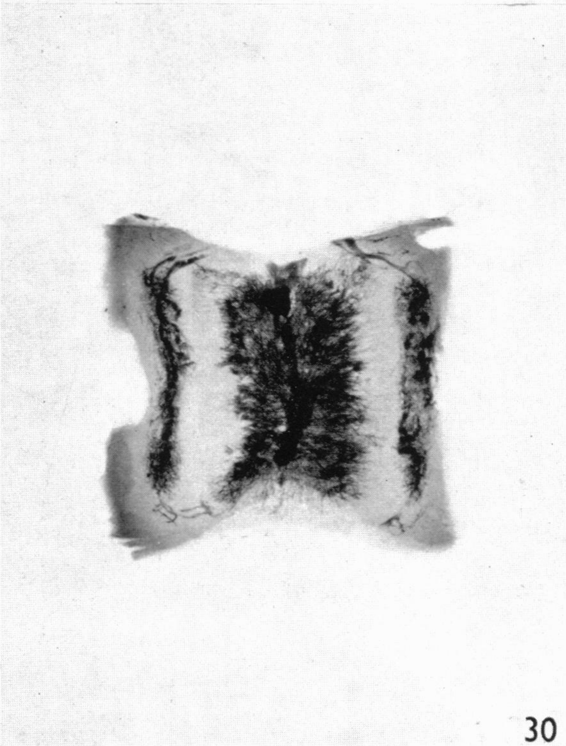

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EXPLANATION OF PLATES

PLATE 1

Fig. 1. A dissection of the dorsal abdominal wall. Greyhound, aged 4 years. The aorta and its branches have been injected with red latex rubber before dissection. The relationship of the aorta and some of its main branches to the lumbar spine is shown. On the left side of the specimen above the diaphragm, one intercostal artery is seen. Lower down, the transverse process of the fourth lumbar vertebra has been cut away.

PLATE 2

Fig. 2. A detailed oblique view of the specimen illustrated in Pl. 1, fig. 1. The tendon of the diaphragm is seen attached to a tubercle on the upper border of L.V. 4. The third, fourth and fifth lumbar arteries are shown. Note the two small branches arising from the lower border of the fourth lumbar artery. These vessels penetrated the vertebral body just cranial to the disc shown, to enter the epiphyseal zone. These are referred to in the text as extraspinal epiphyseal arteries. This fourth lumbar artery is shown penetrating the intertransverse aponeurosis. The fifth lumbar artery is seen arising opposite the middle of the body of the fourth vertebra. It is running parallel to the aorta.

Fig. 3. (Key C 3.3.) Cervical vertebral body seen from the ventral aspect. Young dog. The course of the branches derived from the vertebral arteries on each side is shown in the upper part of the radiograph. These wind around the ventro-lateral aspects of the body to gain its ventral surface. Branches to the epiphysis are shown on the upper left-hand side. The stem of the artery to the centrum is seen in the centre of the specimen.

Fig. 4. (Key A 1.2.) Lumbar vertebra, viewed from cranial aspect. Dog, aged 6 years. Branches of the intraspinal arteries to the pedicles and laminae are shown. Note the anastomoses with extraspinal branches derived from the vessels which supply predominantly the sacrospinalis muscles. Arteries to the centrum are also seen in the basivertebral canal.

Fig. 5. High power view from fig. 8. The clear area in the top right-hand corner of the illustration is the intervertebral disc (arrow). Note the distribution of branches adjacent to the disc on one side and the growth plate on the other. Metaphyseal loops are seen adjacent to the giant cell layers of the growth plate.

Fig. 6. (Key B 2.2.) Cervical vertebral body seen from the side. The neural arch has been discarded. Mongrel dog, aged 6 months. Note the distribution of metaphyseal and epiphyseal arteries on the right side of the specimen. There is no anastomosis between these vessels across the growth plate.

Fig. 7. (Key A 1.0.) Lumbar vertebra viewed from cranial aspect. Dog, aged 5 years. The neural elements have been removed from the specimen. The course of the ventro-lateral extraspinal epiphyseal arteries is shown. The vessels in this specimen are not well filled, so that anastomoses are not shown.

Fig. 8. Low-power photomicrograph of lumbar intervertebral disc and adjacent vertebral bodies. Mongrel dog aged 6 months. The ventral surface of the disc is on the right of the picture. The specimen was injected with a mixture of equal parts of Micropaque and 10 % Berlin Blue solution. The section was unstained (400 μ, thick). In the upper epiphysis an extraspinal epiphyseal artery is shown and an intraspinal epiphyseal artery is seen entering the lower epiphysis.

Fig. 9. (Key C 3.1.) The dorsal surfaces of two lumbar vertebrae are shown. Puppy. The origins of the spinal arterial arcades are shown, particularly on the right side of the specimen. The close relations' ip between these arteries and the arcs formed by the longitudinal vertebral venous sinuses is shown, over the lower vertebra, where these veins appear partly filled. The

delicate branches of the arteries seen crossing the intervertebral disc contribute to the rich anastomosis between the intraspinal arteries supplying the vertebral bodies

Fig. 10. (Key B 2.1.) Lumbar vertebral body viewed from side. Dog, aged 6 years. The tree-like pattern of the centrum artery is shown. Note the fine contribution of intra-spinal arteries to this system. The loosely knit anastomoses between epiphyseal and centrum arteries are clearly shown.

PLATE 3

Fig. 11. (Key B 2.2.) The sixth and seventh lumbar vertebrae and the first sacral segment are viewed from the side. Young dog. The contributions of intraspinal and extraspinal arteries to the supply of the centrum are shown. In the seventh lumbar vertebra the main vessel to the centrum is seen running in the basivertebral canal. Intraspinal epiphyseal arteries are seen in relation to the uppermost intervertebral disc in the illustration.

Fig. 12. (Key A 1.3.) Thoracic vertebral body viewed from cranial aspect. The neural elements have been removed. Adult dog. This illustrates the centrum artery pattern where the main parent vessel has an intraspinal origin.

Fig. 13. (Key C 3.2.) From the same specimen as illustrated in Pl. 2, fig. 3. This shows the tree-like pattern of distribution of the artery to the centrum. Note the epiphyseal arteries arising directly from the vertebral arteries in the lower part of the specimen.

Fig. 14. (Key B 2.0.) Lumbar vertebra viewed from the side. Adult dog. In the upper half of the illustration intraspinal arteries are shown entering the pedicle and coursing outwards in the lamina to the region of the zygapophyseal joints. The arteries to the epiphyses and the centrum, derived from extraspinal sources, are shown in the lower half.

Fig. 15. (Key A 1.4.) Lumbar vertebra viewed from cranial aspect. Adult dog. The straight course of arteries within the transverse processes, spinous process and laminae are shown. Extraspinal arteries to the epiphyseal zone are also shown.

Fig. 16. The central artery of a lumbar spinous process is shown. Note its relation to the partly filled vein lying on its right side in the upper part of the picture.

Fig. 17. (Key C 3.1.) Lumbar vertebra viewed from behind. Dog, aged 4 years. The arcs of the longitudinal vertebral venous sinuses are shown. Towards the centre these veins are filled incompletely. The extravertebral veins are seen in the upper right and left corners of the radiograph. On the right side, the connexions of the pedicle vein are shown.

Fig. 18. (Key A 1.0.) Lumbar vertebra viewed from cranial aspect. Dog, aged 12 years. The delicate arborizing, bilaterally symmetrical veins drain by single stems into the longitudinal vertebral venous sinuses on each side. The connexions of veins draining the lamina and zygapophyseal joint areas are shown where there is a rich anastomosis between extravertebral and spinal canal veins.

Fig. 19. (Key A 1.2.) Thoracic vertebra viewed from cranial aspect. Dog, aged 6 years. Bilateral basivertebral veins are shown converging in the centre of the vertebral body.

PLATE 4

Fig. 20. (Key A 1.2.) Lumbar vertebra viewed from cranial aspect. Dog, aged 4 years. This shows the union of bilateral basivertebral veins in the centre of the vertebra—with the emergence of a large left-sided, and a smaller right-sided branch on the ventral surface of the vertebral body.

Fig. 21. (Key A 1.2.) Cervical vertebra viewed from cranial aspect. Dog, aged 12 years. The single basivertebral vein is shown, bifurcating just before emerging from the ventral aspect of the vertebral body. The passage of veins from the transverse process and neural elements towards the pedicles is shown.

Fig. 22. (Key B 2.0.) Lumbar vertebra viewed from the lateral aspect. The base of the pedicle has been cut across and the vertebral body is shown alone. Dog, aged 12 years. The thick vein seen in the upper right segment of the specimen is running in the pedicle. It joins the longitudinal vertebral venous sinus which is running below and parallel to it, in the region of the intervertebral foramen. The longitudinal vertebral venous sinus appears as a broken heavy line in the illustration. The basivertebral vein connects it with the extravertebral veins, on the ventral surface of the vertebra. Veins from the centrum drain into the basivertebral vein, joining it at right angles. The vein draining the 'epiphyseal' zone of the vertebral body is seen in profile, adjacent to the disc on the right side of the specimen. Note the single stem passing directly into the longitudinal vertebral venous sinus.

Fig. 23. (Key B 2.1.) Another section from the specimen illustrated in fig. 22. The pattern of veins draining the centrum is clearly shown. They enter the basivertebral vein at right angles.

Fig. 24. (Key C 3.2.) Lumbar vertebra viewed from behind. Dog, aged 4 years. The rosette appearance made by the veins draining into the basivertebral vein is shown. Note the main stems of the veins draining the transverse processes. These join the pedicle vein already illustrated in figs. 17 and 22.

Fig. 25. (Key C 3.3.) Lumbar vertebra viewed from behind. Dog, aged 4 years. This shows the rosette pattern of veins draining the centrum. The larger branches enter the bilateral basivertebral veins at right angles.

Fig. 26. (Key B 2.4.) Another section from the same specimen as illustrated in figs. 22 and 23. The outline of the partly filled longitudinal vertebral venous sinus is shown in the upper right hand corner of the photograph, marked with an arrow. The 'epiphyseal' vein is shown entering it.

Fig. 27. (Key A 1.5.) Lumbar vertebra viewed from cranial aspect. Puppy. The grey halo within the vertebral body is made up by the fine veins draining the centrum; they form a background against which the epiphyseal veins are seen. The adult pattern can be made out with some difficulty. Note the many fine branches which are disposed radially around the vertebral body, draining directly into extravertebral veins.

Fig. 28. (Key C 3.0.) Cervical vertebra seen from behind. Adult dog. The vein draining the spinous process is shown bifurcating where the process joins the lamina. Note the confluence of these diverging branches with veins in the pedicles.

Plate 5

Fig. 29. Thoracic spinous process. Dog, aged 4 years. The venous drainage of the spinous process is shown. Note the number of anastomoses between fine branches of this central vein and veins in the periosteum and surrounding tissues.

Fig. 30. (Key B 2.2.) Lumbar vertebral body alone, seen from the side. Puppy. The basivertebral vein is shown in the centre of the specimen. Note the delicacy and concentration of the branches draining into it from the centrum. The course of the epiphyseal veins towards the spinal veins is shown; the latter are not shown in the radiograph.