OBSERVATIONS ON THE VENOUS DRAINAGE OF THE HUMAN VERTEBRAL BODY

H. V. CROCK, H. YOSHIZAWA, MELBOURNE, AUSTRALIA, and
S. K. KAME, NEW DELHI, INDIA

From St Vincent's Hospital, Melbourne

There has been an upsurge of interest in dynamic studies of the spinal circulation during the past ten years, with the clinical applications of selective intercostal angiography and intraosseous vertebral phlebography (Doppman, Di Chiro and Ommaya 1969; Houdart, Djindjian and Hurth 1969; Vogelsang 1970). In clinical practice these investigations have been used to depict mechanical obstructions in the vascular systems or angiomatous malformations.

Over the same period there has been a shift of emphasis from the long established view that disorders of the intervertebral discs result purely from mechanical derangements (Nachemson 1969, Crock 1970). It is becoming evident that the intervertebral disc should be viewed more as a dynamic organ in which the homeostatic and pathological processes are intimately linked with its nutritional systems.

We have been struck, therefore, by the necessity for more detailed studies on the anatomy of spinal circulation. To our knowledge there are no comprehensive works on the intraosseous vessels of the vertebral column with particular reference to the venous side of the circulation in the subchondral zones of the vertebral bodies, adjacent to the intervertebral discs.

In this paper we wish to present some of our findings on the anatomy of the intraosseous veins of the vertebral bodies together with new observations on the subchondral venous plexus adjacent to the intervertebral disc. This material has been selected for preliminary publication from more than 100 human spinal columns in which either arteries or veins had been injected after death, in the course of a wider study of the blood supply of the vertebral column and spinal cord.

METHODS

All the specimens presented here have been prepared from injections made at necropsy, using Micropaque,* usually within twelve hours of death.

A metal cannula, 2 millimetres diameter, was tied into the azygos vein just proximal to its point of entry into the superior vena cava. The superior and inferior venae cavae were ligated at heart level. Opening the abdomen was avoided if possible. However, if the abdominal viscera were to be removed before injection, the inferior vena cava was ligated just below the liver. The renal veins were separately ligated. After removal of the rectum, the bladder was opened and filled with liquid nitrogen, as was the pelvis. If there was any vertebral injury above the level of the azygos vein, the vertebral column was divided and one vertebral body removed. Into this defect liquid nitrogen was poured until the whole area was frozen. In effect, we have used liquid nitrogen to snap-freeze the vertebral column in segments, thus establishing a state equivalent to that in the lower limb after the application of a tourniquet before beginning venous injections. The volume of Micropaque used in an adult of average size for this study has varied between 3 and 5 litres delivered for 30 to 60 minutes at 5 to 10 lbf/square inch (35 to 70 kgf/square centimetre or N/square metre). After the injection of Micropaque, the vertebral column was removed complete with attached muscles.

* Micropaque—supplied by Nicholas Pty. Ltd., Melbourne.

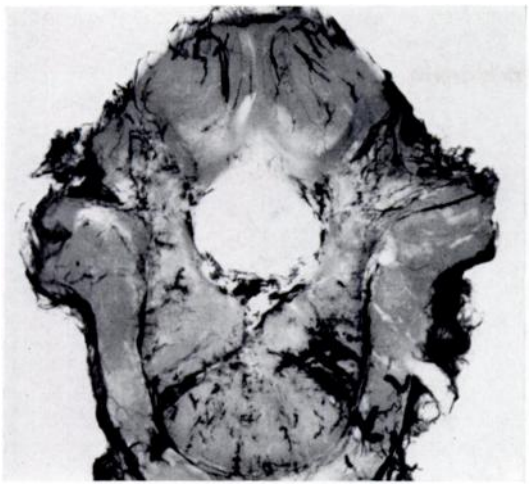

FIG. 1

FIG. 2

Figure 1—A radiograph of a thin transverse section from the centre of a lumbar vertebral body, from a man of 29. The basivertebral veins are partly filled with Micropaque. The radiate pattern of the main branches is shown. Posteriorly the system drains by a single large stem into the anterior internal vertebral venous plexus. Figure 2—A radiograph of a thin coronal section from the central area of a lumbar vertebral body, from a man of 60. On the right side, in the centre of the specimen, part of a radiate segment of the basivertebral vein is seen with vertical tributaries joining it. Note the dimensions and gentle tortuous course of these vessels.

PROCESSING OF SPECIMENS

Specimens were placed in a deep-freezing refrigerator at −40 degrees Celsius for approximately thirty-six hours. Sections of the vertebral columns were then cut in sagittal, coronal and horizontal planes, with an electrically powered industrial meat-cutting band-saw. After fixation in 10 per cent buffered formalin, the specimens were decalcified and cleared by a modified Spalteholz method, excluding the use of benzol.

Finally selected, the specimens were x-rayed with a Softex Type E.S.M., super soft x-ray apparatus, using Agfa-Gevaert graphic film R.O.81, p. Some were photographed by transmitted or reflected light in Spalteholz clearing fluid.

FINDINGS

Traditionally in descriptions of the venous drainage of the vertebral column, attention is focused on the internal and external vertebral venous plexuses and the basivertebral veins. Detailed accounts of the intrinsic veins of the vertebral body are fragmentary, and to our knowledge there are no published accounts of the veins adjacent to the vertebral end-plates.

FIG. 3

A radiograph of a thin coronal section near the central area of a lumbar vertebra, from a man of 60. Note the stellate arrangement of tributaries draining into the central vein of the basivertebral grid system.

THE VEINS OF THE VERTEBRAL BODY

The *basivertebral system of veins* is orientated horizontally in the centrum. It is arranged in the middle of the vertebral body along with the radiate arteries, forming a large-scale venous grid into which the *vertical veins of the vertebral body* flow from above and below. The basivertebral veins converge posteriorly to drain into the anterior internal vertebral

venous plexus, sometimes as a single vein, sometimes as two separate tributaries. Anteriorly they join the external vertebral venous plexuses (Figs. 1 and 2).

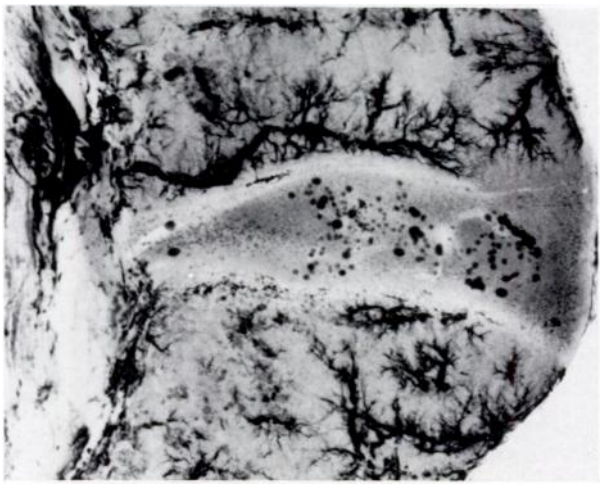

FIG. 4

A radiograph of a thin sagittal section cut laterally near the vertebral pedicle, from a woman of 67. The intervertebral disc is stained with some barium sulphate debris. The *horizontal subarticular collecting vein system* of the vertebral body can be seen running parallel to the vertebral end-plate area. Nearer the disc, of smaller calibre, running parallel to the vertebral end-plate cartilage, the *subchondral post-capillary venous network* can be seen. It is only partly filled. This system drains by vertical stems through perforations in the vertebral end-plate into the larger *horizontal subarticular collecting vein system.* In this specimen only one such stem can be seen joining these two venous systems.

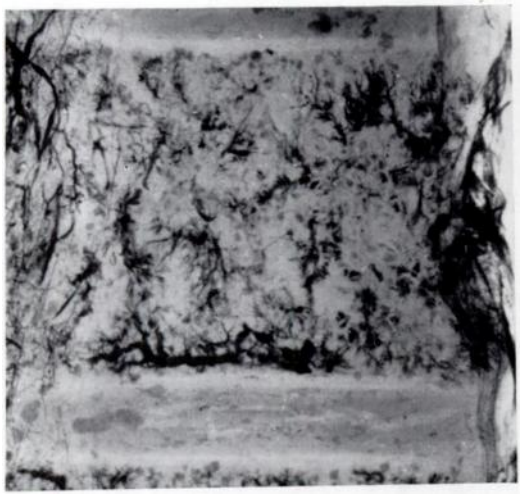

FIG. 5

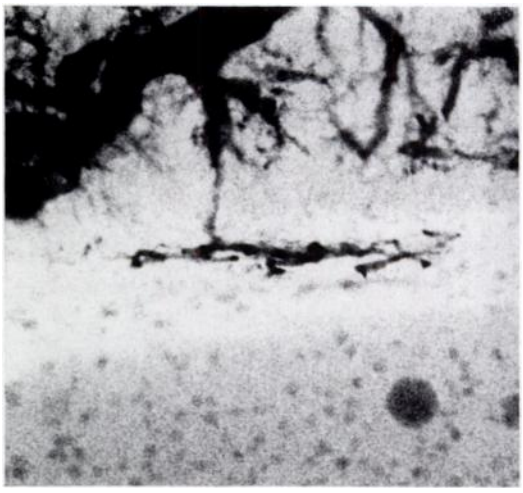

FIG. 6

Figure 5—A radiograph of a thin coronal section from a thoracic vertebra, from a woman of 67. The *horizontal subarticular collecting vein system* can be seen in the central third of the field, adjacent and parallel to the vertebral end-plate area. Figure 6—A detail from the radiograph illustrated in Figure 4, to show the *subchondral post-capillary venous network.*

The main vertical venous channels are of large calibre and run gently tortuous courses. They are formed by the confluence of numbers of equally large branches which enter the

main stems obliquely at regular intervals along their courses and around their circumferences (Fig. 3). Individual branches are themselves formed by the union of innumerable short fine radicles.

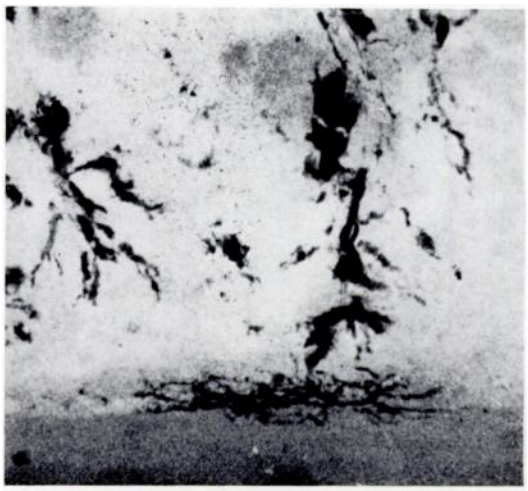

FIG. 7

A radiograph of a thin sagittal section from the centre of a cervical vertebra, from a man of 60, showing a detailed view of the *subchondral post-capillary venous network*. Part of a vertical tributary of the basivertebral vein system is seen in the centre of the field. The horizontal subarticular collecting vein system is not shown in this specimen.

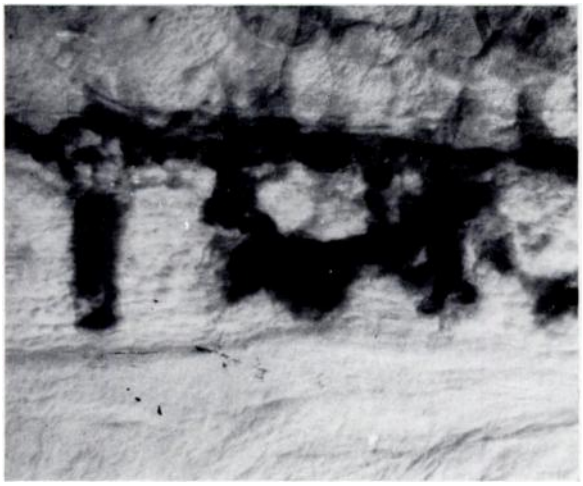

FIG. 8

A photomicrograph taken from the central area of the disc and vertebral body, 500 μ thick, from a woman of 30. Spalteholz cleared specimen, ×80 approximately. The demarcating line between the intervertebral disc and vertebral end-plate cartilage is clearly visible. The disc is at the bottom, the vertebral body is at the top of the illustration. The *vertebral end-plate cartilage capillary bed* is shown, with vertical tributaries draining to the subchondral post-capillary venous network orientated parallel to the vertebral end-plate.

The patterns of intraosseous arteries in the vertebral bodies may be described graphically as resembling the fine branches of a deciduous tree, such as a cherry tree which has shed its

leaves. Intraosseous veins more closely resemble the fibrous root systems of common plants, in which many of the roots are of similar size with clusters of fine radicles called root hairs at their ends.

Beyond describing the macroscopic appearance of the tributaries forming the vertical veins which drain into the basivertebral system we have not concerned ourselves with studies of the capillary beds in the marrow spaces.

In the region of the vertebral body adjacent to the vertebral end-plate, large venous channels are found orientated horizontally running parallel to the end-plate area when viewed in sagittal or coronal sections. This venous system is analogous to the subarticular collecting

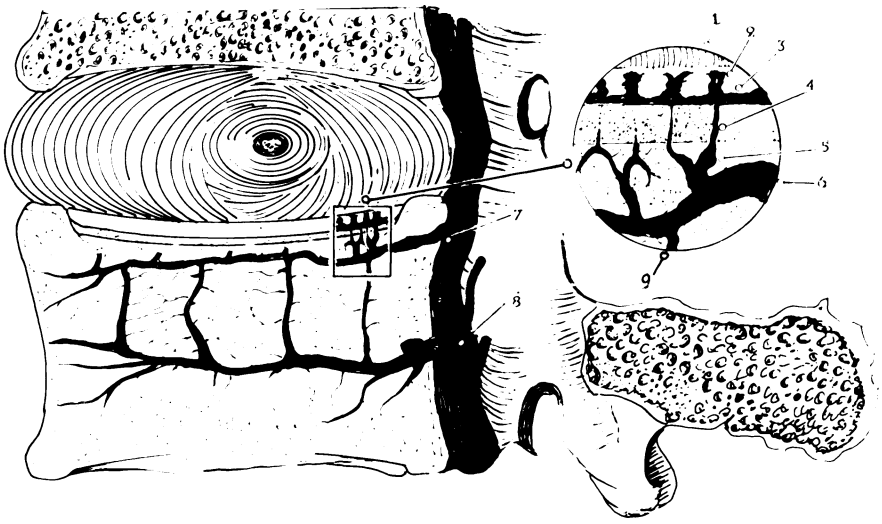

FIG. 9

A schematic drawing to show the spatial relationships of the veins of a typical vertebral body. 1) Intervertebral disc. 2) *Capillary bed* in vertebral end-plate cartilage. 3) *Subchondral post-capillary venous network* on the vertebral end-plate. 4) Vertebral end-plate perforated by short vertical venous tributaries. 5) Vertical tributary from the subchondral post-capillary venous network, draining to the *horizontal subarticular collecting vein.* 6) *Horizontal subarticular collecting vein.* 7) Horizontal subarticular collecting vein joining the *anterior internal vertebral venous plexus.* 8) *Basivertebral vein* joining the anterior internal vertebral venous plexus. 9) Vertical tributary of the basivertebral system of veins.

vein system previously described by one of us (Crock 1962, 1967) in the juxta-articular zones of the bones of the lower limb. In the vertebral body we have described it as the *horizontal subarticular collecting vein system* (Fig. 4).

To understand the anatomy of this system of veins it is necessary to study cleared injected specimens stereoscopically and to examine radiographs in transverse, sagittal and coronal sections. The horizontal subarticular collecting vein system is built up in the central area of the vertebral body by large calibre tributaries of the vertical veins of the centrum, which turn abruptly from their vertical courses to run horizontally, some passing anteriorly, others posteriorly and still others laterally (Figs. 4 and 5). In the posterior part of the vertebral body, some of the tributaries from this horizontally orientated network drain directly into the anterior internal vertebral venous plexus (Fig. 4). Anteriorly and around the circumference of the vertebral body, tributaries of veins draining directly into the extra vertebral venous plexuses also contribute to the formation of the horizontal subarticular collecting vein system (Fig. 4). Properly injected with Micropaque, this system is visible to the naked eye in cleared specimens and it can be seen easily on radiographic films without magnification.

At the vertebral end-plate level we have found another vascular network of smaller calibre, orientated horizontally and parallel to the subarticular collecting vein system. This lies on

the perforated cortical vertebral end-plate, forming what we have named the *subchondral post-capillary venous network* of the vertebral body. Examples of this system are illustrated in Figures 6 and 7, taken from different areas of the vertebral column in adults. Short vertical tributaries from this network drain into the horizontal subarticular collecting vein system, while peripherally some tributaries drain directly into adjacent veins on the surface of the vertebral bodies.

We believe that this subchondral post-capillary venous network receives tributaries at right angles to its plane of orientation from capillaries in the vertebral end-plate cartilage; that is, from the *vertebral-end-plate-cartilage capillary bed* (Figs. 8 and 9).

SUMMARY

1. Because of the importance of nutrition of the intervertebral disc in relation to its disorders, a detailed study has been made of the neighbouring vasculature of the vertebral body.
2. This has been made possible by an injection technique involving prevention of leakage by freezing with liquid nitrogen.
3. By this method capillary beds are found in the vertebral end-plate cartilage in the adult. A very fine subchondral post-capillary venous network has been demonstrated draining by short vertical tributaries to a much coarser horizontal collecting vein system connecting with the familiar basivertebral system.
4. This arrangement may be of special importance in the nutrition of the intervertebral disc.

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REFERENCES

CROCK, H. V. (1962): The Arterial Supply and Venous Drainage of the Bones of the Human Knee Joint. *Anatomical Record*, **144,** 199.

CROCK, H. V. (1967): *The Blood Supply of the Lower Limb Bones in Man.* Edinburgh and London: E. & S. Livingstone Ltd.

CROCK, H. V. (1970): Reappraisal of Intervertebral Disc Lesions. *Medical Journal of Australia*, **1,** 983.

DOPPMAN, J. L., DI CHIRO, G., and OMMAYA, A. K. (1969): *Selective Arteriography of the Spinal Cord.* St Louis, Missouri: Warren H. Green Inc.

HOUDART, R., DJINDJIAN, R., and HURTH, M. (1969): Chirurgie des Angiomes de la Moelle. *Neuro-Chirurgie*, **15,** Supplement 1.

NACHEMSON, A. (1969): Intradiscal Measurements of pH in Patients with Lumbar Rhizopathies. *Acta orthopaedica Scandinavica*, **40,** 23.

VOGELSANG, H. (1970): *Intraosseous Spinal Venography.* Amsterdam: Excerpta Medica.