THE VASCULAR PATTERN AS AN AID TO THE
DIAGNOSIS OF BONE TUMOURS

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The interpretation of the clinical and radiological manifestations of bone tumours may be neither easy nor successful. Biopsy, a procedure not without its hazards, may not always be decisive, for the physical characteristics of bone make microscopy difficult, and sometimes the part of the tumour selected for examination does not represent its true character. Thus

in a recent survey of 517 cases from the Bristol bone tumour register, Walker (1954) found that in fifty-five the diagnosis still remained debatable after careful clinical, radiological, and pathological examination. As weighty decisions have to be made concerning amputation, biopsy, and the best use of surgical and radiation therapy, any attempt to obtain further information seems worth while. A study of the vascular pattern of suspected bone tumours has been found to provide both positive and negative information of value in diagnosis and in planning treatment.

THE NORMAL BLOOD SUPPLY OF BONE

The study of a normal arteriogram of a limb shows that the branches of the main artery follow a slightly curved and undulating course, and that their calibre slowly and
progressively decreases (Fig. 1). None of these vessels is seen to reach the periosteum, nor is the nutrient artery ever visible. Inspection of a long bone from which the periosteum has been removed reveals numerous minute holes along the diaphysis, particularly near the muscular and ligamentous attachments, and some larger holes are found near the epiphyses (Fig. 2). The small foramina transmit tiny periosteal arteries, the larger ones veins. When the periosteum is stripped off the bone at operation, relatively little oozing occurs. These observations might suggest that the blood supply of bone is relatively poor. If, however, a contrast medium is injected directly into the bone it is found that these minute periosteal vessels are capable of dealing with it in a truly remarkable way (Fig. 3). These channels through which the contrast medium leaves the bone are so small that they are invisible radiologically, but so numerous that the deep and superficial veins are flooded with a concentration of opaque material far
greater than that which occurs after it is introduced directly into the venous system (Begg 1954). This rapid dispersion is in no way hampered by thrombosis of the deep veins of the limb (Fig. 4). The capacity of these vessels is well illustrated in the case shown in Figure 5, in which 20 cubic centimetres of 50 per cent diodone were injected into the spinous process of L1 vertebra in four seconds in a patient suffering from thrombosis of the inferior vena cava. A film taken at the end of the injection shows that the medium has already left the vertebra and has reached the heart by way of the paraspinal venous plexus and the azygos vein.

Although most of the medium appears to pass out through the periosteal channels near the site of injection, some passes along the marrow cavity in tortuous communicating vessels which may extend throughout the bone (Fig. 6). In view of this the safety of biopsy seems to be in question, for a tourniquet cannot control the circulation through the bone marrow.

Figure 4 — Radiograph taken at the end of injection of 20 cubic centimetres of 50 per cent diodone into the tibial tuberosity in five seconds, in a case of acute thrombophlebitis of the deep veins of the leg and pelvis. Note rapid dissemination into the superficial thigh veins. No periosteal channels are visible. Figure 5 — Venogram of azygos system, in a case of thrombosis of the inferior vena cava, after injection of the spinous process of the first lumbar vertebra (arrow). Figure 6 — Venogram of the leg showing tortuous vessels throughout the bone marrow in man aged fifty-four years who had suffered from varicose ulceration and eczema for thirty years.
Bone, therefore, appears to behave like a sponge through which a great volume of blood is rapidly circulating. It is supplied by minute periosteal vessels most numerous in the region of the epiphyses. The nutrient artery plays little part in its nourishment and may be regarded as a vestigial structure indicating the situation of the foetal diaphysis and the most avascular region of the adult bone.

METHOD OF EXAMINATION

This is in the main by arteriography. Lesions in most parts of the skeleton may be investigated in this way by selecting the appropriate vessel. It is possible to inject by direct puncture any vessel that can be palpated, and some others such as the aorta, the vertebral and the subclavian arteries by virtue of their good bony landmarks. Arteriography can usually be carried out quickly and easily under local anaesthesia without causing the patient more discomfort than is occasioned by an intravenous pyelogram. Most examinations, therefore, may be carried out as out-patient procedures. Surgical exposure of the vessel should never be necessary.

For lesions of the head and neck the carotid or vertebral arteries are used, for the shoulder girdle or the arms the subclavian artery, and for the forearm the brachial artery. The pelvic bones may be investigated by injecting the abdominal aorta, preferably below the origin of the renal arteries. The thigh is examined by injecting the common femoral artery, either in a proximal or distal direction, or the superficial femoral or profunda femoris artery, according to the region under investigation. The arteries of the leg are usually well demonstrated by injection into the superficial femoral artery, but injection of the dorsalis pedis or posterior tibial arteries may be required to demonstrate the vessels of the foot, especially if oblitative arterial disease is present in the leg.
Figures 8 to 12 relate to the same patient, a man of seventy-four years.

Figure 8—Radiograph of the right elbow showing extensive destructive lesion.

Figures 9 and 10—Brachial arteriogram. Film taken at the end of injection (Fig. 9) shows large arteries feeding the tumour. A film taken two seconds later (Fig. 10) shows the tumour circulation and the drainage by way of large newly formed veins.

Figure 11—Venogram through the lower end of the radius shows the normal arm veins in relation to the tumour.

Figure 12—Section of the lower arm showing the extent of the tumour.
It has been found helpful, and for the shoulder and pelvic girdles essential, to apply a tourniquet immediately distal to the lesion for the short period during which the injection is made (Fig. 7). For this purpose a pneumatic tourniquet of the Conn type has been found suitable, because it is easily applied and released, is relatively comfortable for the patient, and arrests completely the blood flow through the soft tissues at any level in the arm or leg. By this means the smaller arteries are demonstrated, and the flow of the medium is so retarded that rapid serial films become unnecessary. Thirty-five per cent diodone solution has proved sufficient for all arteries except the aorta, where a 70 per cent solution is required. The timing of the exposures is suited to the particular problem in hand. A simple cassette changer which allows three films to be exposed at intervals of two seconds or more is used.

In suspected vascular tumours of the spine or skull direct injection may sometimes reveal the nature of the lesion.

**DISCUSSION AND ILLUSTRATIVE CASE REPORTS**

As in corresponding tumours of the brain and kidney, the blood supply of malignant tumours of bone appears to be increased. This declares itself radiologically by visible arteries to the periosteum and by abnormal vessels feeding the tumour. These vessels no longer decrease in calibre but remain the same size over some distance or increase in diameter and become tortuous. In addition, the rapid circulation through the vascular sinuses of the tumour may be demonstrated, and a general increase in the opacity of the lesion may occur as the contrast medium passes through it.

Some of these characteristic features are illustrated in the case of a man aged seventy-four years. Owing to mental confusion the history was unreliable, but, on examination, a large, hot, tender swelling was found above the right elbow. This pulsed slightly and a bruit could be heard over it. Radiography of the elbow supported the clinical diagnosis of osteosarcoma (Fig. 8). No evidence of Paget's disease was discovered. On injection of the brachial artery with 35 per cent diodone the tremendous vascularity of the lesion became obvious (Fig. 9). Greatly enlarged radial recurrent and supratrochlear arteries were the chief feeding vessels. A film taken two seconds later showed the circulation within the tumour and its venous drainage into the basilic and axillary veins by way of large, newly formed channels (Fig. 10). An increase in the density of the tumour demonstrated its spread into the soft tissues medial to the humerus. A venogram, using the lower end of the radius, showed how the normal veins were displaced but not occluded by the tumour (Fig. 11). Here, then, were two separate circulations of almost equal volume—one to the tumour, the other to the arm. These findings made the diagnosis certain. No treatment was undertaken and the post-mortem examination three weeks later revealed an osteosarcoma arising from the lower end of the humerus (Fig. 12).

It is, however, in cases in which the diagnosis is in doubt, and in which the method of treatment is not clear, that a study of the vascular pattern of suspected bone lesions has been particularly useful. The problems arising in six cases that have recently been investigated will serve as examples.

**Case 1**—Woman aged forty-two years. Nine years previously the patient had sustained a pathological fracture through a cyst in the left radius (Fig. 13) which was successfully treated by a bone graft. Eight years later while combing her hair she first noticed a small, painless swelling on her head. This had possibly increased a little in size since then. A radiograph of the skull (Fig. 14) showed a circumscribed osteolytic lesion in the left parietal bone. Was this another area of dysfibroplasia? In view of her past illness the patient was anxious to know. Direct injection of the lesion under local anaesthesia with 35 per cent diodone showed it to be a cavernous haemangioma (Fig. 15). No immediate treatment therefore was required.

**Case 2**—Woman aged seventy-eight years. This patient developed a small lump in relation to the left mandible. Part was excised by her dentist and reported as a fibroma of the jaw.
The swelling increased in size, and a further biopsy two months later was described as a fibrosarcoma. On admission to hospital a firm, smooth, rounded mass was found in the left thigh, which was thought clinically to be a subfacial lipoma. Radiography showed a deeply placed circumscribed soft-tissue mass adjacent to the normal femoral shaft. Femoral arteriography revealed a large number of tortuous vessels feeding into the lesion (Fig. 16), and two seconds later a brisk tumour circulation (Fig. 17). In view of this primary or secondary malignant tumour no radical treatment was undertaken. When the patient died two months later the leg tumour had doubled its size.

Case 3 Man aged thirty-nine years. Intermittent pain in the left hip had been experienced by this patient for twelve years. Otherwise his health was good until six weeks previously when a tender, painful swelling of the left hip developed, which did not prevent him from carrying on his occupation as a farmer. Plain radiography showed a smooth erosion of the left greater trochanter, with some calcification in the soft tissues nearby (Fig. 18). No evidence of tuberculous disease was seen in the chest or abdomen. Retrograde femoral arteriography with a tourniquet applied in the mid-thigh showed the terminal branches of the lateral femoral circumflex artery stretched around an avascular mass (Fig. 19). No evidence of tumour circulation was seen. This was thought to confirm the diagnosis of a tuberculous bursitis. At operation the trochanter was found to be flattened and a large tuberculous abscess was drained.
Case 2—Femoral arteriogram. Film taken at the end of injection (Fig. 16) shows large number of tortuous vessels feeding into the tumour, and film two seconds later (Fig. 17) shows an increase in the density of the mass as the contrast medium circulates through it.

Case 3. Figure 18—Radiograph of the left hip. Smooth erosion of the greater trochanter and calcification in the soft tissues (arrow). Figure 19—Femoral arteriogram with tourniquet applied to the upper thigh shows displacement of the terminal branches of the lateral femoral circumflex artery.
Case 4. Figure 20—Film of acromion process shows small osteolytic areas and a rounded soft-tissue swelling. Figure 21—Subclavian arteriogram with tourniquet applied to the upper arm shows slightly enlarged branch of the posterior circumflex humeral artery (arrows) feeding into the lesion.

Case 5. Figure 22—Radiograph of the left knee showing erosion of the upper portion of the fibular head and osteolytic lesions in the shaft. Figure 23—Superficial femoral arteriography with a tourniquet applied to the upper third of the leg shows no abnormality of the vascular pattern. This film taken fifteen seconds after the injection shows how the contrast medium is retarded by the tourniquet with good visualisation of the smaller vessels. Figure 24—Section of surgical specimen shows cystic spaces and fibrosis in the upper three inches of the fibula.
Case 4—Woman aged thirty-three years. Seven years previously excision of a lump above the right elbow revealed a lymphosarcoma. Recurrences in various places always responded rapidly to deep x-ray treatment. The patient was well until two weeks before when she suddenly complained of severe pain over the left acromion process. This was thought to be due to bursitis. Plain radiography showed small areas of rarefaction in the tip of the acromion beneath a small, smooth, soft-tissue swelling (Fig. 20). Were the changes in the bone secondary to the overlying inflammation, or was the soft-tissue swelling secondary to lymphosarcomatous deposits in the acromion? Injection of the subclavian artery with a tourniquet applied to the upper arm showed that one of the terminal branches of the posterior circumflex humeral artery maintained and even increased its calibre slightly as it neared the acromion (Fig. 21). This was taken to indicate that the lesion was a secondary lymphosarcomatous deposit. Symptoms, and the tumour, rapidly disappeared with deep x-ray treatment.

Case 5—Woman aged twenty-five years. This teacher was moving a piano at school when it fell over on to her left leg, grazing her knee and injuring her foot. Clinical examination suggested the possibility of injury to the bones of the foot and possibly to the patella. Radiography of the foot and knee showed no evidence of injury but revealed pathological changes in the upper part of the left fibula (Fig. 22). Here parts of the cortical bone had disappeared and osteolytic areas extended three inches down the fibular shaft. Injection of the superficial femoral artery with a tourniquet applied around the middle of the leg (Fig. 23) showed that the vessels in relation to the head of the fibula were normal, and that there was no increase in vascularity. This was taken to indicate that the lesion was simple, and that it was not a haemangiomia. The upper part of the shaft of the fibula was exposed and, because no infiltration of the surrounding tissues was observed, it was excised. Pathological examination showed fibrous dysplasia of bone (Fig. 24).

Case 6—Woman aged twenty years. This patient complained of a slight stiffness of the left knee eleven weeks previously and, six weeks later, occasional stabbing pains over the inner aspect of the left knee. Clinically, apart from a little tenderness over the lower femur, nothing abnormal was found. Radiography showed an area of periosteal reaction over the inner aspect of the lower femoral shaft and a vague area of osteolysis (Fig. 25). Tomography demonstrated the extent of the lesion better, and revealed a small break through the cortex (Fig. 26). Was this an osteosarcoma? Femoral arteriography showed that a branch of the descending genicular artery was considerably increased in size (Fig. 27). Periosteal vessels were visible and a tumour circulation was demonstrated. This was taken to indicate that the lesion was in fact an osteosarcoma. A frozen section biopsy taken after the application of a tourniquet confirmed this, and amputation through the thigh was performed. Figure 28 shows a cross-section of the tumour.

CONCLUSIONS

It will be seen that a study of the vascular pattern of suspected bone tumours has proved helpful in both a positive and negative way. This additional information has permitted a more certain diagnosis, and in some cases appears to provide such sure evidence of osteosarcoma that any hazard of dissemination by biopsy may be avoided. It seems that the following may be taken as positive evidence of malignant tumours: 1) visible periosteal vessels; 2) an increase in the calibre of feeding arteries and draining veins; and 3) a tumour circulation.

SUMMARY

1. Direct injection of contrast material into bone indicates its extreme vascularity, particularly near an epiphysis, and emphasises the extraordinary capacity of the minute periosteal vessels. The nutrient artery of a long bone appears to play little part in its nourishment and may be regarded as a vestigial structure.
Case 6. Figure 25—Radiograph of lower left femur shows periosteal reaction and vague areas of osteolysis in the lower femur. Figure 26—Tomograph shows the extent of the lesion better and demonstrates a small rupture of the cortex (arrow).

Case 6. Figure 27—Femoral arteriogram shows an abnormal branch of the descending genicular artery, visible periosteal vessels (arrow), and a tumour circulation. Figure 28—Section of the left thigh shows the extent of the osteosarcoma.
2. The vascular pattern of bone tumours may be investigated by injection of the appropriate artery, and sometimes, if a haemangioma is suspected, by direct injection into the lesion.

3. The examination is easily and quickly carried out by direct arterial puncture under local anaesthesia and injection of 35 per cent diodone. A tourniquet applied distally at the appropriate level is often helpful.

4. A study of the vascular pattern of suspected bone tumours has provided useful information in a positive and negative way, assisting both the diagnosis and the planning of treatment. The pathological diagnosis of some tumours, notably osteosarcomas and haemangiomas, may be made with such assurance that possible dissemination of the tumour by biopsy may be avoided.

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