CHONDROSARCOMA OF BONE

R. BARNES and MARY CATTO, GLASGOW, SCOTLAND

From the University Departments of Orthopaedic Surgery and of Pathology,
Western Infirmary, Glasgow

Although chondrosarcoma was described in the late nineteenth and early twentieth centuries in the Continental and British literature (Volkmann 1855, Paget 1870), the original classification of the Bone Sarcoma Registry of the American College of Surgeons (Codman 1922) did not differentiate chondrosarcoma from other tumours arising from bone, all being designated "osteogenic sarcoma" (Kolodny 1927). While Keiller (1925) regarded chondrosarcoma as a pathological entity, Phemister (1930) was the first to emphasise that malignant cartilage tumours not only had a distinct morphological and radiological appearance, but also a longer natural history and a better prognosis than osteosarcoma. At first, Codman (1934) did not confirm Phemister's view, but later it was accepted by the Committee of the Bone Sarcoma Registry (Ewing 1939), who included chondrosarcoma as a separate entity in their revised classification. Even so, the criteria for accepting a malignant bone tumour as a chondrosarcoma remained rather vague until Lichtenstein and Jaffe (1943) made a clear distinction between chondrosarcoma and osteosarcoma, and defined the morphological features of benign and malignant cartilage tumours.

We include in this review not only malignant cartilage tumours which kill by metastatic spread but also tumours of low grade malignancy which run a chronic course over a period of several years and may eventually kill the patient by direct local extension without the production of metastases.

CLINICAL FEATURES

Types of chondrosarcoma—It is customary to divide chondrosarcomata into primary tumours which originate in a previously normal bone, and tumours which develop from a benign enchondroma, the cartilage cap of an osteocartilaginous exostosis or very rarely from a juxtacortical enchondroma. These are usually described as "secondary" chondrosarcomata. Although this is an unsatisfactory description for a tumour that is not metastatic, we have felt impelled to accept it because the term is now in general use. Chondrosarcomata are also often designated as peripheral or central according to their position in the affected bone. A typical peripheral tumour is one arising from an osteocartilaginous exostosis in which the bulk of the chondrosarcoma is outside the bone (Figs. 1 and 2). A central tumour originates within the bone and it may remain confined by the cortex or erupt through it, producing a mass in the soft tissues (Fig. 5).

Location of tumour—The commonest sites of chondrosarcomata are the pelvis, proximal femoral shaft, ribs and shoulder girdle. Although the tumour may arise in any bone preformed in cartilage, it is extremely rare in the forearm or hand, and in the bones of the foot, with the exception of the calcaneus. In contrast, these are the common sites for benign enchondroma.

Sex—In any large series approximately two-thirds of the patients are males.

Age—Chondrosarcoma may occur at any age between ten and eighty years. The peak incidence in Henderson and Dahlin's (1963) series of 288 cases was between thirty and sixty years, and in the series of 151 cases of McKenna, Schwinn, Soong and Higinbotham (1966) thirty to fifty years. "Secondary" chondrosarcomata occur, on the average, in patients ten years younger than those with primary tumours, but even they are appreciably older than
patients with osteosarcomata. In Thomson and Turner-Warwick’s series (1955) of sixty-eight chondrosarcomata, six in patients over the age of sixty-five were associated with Paget’s disease. Chondrosarcoma is, however, much less common in Paget’s disease than either osteosarcoma or an undifferentiated pleomorphic sarcoma.

**Pain**—Pain is not a marked feature of most chondrosarcomata. It is seldom severe and in many patients it is the appearance of a tumour rather than pain which causes them to seek treatment. This is particularly true of the peripheral chondrosarcomata which seldom cause more than slight discomfort unless there is pressure on a nerve trunk (Case 7). In highly malignant central tumours—especially those that erupt through the bone cortex early in their course—the pain may be severe, and it is usually proportionate to their rate of growth (O’Neal and Ackerman 1952).

**RADIOGRAPHIC FEATURES**

The radiographic features of a chondrosarcoma depend on its location. 

*Central tumours* are usually situated in the shaft rather than in the articular ends of long bones. They produce an area of transradiancy which may involve a considerable length of the medullary cavity and there is often thickening and expansion of the adjacent cortex; this is in part caused by the presence of the tumour and in part by reactive periosteal new bone (Fig. 36). Blotchy calcification is usually visible within the transradiant area, and some
low grade tumours are occasionally densely calcified (Roberg 1935, O’Neal and Ackerman 1952). The more malignant chondrosarcomata may show no calcification; they often destroy the bone cortex rapidly (Case 11) and produce little or no expansion of the shaft. When a tumour is situated in a juxta-articular position and there is no discernible calcification in the transradiant area, it may be radiologically indistinguishable from a giant-cell tumour (Fig. 3) (Coley and Santoro 1947).

Important points in distinguishing a benign chondroma from a central chondrosarcoma are: 1) in a benign tumour the limits of the lesion are well defined, whereas the reverse is often the case in a malignant tumour; 2) fusiform thickening of the shaft is highly suggestive of malignancy (Middlemiss 1964), and 3) perforation of the cortex makes the diagnosis almost certain.

Peripheral tumours are often very large (Figs. 53 and 54). The radiographic appearances are characteristic. The central part of the lesion is usually heavily calcified, and from it blotches or streaks of calcification extend towards the periphery of the tumour which is lobulated, transradiant and usually not calcified (Figs. 1 and 2). In some tumours the base of the original osteocartilaginous exostosis may be visible; in others one can only surmise their origin.

The points of importance in distinguishing a peripheral chondrosarcoma from an osteocartilaginous exostosis are: a thick cap of cartilage persisting into adult life, widespread blotchy calcification and the disappearance of the sharp boundary between the core of cancellous bone and its cartilage cap (O’Neal and Ackerman 1952, Dahlin and Henderson 1956).

It is sometimes possible by radiography alone to make a diagnosis of chondrosarcoma, as Lindbom, Söderberg and Spjut (1961) found in thirteen of their thirty-nine patients.

CASE REPORT

Case 1—This woman was sixty-eight years old when she first noticed a swelling of the right thigh. This was accompanied by pain which increased in severity for six months before she came to hospital. On examination, a massive firm tumour attached to the femur was palpable and a radiograph revealed some sclerosis and thickening of the femoral shaft with a little spotty calcification in the uppermost third of the medullary cavity. The outline of a large soft-tissue swelling, patchily calcified, was also seen (Fig. 4). Because the lesion was regarded as malignant and probably chondrosarcomatous, disarticulation of the hip without preliminary biopsy was performed. Five years later the patient was well with no evidence of local recurrence or pulmonary metastasis.

Section of the femur revealed a central cartilaginous tumour which occupied the upper part of the medullary cavity. This was multinodular, patchily calcified, and had perforated the cortex, spreading into the soft tissues to form a large lobulated mass with much degeneration and liquefaction of the centre of the lobules (Fig. 5) some of which were eroding the periosteal surface of the bone. Microscopy showed that a few intraosseous nodules appeared benign and partly calcified, but interspersed with these were others with myxomatous degeneration, plump and double nuclei, occasional tumour giant cells and mitotic figures. The soft-tissue component was more markedly pleomorphic, with many multinucleated tumour giant cells, numerous mitotic figures and large vesicular nuclei (Fig. 6). The appearances suggested the possibility that this histologically highly malignant chondrosarcoma had arisen from a previous benign enchondroma, but since malignancy

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in cartilage tumours is often patchy this could not be established with certainty. The involvement of the medullary cavity was much more extensive than the radiograph suggested because the tumour had spread between trabeculae without notably eroding them (Fig. 16).

Disarticulation without biopsy was justified in this case because the clinical and radiographic features made the diagnosis of malignancy certain and the cartilaginous origin highly probable. Although this appeared histologically to be a highly malignant chondrosarcoma, the patient was well five years later with no evidence of recurrence or pulmonary metastases, though the prognosis must still be guarded.

Case 12 is that of another patient in whom hind-quarter amputation was performed without resort to biopsy (p. 757).
PATHOLOGY
DISTINCTION OF CHONDROSARCOMA FROM OSTEOSARCOMA

Although the Committee of the Bone Sarcoma Registry in 1939 (Ewing) included chondrosarcoma as an entity distinct from osteosarcoma, the precise morphological criteria for placing any tumour in this category remained a little vague. Keiller (1925) had simply excluded from her group of chondrosarcomata all cartilaginous tumours which contained bone, whereas Phemister (1930) separated them from osteosarcomata on the basis of the amount of cartilage present, stating: "It is better in general to designate sarcomata consisting largely of cartilage as chondrosarcomata, and those containing tumour bone with cartilage either absent or present only in small amounts in the regions of ossification as osteogenic sarcoma." This method of differentiation was later used by Thomson and Turner-Warwick (1955). Lichtenstein and Jaffe (1943) distinguished more clearly between the two. They considered that a chondrosarcoma developed from full-fledged cartilage, and although it might become myxomatous or even calcified or ossified it never, in contrast to osteosarcoma, showed neoplastic osteoid tissue or bone evolving directly from a sarcomatous stroma. The differentiation between osteosarcoma containing cartilage, the chondro-osteosarcoma of the older literature or chondroblastic osteosarcoma as it is now sometimes called (Coventry and Dahlin 1957, Dahlin 1957, Price 1961, Middlemiss 1964), and chondrosarcoma itself is an important one from the point of view of prognosis in adults.

CASE REPORT

Case 2—This fifty-one-year-old woman began to have pain in the left groin radiating along the course of the left sciatic nerve to the ankle eighteen months before admission. The pain increased in severity until the patient was hardly able to move and was also present at rest. On examination, the patient was pale and drawn, obviously in pain and had suffered some loss of weight. Radiological examination revealed a transradiant area in the left ilium extending as far as the roof of the acetabulum and producing bone expansion on the pelvic side with perforation of the lateral cortex (Fig. 7). An immediate frozen section was performed on biopsy material. This tissue consisted entirely

Fig. 7
Case 2—Osteosarcoma of ilium. Figure 7—The transradiant lesion has produced expansion of the ilium on the pelvic aspect and there is perforation of the lateral cortex above the superior lip of the acetabulum. The appearances are similar to those of a central chondrosarcoma. Figure 8—Although nodules of cartilage are seen the presence of tumour bone and osteoid tissue in this material from the amputation specimen establishes the diagnosis of osteosarcoma. (Haematoxylin and eosin, × 50.)
of malignant cartilage, and a hind-quarter amputation was carried out because it was thought that the tumour was a chondrosarcoma. Pulmonary metastases rapidly became apparent and the patient died three months after amputation. The tumour in the amputation specimen contained much cartilage but there was also unequivocal evidence of tumour bone formation (Fig. 8).

This case illustrates the danger that, if only a small fragment is examined at biopsy, a cartilage containing osteosarcoma may be diagnosed as a chondrosarcoma. The area of tissue which can be readily examined by immediate frozen section is only about one square centimetre, and the material submitted did not contain any neoplastic osteoid tissue or bone. Had the true diagnosis been made the patient might have been treated initially by radiotherapy and saved a mutilating and useless operation.

The diagnosis of chondrosarcoma in children, especially in those who have not a pre-existing benign cartilage tumour, must be viewed with suspicion since these are rare tumours. Henderson and Dahlin (1963) analysing 288 cases of chondrosarcoma found only ten in patients under twenty years old. Frequently even a sizeable biopsy from an osteosarcoma in this age group may consist entirely of malignant cartilage and fail to show evidence of the formation of neoplastic bone. It may be only when the amputation specimen is carefully studied that small areas of tumour bone are found and the true diagnosis of osteosarcoma is reached. In the few instances in which examination of the amputation specimen has shown the tumour to be entirely cartilaginous, the prognosis is frequently that of an osteosarcoma (Coley and Higinbotham 1953, Gilmer, Higley and Kilgore 1963), the child rapidly developing pulmonary metastases. The distinction then between the common osteosarcoma and the uncommon primary chondrosarcoma in children, if indeed it exists at all (Aegerter and Kirkpatrick 1958), though of academic interest, is usually of little practical importance.

**CASE REPORT**

**Case 3**—This eighteen-year-old girl complained of pain in the outer aspect of the left knee for two and a half months, mild at first but recently becoming more severe. On examination, there was slight fullness and acute tenderness over the lateral aspect of the left knee. Radiological examination revealed slight alteration of the normal texture of the trabeculae of the lateral femoral condyle and some subperiosteal new bone formation (Fig. 9). A frozen section in the operation theatre showed a highly cellular sarcoma with marked nuclear pleomorphism and abundant mitotic figures. There were small patchily calcified areas of cartilaginous matrix. Although evidence of tumour bone formation could be seen in neither the cryostat nor the paraffin sections of the biopsy material, nevertheless it seemed likely in view of the patient’s age and the clinical and radiological findings that the tumour was an osteosarcoma. The leg was disarticulated at the hip joint and examination of tissue from the amputation specimen showed that although the periphery of the tumour consisted chiefly of undifferentiated tumour cells and cartilage (Fig. 10) there was abundant tumour osteoid elsewhere which established the diagnosis of osteosarcoma (Fig. 11). Pulmonary metastases became radiologically recognisable four months after amputation, the patient later became blind and finally died ten months after operation.

The biopsy in this patient was misleading. However, even had the lesion proved to be entirely cartilaginous a very similar outcome might have been expected.

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**FIG. 9**

**Case 3**—Osteosarcoma of left femur. There is periosteal reaction at the lateral supracondylar ridge and some destruction of the underlying bone. The diagnosis was made on the radiographic appearances and in the absence of any clinical signs of infection.
Case 3—Osteosarcoma of left femur. Figure 10—The periphery of the tumour consists of undifferentiated spindle cells and partially calcified lobules of cartilage. (Haematoxylin and eosin, × 42.) Figure 11—Fine strands of tumour osteoid tissue are seen surrounding medullary trabeculae (marked by arrows) in the centre of this vascular and pleomorphic osteosarcoma. (Haematoxylin and eosin, × 110.)

DISTINCTION OF CHONDROSARCOMA FROM CHONDROMYXOID FIBROMA

Another possible source of error in histological diagnosis, especially in children and young adults, is that the benign lesion of chondromyxoid fibroma (Jaffe and Lichtenstein 1948) may be mistaken for a chondrosarcoma with myxomatous degeneration (Roberg 1935 (Case 1) and probably Brailsford 1939 (Case 6)). A reasonably sized biopsy from a chondrosarcoma, even when it shows myxomatous change, will quite often include at least an occasional small
cartilage lobule with hyalin matrix and well formed lacunae containing rounded chondrocytes (Fig. 12), appearances which are not seen in a chondromyxoid fibroma. The matrix in a chondrosarcoma is divided into lobules by strands of collagenous tissue whereas chondromyxoid fibroma is pseudo-lobular, the "lobules" being separated by crowded condensations of tumour cells (Fig. 13).

![Figure 13](image)

**Figure 13**—This chondromyxoid fibroma from an 8-year-old girl is separated into pseudo-lobules by condensations of tumour cells, many of which are spindle shaped. (Haematoxylin and eosin, × 50.)

There is seldom any difficulty in diagnosis after a consideration of the clinical features and radiological appearances. Chondromyxoid fibroma is most commonly seen in children and adolescents, and unlike chondrosarcoma it usually presents a sharply defined zone of bone destruction in the metaphysis of a long bone (Fig. 14). Certainly any doubt as to the diagnosis should lead the pathologist to consider all the relevant information.

**VARIETIES OF CHONDROSARcoma AND THEIR PATHOLOGICAL IDENTIFICATION**

Most cartilage tumours arise in normal bone and in relatively few is it possible to establish their origin from an enchondroma or simple osteocartilaginous exostosis. While dense, blotchy calcification, slow growth and a long history suggest that the chondrosarcoma is "secondary," these features are not conclusive evidence; nor is the presence of endochondral ossification, for it may be seen not only in exostoses but in tumour recurrences and even in metastases (O'Neal and Ackerman 1952). The only certain histological evidence of a previous benign tumour is the identification of the unaltered bony base or pedicle in a chondrosarcoma which has arisen from an osteocartilaginous exostosis (Morton and Mider 1947, Dahlin and Henderson 1956).

It may be impossible to establish convincingly by histological means alone the presence of a pre-existing enchondroma associated with a central chondrosarcoma (Lindbom and colleagues 1961, Ackerman and Spjut 1962, Henderson and Dahlin 1963). Dahlin and Henderson (1956) stated that on reviewing the biopsy material from chondrosarcoma which had been said to arise from enchondromata, they found the initial diagnosis to have been wrong. The tumours had shown low grade malignancy from the start, the changes being confined to small and scattered areas.
Chondrosarcomata may also be divided according to their site of origin, most being central or peripheral. Rarely they may arise from a juxta cortical or subperiosteal chondroma. These tumours are uncommon (Lichtenstein and Hall 1952, Feinberg and Wilber 1956, Dahlin 1957, Jaffe 1956, 1958, Meyer 1958, Cary 1965, Lichtenstein 1965), they erode the bony cortex without penetrating to the medullary canal (Fig. 15), and may occasionally recur (Scaglìetti and Stringa 1957, Lichtenstein 1965) and become malignant (Lichtenstein 1955, Jaffe 1958, Cooper 1965). Henderson and Dahlin (1963) reported thirteen of 288 chondrosarcomata arising in the periosteal region. It is often easy to recognise in the early stages whether a chondrosarcoma is central or peripheral in a large tubular bone, but when the tumour is big and especially if it has arisen in relation to a flat bone (Dahlin and Henderson 1956) which may be completely destroyed (O’Neal and Ackerman 1951) its original site may be impossible to decide even on histological examination. Of forty chondrosarcomata O’Neal and Ackerman (1952) were unable to establish whether five had arisen centrally or peripherally, and Lindbom and his colleagues (1961) had the same difficulty in six of thirty-nine tumours.

**GROSS PATHOLOGY**

*Central chondrosarcoma*—The cartilage within the medullary cavity is usually bluish-white, translucent and lobulated so that it may have produced some scalloping of the endosteal surface of the bone cortex. It is sometimes speckled by yellowish or white areas of calcification. While the intraosseous cartilage may be mucoid it rarely becomes completely degenerate (Fig. 38). The border of the tumour may be ill defined and the extent of medullary spread difficult to recognise (Morton and Mider 1947, Ghormley 1951) with the naked eye, there being marrow permeation at some distance from the main mass (Dahlin and Henderson 1956). Often
the infiltration of the marrow spaces is not accompanied by any marked trabecular destruction (Fig. 16), so that the extent of the tumour recognisable by radiology is much less than its true size (Ghormley 1951, Gilmer, Higley and Kilgore 1963, Gilmer, Kilgore and Smith 1963, Goldenberg 1964). Sometimes there may be slight expansion of the shaft, the cortex at the periphery of the tumour becoming thickened and buttressed due to the laying down of reactive new bone (Figs. 36 and 38) (Phemister 1948, O'Neal and Ackerman 1952). This usually happens in the more slowly growing (Aegerter and Kirkpatrick 1958) and less malignant tumours (Gilmer, Kilgore and Smith 1963). In others, often more rapidly growing and more malignant, there is no notable formation of reactive bone, and perforation of the cortex occurs early (Fig. 5), commonly at only one site. It is generally agreed to be a certain sign of malignancy (Lichtenstein and Jaffe 1943, O'Neal and Ackerman 1952, Aegerter and Kirkpatrick 1958, Gilmer, Kilgore and Smith 1963, Goldenberg 1964). Rupture of tumour through the articular cartilage into the joint has been reported (O'Neal and Ackerman 1952). The soft-tissue component of the tumour, particularly if it is large, often shows central degeneration of the lobules which may become converted into ragged cavities containing thick viscid fluid and shreds of tissue like boiled rice (Fig. 5). Extraosseous calcification is less common than in peripheral chondrosarcomata. In spite of malignancy the soft-tissue tumour may appear well defined due to compression of surrounding tissues which form an apparent capsule. In chondrosarcoma of the thorax where a

![Figure 17](image1.jpg)   ![Figure 18](image2.jpg)  
A large low grade chondrosarcoma of the chest wall from a 55-year-old crofter. Figure 17—On section the tumour is seen to be lobulated with some calcification and degeneration. The exact site of its origin in relation to the ribs cannot be identified. Figure 18—The pleural surface of the tumour is studded with numerous, readily detached, satellite nodules. (Mr Kenneth Fraser’s case.)

![Figure 19](image3.jpg)  
A large low grade chondrosarcoma of the chest wall. A cartilaginous nodule attached to the visceral pleura. There was no evidence of metastatic spread in the excised lung tissue. (Haematoxylin and eosin, ×50.) (Mr Kenneth Fraser’s case. Reproduced by courtesy of Mr Fraser.)
large part of the mass may protrude into the chest, the main bulk of the tumour may be covered on its pleural surface by innumerable tiny seeds which readily become detached, and nodules on the lung surfaces are presumably derived from these (Figs. 17, 18 and 19) (O'Neal and Ackerman 1951).

**Peripheral chondrosarcoma**—These tumours, especially the group of low grade malignancy, may still have a well defined bone base or pedicle indicating their origin from a benign exostosis (Lichtenstein and Jaffe 1943, Morton and Mider 1947, Dahlin and Henderson 1956), but some are entirely cartilaginous. The size varies from less than ten centimetres in diameter to enormous tumours weighing many pounds, commonly found in relation to the pelvic or shoulder girdles (Fig. 54) (Ghormley, Meyerding, Mussey and Luckey 1946, Ghormley 1951). Usually their cartilaginous nature is very clear and they are hyaline and markedly lobulated. The large tumours especially may be more mucoid, and degenerative changes in the lobules are often marked, as is sometimes seen in the soft-tissue extension of a central chondrosarcoma (see above). Dense calcification or ossification may also be present, though the periphery of the lobules is usually spared. These lesions are at first bounded by fibrous tissue continuous with the periosteum but may later break through. However, on naked eye examination, it may be impossible to make the distinction between distortion of the tissues from pressure and invasion (O'Neal and Ackerman 1952). The appearance of encapsulation is misleading and dangerous since the surface of the tumour may be bossellated, some of these peripheral nodules having only a tenuous connection with the main mass (O'Neal and Ackerman 1951).

**HISTOLOGICAL CRITERIA OF MALIGNANCY**

Cartilage tumours present an unbroken spectrum in both their histological appearances and clinical behaviour from the entirely benign to the frankly malignant. The frankly malignant group present no great difficulty in microscopic diagnosis, there being marked variation in nuclear and cell size, numerous plump cells with multiple nuclei, uninuclear giant cells and nuclear hyperchromatism and vesiculation. Mitotic figures may be moderately numerous (Figs. 6, 29 and 50). There may, however, be difficulty in drawing a line between a benign tumour (Figs. 20 and 21) and one of low grade malignancy (Figs. 39, 41, 46 and 47).

Earlier writers laid much stress on the cellularity and on the appearances of the cartilaginous stroma, myxomatous changes being thought to be of sinister significance (Spuler 1902, Ernst 1905, Merkel 1908). Lesions of low grade malignancy were frequently "underdiagnosed" by the pathologist and many authors drew attention to the discrepancies between the clinical outcome of a case and the histological diagnosis (Castrén 1931, Flörcken 1932, Geschickter and Copeland 1936, Brailsford 1947, Coley and Higinbotham 1953). For instance, the patient reported by LeConte, Lee and Belk (1925) was finally killed by a cartilage

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**Fig. 20**

A 34-year-old housewife was found at mass radiography to have a "cyst" in the medial part of the clavicle. It was symptomless. Curettage revealed a benign enchondroma with small uniform nuclei and scanty double nuclei. There is no recurrence of the tumour six years later. (Haematoxylin and eosin, × 60.)
tumour of the femur which had recurred four times, the pathologist maintaining that the lesion was an enchondroma. It became generally assumed that the diagnosis of chondrosarcoma could only infrequently be made on histological grounds.

Keiller in 1925 emphasised the importance of nuclear changes and found that slight irregularity in nuclear size and the occasional presence of two nuclei in one cell suggested malignant transformation even when only small areas of the tumour were affected. She considered that cells with multiple nuclei, a single very large nucleus or atypical mitoses were proof positive of chondrosarcoma. Keiller also disagreed with the idea that myxomatous stromal change was in itself sinister. Unfortunately her paper appears to have had little impact, and it is only since Lichtenstein and Jaffe (1943) re-emphasised the overwhelming importance of the nuclear appearances that the histological diagnosis of cartilage tumours has more nearly corresponded with their clinical behaviour. Lichtenstein and Jaffe reported from their own experience of fifteen chondrosarcomata "that a cartilage tumour is no longer to be regarded as benign if, when viable non-calcifying areas are examined, it shows, even in scattered fields: 1) many cells with plump nuclei; 2) more than an occasional cell with two such nuclei; and especially 3) giant cartilage cells with large single and multiple nuclei or with clumps of chromatin" (Figs. 39, 46 and 47). These criteria, which are now generally accepted, were developed on the premise that malignancy included not only those tumours capable of relatively early metastasis but also those only capable initially of recurrence and which commonly kill the patient from local extension, though occasionally by late metastases. O'Neal and Ackerman (1952), using these points, found that tumours, excluding those of the small bones of the hands and feet, which have more than 3 per cent of abnormal nuclei may be classified as malignant though the histological diagnosis may precede clinical evidence of malignancy by some years. Other nuclear changes such as irregularity of nuclear outline and prominence of nucleoli are said to be suggestive of malignancy (Aegerter and Kirkpatrick 1958). It is recognised that mitotic figures are uncommon in chondrosarcomata (Morton and Mider 1947, O'Neal and Ackerman 1951), and their absence is not a guarantee of benign behaviour (Lichtenstein and Jaffe 1943, O'Neal and Ackerman 1952, Sherman 1955, Goldenberg 1964). When many are seen they are of sinister significance (O'Neal and Ackerman 1951, Aegerter and Kirkpatrick 1958), as are the presence of numerous tumour giant cells (Morton and Mider 1947).

The nuclear changes on which the diagnosis of malignancy is based are frequently patchy (Coley and Santoro 1947, Ghormley 1951) and this has important implications in regard to the biopsy. A generous sample of tissue is desirable (Morton and Mider 1947, Sherman 1955, Aegerter and Kirkpatrick 1958, Lindbom and colleagues 1961) and all of it should be processed, many sections being examined. Punch biopsy (Lichtenstein and Jaffe 1943) or aspiration biopsy (Meyering and Bateman 1951, Coley 1960) tends to be unreliable because of the small amount of tissue obtained. While immediate frozen section in theatre has obvious advantages in the treatment of some bone tumours, there is usually no desperate urgency in chondrosarcomata, and in a difficult case the preparation of paraffin sections allows a more valid decision to be reached on a larger bulk of tissue. Not only is the amount of tissue of consequence but the site from which it is taken must be carefully chosen. Degenerate and calcified areas should be avoided (Lichtenstein and Jaffe 1943, O'Neal and Ackerman 1951, Dahlin and Henderson 1956) because the cartilage cells and their nuclei are likely to be swollen for reasons unassociated with malignancy (Lichtenstein and Jaffe 1943) or there may be few viable cells for assessment. Material is best taken from the zone most likely to show evidence of malignancy, that is from the growing edge of the lobules (O'Neal and Ackerman 1951, Sherman 1955) which is usually soft even in heavily calcified and ossified peripheral tumours (O'Neal and Ackerman 1952).

Although Lichtenstein and Jaffe (1943) emphasised that all heavily calcified or ossified tumours were not necessarily benign, it is reported that there is a better prognosis in this
group (Roberg 1935, Speed 1951) (Case 12), whereas the more malignant tumours tend to have less bone (Case 11) (O'Neal and Ackerman 1951).

Stromal changes of myxomatous type were originally thought to be indicative of malignancy, the tissue being considered to be an embryonal form of cartilage (Geschickter and Copeland 1936, Fodden 1950, Copeland 1956, Copeland and Geschickter 1965) and the prefix myxo- was added to chondromata and to chondrosarcomata. However, Keiller (1925) and Roberg (1935) amongst others suggested that the myxomatous element was the result of degeneration and it is now generally agreed, except by Henderson and Dahlin (1963) who still regard it as an ominous sign, that myxoid change is not significant in the diagnosis of malignancy (Fig. 21) (Roberg 1935, Lichtenstein and Jaffe 1943, Morton and Mider 1947, O'Neal and Ackerman 1951, 1952).

High cellularity, the other criterion of malignancy much emphasised in the early literature, is thought now also to have of itself little sinister connotation (Eyre-Brook 1961), nuclear atypism being more important (O'Neal and Ackerman 1951) (Fig. 21).

Keiller (1925) thought that tumours which were more vascular had a worse prognosis and Morton and Mider (1947) postulated that this might result from greater ease of metastasis. Lagergren, Lindbom and Söderberg (1961), as a result of histological, angiographic and micro-angiographic studies, have suggested that although malignant tumours may be more vascular with penetration of vessels into the lobule and separation of malignant cells from the blood-stream by only a single layer of endothelium, nevertheless those tumours with poor vascularity, or vascularity not exceeding that of the surrounding tissues, are not necessarily benign.

Recent autoradiographic studies by Gottschalk and his co-workers (Gottschalk and Allen 1952, Gottschalk, Alpert and Miller 1959, Gottschalk 1960, Gottschalk and Smith 1963) suggest that the uptake of radioactive sulphur reflects the growth of the tumour, and although investigations along these lines (Wolfe and Vickery 1964) and others on enzyme activity (Anderson, Ludowieg, Eyring and Horowitz 1963) are yet in their early stages they may later prove to be of diagnostic value.

DISCREPANCIES BETWEEN HISTOLOGICAL APPEARANCES AND BIOLOGICAL BEHAVIOUR

Site—Even with the careful study of cartilage tumours, bearing Lichtenstein and Jaffe's histological criteria in mind, it is apparent that all tumours with the same histological appearances do not behave in the same way (Sherman 1955, Gilmer, Kilgore and Smith 1963, Henderson and Dahlin 1963). It has long been recognised that cartilage tumours of the small bones of the hands and feet may show cytological evidence of low grade malignancy but they behave as benign tumours (Bloodgood 1924, Roberg 1935, Geschickter and Copeland 1936, Brailsford 1939, 1947, Luck 1943, O'Neal and Ackerman 1952) with rare exceptions (Volkmann 1855). Chondrosarcomata of the feet were recently reviewed by Pachter and
Alpert (1964) and those of the hand by Gottschalk and Smith (1963). The lesions of multiple enchondromatosis are often also more cellular than those of solitary enchondroma while remaining in a "pre-cancerous state" (Jaffe 1958). Periosteal chondromata (Lichtenstein and Hall 1952) or juxta-cortical chondromata (Jaffe 1956) may sometimes show an alarming histological appearance which is not always matched by their subsequent clinical behaviour (Jaffe 1958, Henderson and Dahlin 1963). Very occasionally tumours at more central sites deemed to be of low grade malignancy and inadequately treated unexpectedly fail to run a malignant course (Dahlin and Henderson 1956, Henderson and Dahlin 1963). More frequently, however, cartilage tumours of the axial skeleton and proximal limb bones may behave more aggressively than the histology would lead one to expect. Although this discrepancy may be explained as the result of failure of the pathologist to appreciate the more subtle signs of malignancy, or of the surgeon to obtain material from the growing edge of the tumour, it is of considerable practical import. It has led orthopaedic surgeons to accept unquestioningly the histological diagnosis of malignancy (Coley 1960) in these cases but to view with reservation reports of benignity when the clinical or radiological features do not conform (Coley and Santoro 1947, Morton and Mider 1947, Luck 1956), and many of them have formulated clinical criteria which they have found by experience to be helpful in dealing with these cytologically "borderline" cases. Most clinicians and pathologists would agree that the final diagnosis should not rest on the histology alone but should take into account all the available information (Case 9) (Morton and Mider 1947, Coley and Higinbotham 1954, Luck 1956, Coley 1960, Henderson and Dahlin 1963, Middlemiss 1964).

Age—Apart from the variations of behaviour associated with different sites some allowance may be made in the interpretation of the histology in relation to the age of the patient. A greater degree of cellular atypism may be tolerated in cartilage tumours in children and adolescents where physiological growth is continuing than would be accepted in tumours from the same site in adult patients (Coley 1960, Gilmer, Kilgore and Smith 1963). Although continuing growth of a cartilaginous lesion after the age of twenty must arouse suspicion of malignant change this is not always warranted and sometimes endochondral ossification of an exostosis may continue into the middle of the third decade (Case 5).

RECURRENCES

Chondrosarcoma is a tumour peculiarly prone to local recurrences and these are responsible for death in most of the unsuccessfully treated patients (O'Neal and Ackerman 1951, 1952, Dahlin and Henderson 1956, Henderson and Dahlin 1963). Although in many recurrences there is no apparent alteration in growth rate (Lindbom and colleagues 1961) (Figs. 46 and 47), in some there may be an increase in both clinical and cytological malignancy (Roberg 1935, Morton and Mider 1947, Ghormley 1951) as Dahlin and Henderson (1956) found in thirteen of 154 recurrences. Occasionally the histological changes do not run parallel to the clinical course, there being little increase in cellular atypism (O'Neal and Ackerman 1952) though there may be diminution in the amount of calcification and ossification (O'Neal and Ackerman 1951). The increased spread in these cases may be the result of breakdown of mechanical barriers such as the perichondrium, and the opening up of tissue planes by the previous operation, some of the tumours then becoming inoperable (O'Neal and Ackerman 1951).

METHOD OF SPREAD AND METASTASIS

As well as medullary spread and local extension in the soft tissues chondrosarcoma may eventually break into the regional veins (Virchow 1855, Phemister 1930, Lichtenstein and Jaffe 1943, Morton and Mider 1947). In chest wall tumours metastases to the epidural space may result from extension along the intercostal and vertebral veins (O'Neal and Ackerman 1951). From the lower limb, pelvis and lower vertebral column in particular intravascular
extension sometimes reaches the heart and lungs, especially in more slowly growing (Sherman 1955) and peripheral tumours (Aegerter and Kirkpatrick 1958). This extension may occasionally be without evidence of any metastases (Ernst 1900, Kósá 1929), whereas in others pulmonary (von Biesiadecki 1868, Fry and Shatlock 1926, Warren 1931) and liver secondaries (Weber 1866) are seen. Although pulmonary metastases are the most frequent and are said occasionally to be followed by arterial emboli (Lindbom and colleagues 1961), liver, cerebral and renal secondaries are sometimes reported and cutaneous (Cruickshank 1945) and bony involvement have also been seen (Case 11) (O’Neal and Ackerman 1952). Lymph node secondaries are extremely rare (O’Neal and Ackerman 1952, Dahlin and Henderson 1956, Lindbom and colleagues 1961, Ackerman and Spjut 1962, McKenna, Schwinn, Soong and Higinbotham 1966) and it has been suggested (Lichtenstein and Jaffe 1943) that in some instances what appear to be lymph nodes completely replaced by metastatic growth may in reality have been soft-tissue tumour nodules adjacent to the main mass.

CASE REPORT

Case 4—This seventy-three-year-old housewife complained of pain radiating from the right groin to the knee for six months. Examination showed that there was limitation of abduction in the right hip and some tenderness over the symphysis pubis but radiology failed to reveal any abnormality until two months later when a destructive lesion became apparent in the floor of the acetabulum. At operation specimens were taken from a tumour which seemed to arise in the superior part of the acetabulum and extend into the pubic ramus. Microscopy revealed that the tumour was a chondrosarcoma but since the patient had severe ischaemic heart disease hind-quarter amputation was out of the question. Treatment with the Orbitron cobalt 60 unit was given, a tumour dose of 6,500 rads being administered. The patient remained relatively well for about eighteen months and then it became apparent that the tumour had extended and it finally formed a large mass within the pelvis, the right leg becoming grossly oedematous. The patient died three years after her first admission. At necropsy a large tumour was found to arise from the right innominate bone and to extend into the sacrum and also across the symphysis pubis into the left pubic ramus. The right common iliac vein contained a mass of soft, gelatinous cartilage which extended into but did not completely occlude the inferior vena cava (Fig. 22). No tumour was found in the heart but the pulmonary artery to the left lung was completely blocked by cartilaginous tissue and thrombus which projected into the pulmonary trunk. Many branches of the pulmonary artery in both lungs contained tumour and there were numerous wedge-shaped infarcts. Microscopy showed that the chondrosarcoma in the lungs appeared to be confined to the lumen of the pulmonary arteries and no spread to the lung parenchyma was demonstrable (Fig. 23). Liver metastases were present and adjacent portal venules were occluded by chondrosarcoma (Fig. 24).

There are several points of interest in this case history. The delay in diagnosis of acetabular lesions is well known (Aegerter and Kirkpatrick 1958, Lindbom and colleagues 1961); sometimes rectal examination will reveal a tumour before any alteration is recognised radiologically. Radiotherapy is agreed to be of little value in the treatment of chondrosarcomata and it certainly failed to control this tumour. The extension of the tumour into local pelvic cavas and inferior vena cava with consequent embolic spread to the pulmonary arteries is well illustrated.
Case 4—Spread of chondrosarcoma. Figure 23—A small branch of the pulmonary artery is partially occluded by a mixture of chondrosarcoma and thrombus. (Haematoxylin and eosin, × 90.) Figure 24—In the liver, adjacent to a nodule of secondary chondrosarcoma, a portal triad contains a portal venule plugged by tumour. (Haematoxylin and eosin, × 70.)

ALTERATION OF THE CHARACTER OF THE TUMOUR

Occasionally undifferentiated fibrosarcoma may be seen at the periphery of a chondrosarcoma (Henderson and Dahlin 1963, McKenna and colleagues 1966), especially in the soft-tissue extension from a central tumour (Fig. 25) (Jaffe 1958) or following recurrence (Dahlin and Henderson 1956, Eyre-Brook 1961). More rarely a purely cartilage tumour is said to recur as an osteosarcoma (Henderson and Dahlin 1963). These more anaplastic tumours are thought to have a worse prognosis than chondrosarcoma in general (Morton and Mider 1947, Henderson and Dahlin 1963). Rather less infrequently pulmonary metastases from a purely cartilaginous primary may be undifferentiated (Martin 1925), or entirely fibrosarcomatous (Phemister 1930, O'Neal and Ackerman 1952).

SECONDARY CHONDROSARCOMA

Secondary chondrosarcoma may develop from the cartilage cap of an osteocartilaginous exostosis or from a benign enchondroma. A solitary exostosis rarely becomes malignant, but the risk of chondrosarcoma in multiple exostoses is
appreciable. This could be attributed to the greater number of exostoses at risk in diaphysial aclasia, but there is some evidence that these tumours are intrinsically more liable to the development of a sarcoma (Jaffe 1953). One of our patients with multiple exostoses, a man of thirty-three, had two separate chondrosarcomata which arose from exostoses situated in the upper end of the left femur and right ilium, and Knight (1960) has reported chondrosarcoma in three brothers who suffered from diaphysial aclasia.

The incidence of chondrosarcoma in patients with multiple exostoses has been given as 5 per cent by Ehrenfried (1915), and as 11 per cent by Jaffe (1943), though both the latter author and O’Neal and Ackerman (1952) thought the figure was too low, because some of the patients studied were children and might later in life develop sarcoma. Whilst this is true, it must be remembered that many patients with multiple exostoses, especially those with a family history, do not seek treatment unless one of the tumours limits joint movement, causes pressure on a nerve or major blood vessel or becomes appreciably larger than the remainder.

A chondrosarcoma may develop from an exostosis at any age between ten (Bennett and Berkheimer 1941) and sixty years, but usually after growth has ceased, and most commonly between thirty and forty years of age. Exostoses of the trunk become sarcomatous much more frequently than exostoses of the distal part of the limbs. In a series reported by McKenna and his co-workers (1966) only one of the twelve “secondary” chondrosarcomata was situated in the distal skeleton.

It is for two reasons impossible to give even a rough estimate of the frequency of malignant degeneration in a benign enchondroma. 1) A chondrosarcoma may obliterate all trace of its benign precursor; 2) because malignant histological changes are sometimes patchy the presence of apparently innocuous cartilage nodules is of doubtful significance. When a chondrosarcoma develops in Ollier’s disease or Maffucci’s syndrome, it is reasonable to assume that one of the enchondromata has undergone malignant transformation. In a review of twenty cases of Maffucci’s syndrome, Carleton, Elkington, Greenfield and Robb-Smith (1942) reported that a chondrosarcoma had developed in four of the patients, and possibly in three others. O’Neal and Ackerman (1952) stated “that possibly the ultimate fate of all enchondromata of large bones that do not become quiescent after adolescence, is the development of an overt chondrosarcoma.” On the other hand, Dahlin and Henderson (1956) did not find unequivocal evidence of a benign origin for any of their central chondrosarcomata, and Ackerman and Spjut (1962) were only willing to concede the possibility of malignant change in two patients (one with a ten-year and the other with a thirty-year history) of the thirteen “secondary chondrosarcomata” reported by Coley and Higinbotham (1949). Sometimes, however, there is strong presumptive clinical evidence of a chondrosarcoma supervening on a benign enchondroma as in one of our patients (Case 6).

**CLINICAL CRITERIA OF MALIGNANCY**

The accurate diagnosis of malignancy in a cartilage tumour is a severe test of the diagnostic acumen of surgeons, pathologists and radiologists. Often it is impossible to be precise, for cartilage tumours present an unbroken gradation from the completely benign to the highly malignant in which the zone between innocent tumours and chondrosarcoma is ill defined.

One of the most difficult problems is the detection of malignant change in an osteocartilaginous exostosis. Most exostoses appear during the first decade of life and growth is most active in the years before skeletal maturity; by the early twenties almost all growth has ceased and the cartilage cap atrophies and may disappear. There are, however, exceptions, and we have seen continued growth in some benign tumours well into adult life.

**CASE REPORT**

*Case 5—An eighteen-year-old male gave a history of multiple exostoses first noticed at the age of three years. Exostoses continued to appear during childhood and adolescence until there were many tumours throughout the skeleton, and an associated disturbance of bone growth. The exostoses*
arising from the left tibia, left ilium and left scapula were excised because they were appreciably larger than the remainder. He was kept under observation and when he was twenty-four years of age he reported that an exostosis arising from the upper end of the right humerus was increasing in size; it was not painful. A radiograph (Fig. 26) confirmed that the exostosis was much larger than at the time of his first attendance six years previously. It was excised (Fig. 27); in places the cartilage cap persisted and there were patchy areas of continuing growth, but no evidence of malignancy. The patient is now twenty-nine years old. There has been no recurrence of the exostosis, and there has been no further growth in the remaining tumours.

This case is unusual; renewed growth of an exostosis after skeletal maturity is suggestive of malignancy, as is the appearance of an exostosis for the first time in adult life.

Pain is the most reliable indication of malignancy in a centrally located cartilage tumour of the axial skeleton or long bones (Coley and Higinbotham 1954). It is often insidious in onset, mild and inconstant, but it should arouse suspicion in an adult unless there is a pathological fracture, and the diagnosis is almost certain if radiography reveals buttressing or perforation of the cortex.

In general, all recurrent tumours where both the cartilage and the covering perichondrium were completely excised should be regarded as at least locally malignant irrespective of their histological appearance. Tumours of the axial skeleton are often malignant, particularly those of the ribs and sternum and sessile lesions in the pelvis. O'Neal and Ackerman (1951) reviewed ninety-eight cartilaginous tumours of the thoracic cage, thirty-six of which were previously regarded as benign, but most of these recurred several times after treatment and only one remained unchanged over a period of seventeen years. In contrast, tumours of the hand and foot, excepting those of the calcaneus, are almost invariably benign even when causing some pain. The following case illustrates an exception to this general rule.
CASE REPORT

Case 6—This sixty-seven-year-old gamekeeper stated that he had had a swelling over the base of the right thumb for thirty years. About ten months previously a stone had fallen on his hand and since then the swelling had gradually increased in size and had now become painful. A radiograph revealed an apparent enchondroma occupying the greater part of the metacarpal bone of the thumb, but at its base the tumour had erupted through the bony shell and there was spotty calcification within the tumour, extending out into the soft tissues (Fig. 28).

A biopsy showed an infiltrating, pleomorphic chondrosarcoma with some mitotic figures and numerous multinucleated tumour cells (Fig. 29). The tumour was excised radically by amputation of the thumb and index finger, and the corresponding metacarpals, together with the trapezium, trapezoid and the distal half of the scaphoid. Much of the metacarpal was replaced by pleomorphic cartilage which had broken through the cortex and was infiltrating the soft tissue. In the distal part of the metacarpal there were a few separate and partly calcified nodules of apparently innocuous cartilage. The patient died of ischaemic heart disease eight years later without evidence of local recurrence or of metastases.

![Figure 28](image_url)  ![Figure 29](image_url)

Case 6—A chondrosarcoma of the metacarpal of the thumb. Figure 28—The distal part of the bone is expanded and there are several translucent areas suggestive of an enchondroma, but the tumour has erupted through the cortex at the base of the metacarpal. There is blotchy calcification characteristic of chondrosarcoma extending into the soft tissues. Figure 29—There are marked variations in nuclear size, many nuclei being plump. Multinucleated and binucleate cells are prominent (Haematoxylin and eosin, ×300.)

This is a rare example of a chondrosarcoma which appeared from the clinical history to have developed from a benign enchondroma of the metacarpal, and was possibly related to the injury sustained ten months earlier. While most of the metacarpal had been replaced by malignant tumour the presence of a few histologically benign nodules at a distance from the main mass gives some support to the clinical impression that this was a “secondary” chondrosarcoma.

CLINICAL COURSE

The natural history of chondrosarcoma varies from the rapidly fatal course indistinguishable from that of osteosarcoma or of the rare primary chondrosarcoma in children, to the prolonged course of the low grade tumours which may gradually kill the patient from massive local extension without metastases.

CASE REPORT

Case 7—This thirty-one-year-old radiographer suffered from hereditary multiple exostoses, as did her father and sister. She complained of pain in the buttock which had been present for about eighteen months. Radiography revealed a tumour three or four inches in diameter in the region of
the left sacro-iliac joint (Fig. 30). This was regarded as an osteocartilaginous exostosis and no surgical treatment was advised.

She continued to have pain in her leg from pressure on the roots of the lumbo-sacral plexus, and the tumour increased slowly in size. Two and a half years after her first attendance an attempt was made to excise it completely but this was impossible because of its situation. The pain persisted and six months later a tumour nodule which was bulging into the intervertebral foramen between the fifth lumbar and first sacral vertebra on the left side was removed. Although this temporarily relieved the sciatica, within a few months another partial excision was performed and a cordotomy was later required (Fig. 31). The chondrosarcoma continued to grow and eventually occupied a large part of the abdominal cavity so that a colostomy and a bilateral nephrostomy were necessary. The patient died fourteen years after her first symptoms; at the time of her death there was no clinical or radiological sign of metastases.

Pain and renewed growth of the exostosis after skeletal maturity was a sign of malignancy. This tumour proved histologically to be a low grade chondrosarcoma and should have had a good prognosis but unfortunately its situation made radical resection impossible. As in many such tumours death occurred from local extension after a long period.

![Figure 30 and 31](image-url)

**Case 7**—The patient had complained of pain in the left buttock for eighteen months before the radiograph (Fig. 30) was taken. The tumour was well defined and regarded as an osteocartilaginous exostosis. However, the tumour continued to grow and the pain became more severe indicating that it was a chondrosarcoma. Histology confirmed the diagnosis. Figure 31—Four years later, after two unsuccessful attempts at removal.

Often in these low grade, secondary, peripheral chondrosarcomata, there is a long history of many years' slow increase in size, and because the pain is slight the patient may wait until the tumour is of considerable dimensions compared with his other exostoses before seeking treatment. Patients with multiple exostoses should therefore be asked to return at yearly intervals for review.

Central tumours, though they tend to be more active than peripheral ones, may also be of low grade malignancy. It is striking that even these low grade tumours frequently recur after an apparently adequate local excision. In the past, the history of these patients has been punctuated by numerous operations followed by further extension of the tumour (Case 10). Sometimes a patient has died as long as twenty years after the first symptom from local spread in the mediastinum or from renal infection following obstruction of the ureters by a large intrapelvic chondrosarcoma (Thomson and Turner-Warwick 1955, Coley 1960).

Even metastasising tumours may run a protracted course, and it is not unusual for a patient to survive for several years after the appearance of pulmonary secondaries.
CASE REPORT

Case 8—This fifty-three-year-old butcher attended hospital in July 1954 and stated that five years previously he had injured his left knee; from that time he had noticed a virtually painless swelling over the lateral aspect of the lower thigh. Clinical examination revealed a fairly large, slightly tender swelling attached to the outer aspect of the lower end of the femur and radiography confirmed the presence of a faintly speckled tumour, mainly extraosseous in location, associated with periosteoal reaction (Fig. 32).

A biopsy was advised but refused by the patient. He eventually agreed to surgical treatment in August 1955. A local excision of the tumour was performed. Histologically it had the appearances of a relatively low grade chondrosarcoma with myxomatous change. Within a year the tumour recurred and radiographs revealed a translucent lesion in the upper end of the fibula. A radical excision of the tumour was now performed; the histological appearances were similar to the original specimen.

The tumour again recurred and now involved the upper third of the tibia. An amputation was performed in August 1957; it was noted that the tumour extended to within a short distance of the level of section of the femur (Fig. 33).

Six months later metastases were noted in the base of the left lung and within two years these were followed by similar lesions in the right lung (Fig. 34). Later, the tumour recurred in the amputation stump (Fig. 35). The patient continued to work until within a few months of his death in February 1965 from metastases in the lungs and brain.

Two inadequate operations were performed on this low grade chondrosarcoma. The amputation for the second recurrence was only a short distance above the limit of the tumour, and was followed by a recurrence in the stump. There was radiological evidence of metastases in the lungs seven years before death which occurred sixteen years after his first symptoms.

Only three patients, all under thirty years of age, of the thirty-five chondrosarcomata treated at the Western Infirmary, died within three years of operation. Clearly, patients suffering from these tumours must be followed up for many years after treatment before a cure can be claimed. Dahlin and Henderson (1956) rightly insisted that a ten-year survival without recurrence or overt metastases was mandatory before a cure was established.

When chondrosarcomata metastasise, this is often to the lungs, sometimes to the liver, and less frequently to a wide variety of other sites such as the brain, kidney, subcutaneous tissues or other bones (Cases 4 and 11). There is a tendency particularly in pelvic chondrosarcomata for veins near the tumour to become plugged with cartilaginous tissue which may break off, forming tumour emboli in the pulmonary arteries or, rarely, reach the lungs by continuous spread through the heart (Fry and Shatlock 1926, Kósa 1929).

BIOPSY—ITS MANAGEMENT AND INTERPRETATION

In some instances a diagnosis can be made on the clinical and radiographic features of the tumour (Cases 1 and 12), but a biopsy is frequently necessary before surgical treatment. If it is suspected that a tumour may be cartilaginous, an open biopsy is preferable, for it is seldom possible to give an authoritative opinion on the small fragment of tissue obtained by aspiration (O'Neal and Ackerman 1952, Dahlin and Henderson 1956).

Biopsy must be planned with care and an adequate specimen taken from the growing edge of the tumour. The procedure is not without risk; tumour cells may be disseminated in the tissues and continue to grow as their nutrition is not dependent on a direct blood supply. It is therefore important to expose the tumour by the most direct route, keeping the wound as small as possible and at the same time ensuring that it can be excised completely in any subsequent operation (Dahlin and Henderson 1956). The risks of implanting malignant cartilage cells in a wound are illustrated in the case reported by Durbin and Stewart-Smith (1955). The patient, a male aged sixty-one, had what was thought to be a chondroma of the calcaneus. The tumour was curetted and the cavity packed with grafts taken from the upper end of the tibia of the same side. It recurred on two occasions and a below-knee amputation was performed seven years after the first operation. The wound failed to heal, and it was then discovered that a chondrosarcoma had developed at the site from which the grafts were taken. The patient died from lung metastases twelve years after the initial operation.
Case 8—Chondrosarcoma of femur in a man of 53 years. Figure 32—The tumour is mainly extraosseous with some periosteal reaction at its lower border. There is faint speckling of the soft tissues. Figure 33—A lobulated, gelatinous chondrosarcoma with some central haemorrhage and degeneration is present in the lower end of the femur and in the soft tissues, the cortex having been destroyed. The knee joint appears free of tumour. Figure 34—Metastases in the lungs are seen nine years after the patient's first symptoms. He lived for seven years after this radiograph was taken. Figure 35—Recurrent chondrosarcoma in the amputation stump.
There are two possible sources of error in the histological interpretation of a biopsy. The pathologist may underestimate the malignant propensities of a cartilage tumour or he may be presented with a portion of tissue from the less malignant part. Treatment must always be based on the most unfavourable features of the tumour, be they clinical, radiographic or histological (Coley and Higinbotham 1954).

The following is an example of a low grade chondrosarcoma which appeared to be benign on histological examination of the biopsy.

**CASE REPORT**

**Case 9**—This sixty-seven-year-old housewife gave a history of pain in the right buttock of six months duration, radiating down to the knee and inner side of the leg. It had gradually increased in severity and clinical examination revealed a tender swelling of the middle third of the shaft of the right femur. Radiography disclosed a transradiant lesion which had produced considerable expansion of the bone.

**Fig. 36**—Chondrosarcoma of the femur in a woman of 67 years. **Fig. 37**—There is some expansion and buttressing of the mid-shaft of the femur. The endosteal surface of the cortex is a little scalloped. Blotchy calcification in the medullary canal is seen in the upper third of the shaft. **Figure 37**—Tissue removed at biopsy is degenerate and the nuclei are scanty and pyknotic. (Haematoxylin and eosin, × 300.)

Extensive subperiosteal new bone formation extended from the lesser trochanter to the lowest third of the shaft of the femur. Blotchy calcification was seen in the medullary canal between the upper border of the translucent lesion and the intertrochanteric line (Fig. 36). A small cube of tissue was removed from the lateral aspect of the tumour for microscopic examination. Histologically, this was largely degenerate and showed no evidence of malignancy, the nuclei being scanty and pyknotic (Fig. 37).

The patient experienced complete relief from pain after the biopsy and refused further surgery at this time. Because the clinical and radiographic diagnosis was that of low grade chondrosarcoma, the patient was kept under review. A year later she stated that the pain had returned and was now severe. Radiographs indicated some increase in size of the tumour, and a disarticulation at the hip was performed. Six years later there is no recurrence of the tumour nor are there any metastases.

Examination of the femur revealed in the proximal medullary cavity partially calcified discrete nodules of apparently innocuous cartilage tumour. In the expanded part of the shaft the tumour was more myxomatous (Fig. 38) and this corresponded to microscopic features of a low grade chondrosarcoma, there being some plumping of nuclei and numerous cells with double nuclei (Fig. 39).
Case 9—Chondrosarcoma of the femur in a woman of 67 years. Figure 38—The more opaque calcified nodules in the upper femoral shaft contrast with the gelatinous mucoid tumour in the area of medullary expansion. Figure 39—Tissue from the amputation specimen at the level of the bone expansion has the appearances of a low grade chondrosarcoma with plump nuclei and numerous double nuclei. (Haematoxylin and eosin, ×250.)

Central chondrosarcoma in a woman aged 55 years. Figure 40—There is a well defined transradiant lesion at the base of the femoral neck and no buttressing of the cortex. This tumour was regarded initially as an enchondroma but there was a history of pain in the right groin for six months suggesting malignancy. Figure 41—Plump nuclei, numerous double nuclei and occasional cells with more than two nuclei establish the diagnosis of chondrosarcoma. (Haematoxylin and eosin, ×300.)
Sometimes the histological diagnosis of malignancy cannot be made on tissue submitted from a low grade chondrosarcoma, but if the clinical and radiographic features are those of a malignant cartilage tumour, appropriate surgical treatment should be undertaken. Fortunately, although there was a delay of a year between biopsy and amputation, the patient is well, without recurrence, six years later.

Occasionally the radiographic appearances may not suggest malignancy although the clinical and histological features are those of a low grade chondrosarcoma (Figs. 40 and 41).

PRINCIPLES OF TREATMENT

Chondrosarcoma is a radio-resistant tumour. We are not aware of any that have been successfully treated by radiotherapy, even of the super voltage type. This is confirmed by others (Lindbom and colleagues 1961, Platt 1962, McKenna and colleagues 1966). The treatment is therefore by radical resection or amputation. The choice between these two procedures often requires considerable judgement and is based on a number of factors, such as the size and site of the lesion and its degree of malignancy.

Low grade tumours can often be treated successfully by resection, especially if they are small, and situated distal to the upper end of the humerus and femur (Fig. 42). Hatcher (1956)

![Figure 42](image)

This peripheral chondrosarcoma arising in the fibula in a 38-year-old housewife was treated successfully by radical resection.

has even advocated wide excision for tumours of the upper end of the femur, function being restored by bringing the femoral shaft into contact with uninvolved ischium; alternatively, the upper end of the femur can be replaced by a prosthesis. If a chondrosarcoma is regarded as suitable for resection the tumour, and any biopsy wound, must be excised en bloc with an adequate margin of normal tissue so that the surgeon does not break into or see the tumour at any time (Dahlin and Henderson 1956).

Although there is a greater risk of recurrence after resection than after amputation, this does not necessarily prejudice the patient's prospects of long-term survival, provided it is still possible to amputate the limb, keeping well clear of the tumour. Under these circumstances no further attempt at local excision should be made. Most pelvic tumours are best treated in the first place by a hind-quarter amputation, for recurrences can seldom be cured by a hemipelvectomy (Case 11).

The more malignant chondrosarcomata (Case 11), large peripheral tumours (Case 12) and central ones that have involved a considerable length of the shaft of a long bone (Case 9) should be treated by amputation. Because the spread of chondrosarcomata is often well beyond the radiological limits of the tumour, it is a sound policy to amputate at least one
joint ahead of the lesion to avoid the risk of a recurrence in the stump (Case 8) (Lichtenstein and Jaffe 1943, Goldenberg 1964). Tumours of the femur or humerus other than those suitable for resection should be treated by disarticulation of the hip or shoulder, unless the

![Fig. 43](image1)
![Fig. 44](image2)
![Fig. 45](image3)

**Case 10—Central chondrosarcoma of sternum.** Figure 43—Eighteen months after the onset of symptoms. Figure 44—Five years later. Figure 45—Nine years after onset.

![Fig. 46](image4)
![Fig. 47](image5)

**Case 10—Histological appearances.** There is no apparent increase of histological malignancy between the tumour removed at the first resection (Fig. 46) and that removed at the third, three years later (Fig. 47). Both show the features of a low grade chondrosarcoma. (Haematoxylin and eosin, × 250.)

tumour has perforated the cortex and invaded the soft tissues around the joint when a hind-quarter or fore-quarter amputation is indicated.

It is remarkable how much inadequate surgery is performed on these tumours in which "the pathologist is often the accomplice of the hopeful surgeon" (O'Neal and Ackerman
1952). There is never any justification for enucleating or curetting a potentially malignant cartilage tumour. Any supposedly benign tumour that recurs is at least locally malignant irrespective of the histological diagnosis, and should usually be treated by amputation or, if this is not possible, radical resection. The following case is an example of ineffective treatment which was responsible for the ultimate death of the patient.

CASE REPORT

Case 10—This forty-four-year-old man attended hospital in October 1950 complaining of pain in the sternum for eighteen months and of a swelling which had been slowly increasing in size for the past six months (Fig. 43). The tissue from a biopsy was reported to be a simple chondroma and no treatment was given. The tumour continued to grow and incomplete excisions were performed in 1951, 1953 and 1954. On each occasion the tissue was submitted for histology and was reported to be benign. There was another recurrence and the tumour was now too large for radical surgery (Fig. 44); it continued to grow and in 1959 was treated by super voltage radiotherapy (Fig. 45). He died in 1961 from pressure of the mass on the heart and great vessels, but there was still no clinical or radiological evidence of metastases.

On reviewing the numerous histological sections from the three surgical interventions, it was plain that this had been a low grade chondrosarcoma from the outset. In the specimens from each of the three operations there was plumping of nuclei and numerous double nuclei; virtually no increase of histological malignancy could be detected (Figs. 46 and 47).

TUMOURS IN SPECIAL SITES

Ribs and sternum—All cartilaginous tumours of the ribs and sternum should be regarded as potentially malignant; they are best treated by radical resection (Mayer 1941, O’Neal and Ackerman 1951). The tumour often extends for some distance within the bone and it is important to excise one or more ribs and the intercostal muscles en bloc, with any pleura, lung or pericardium that may be infiltrated by the tumour (Figs. 17 and 18) (Dorner and Marcy 1948).

Shoulder girdle—Low grade chondrosarcomata of the scapula can often be successfully treated by total scapulectomy, with the preservation of useful function in the upper limb (Platt 1962). Similar tumours of the upper end of the humerus which have not perforated the bony shell may be resected with adjacent muscle, keeping well clear of the tumour, and the upper end of the humerus can be replaced by a metallic prosthesis or a long fibular graft (Platt 1951, Burrows 1964).

Chondrosarcomata that have invaded the shoulder joint are a difficult problem and most of them are best treated by a fore-quarter amputation. It is sometimes possible to preserve useful hand function even after extensive resection of the shoulder girdle, provided the tumour has not infiltrated the soft tissues (Francis and Worcester 1962). The shoulder joint must be removed in its entirety with the humerus by dividing the base of the glenoid whilst the capsule of the resected specimen is kept intact. It is important to preserve the attachment of the lowest fibres of pectoralis major to the humerus to prevent traction on the neurovascular bundle.

Pelvis—Most tumours of the pelvis and in particular those on its inner surface (Ghormley and colleagues 1946) are best treated by a primary hind-quarter amputation (Case 12). Occasionally small low grade peripheral chondrosarcomata may be treated by radical resection, especially if they are situated in the anterior part of the ilium and it would still be possible to treat a recurrence by hemipelvectomy. Exceptionally pedunculated, low grade tumours of the posterior part of the ilium may be resected. If any chondrosarcoma of the pelvis recurs it should, regardless of its grade of malignancy, be treated by hind-quarter amputation if this is still feasible. The prognosis is much worse when the operation is done as a last resort after one or more unsuccessful attempts at a local resection (Ghormley 1951, Troup and Bickel 1960).
Case 11—Chondrosarcoma of the right ischium. Figure 48—The transradiant lesion has caused some expansion of the bone; there is no calcification within the tumour. Figure 49—A radiograph taken six weeks later shows that the tumour has increased in size and the cortex is perforated. These features and the absence of calcification indicate a more malignant type of chondrosarcoma. Figure 50—Two mitotic figures (arrowed) are seen in this chondrosarcoma which contains plump vesicular nuclei and moderate numbers of double nuclei. (Haematoxylin and eosin, × 300.)

Case 11. Figure 51—The cut surface of the ischium is seen in the specimen which has been dissected free of soft tissues. Chondrosarcoma is present in the medullary cavity and has destroyed the cortex. The soft-tissue extension has surrounded the bone. Figure 52—There are metastases in the bones and soft tissues of the foot.
CASE REPORT

Case 11—This thirty-four-year-old housewife complained of pain in the right hip radiating to the knee, of two years duration. There was tenderness over the ischial tuberosity and a radiograph revealed a translucent, uncalcified, expanding lesion of the ischium (Fig. 48). The patient did not return for six weeks and in that time the tumour was found to have increased in size and to have ruptured the bone cortex (Fig. 49).

A biopsy was performed through a transverse incision in the fold of the buttock and microscopy confirmed the clinical diagnosis of a chondrosarcoma. It appeared to be of moderate malignancy, being very cellular with a poorly formed matrix, fairly numerous mitotic figures, tumour giant cells and large vesicular nuclei (Fig. 50). A block excision of the sarcoma and surrounding muscle was performed, keeping well clear of the tumour (Fig. 51).

The patient's progress after operation was satisfactory and she remained well for just over three years when a recurrence was discovered, but hind-quarter amputation was now impossible. Six months later a radiograph revealed bilateral pulmonary metastases and the patient died four years and nine months after operation. At necropsy, a large recurrence of the tumour filled much of the right side of the pelvis, obstructing the ureter and invading the labia. In addition, there were widespread metastases. The bones of the left foot were largely replaced by tumour tissue (Fig. 52) and there were also numerous subcutaneous nodules in the left leg. Metastases were present in the ribs, in the lung parenchyma and the right kidney was almost completely destroyed by chondrosarcoma.

The correct treatment for this tumour in view of its rapid growth and proximity to the perineum was a hind-quarter amputation. Metastatic spread of chondrosarcoma to other bones is unusual, though subcutaneous metastases have previously been reported by Cruikshank (1945).

In large peripheral pelvic tumours there is seldom any difficulty in making a radiographic diagnosis. In these cases amputation should be performed without a preliminary biopsy to avoid disseminating tumour cells in the soft tissues. For tumours of the middle and posterior third of the ilium it is wise to excise the ilium completely and, if the tumour encroaches on the symphysis pubis or sacro-iliaic joint, a portion of the ala of the sacrum or the opposite pubis should be removed with the amputation specimen.

Sugerbaker and Ackerman (1945) reported eight local recurrences after forty-five hind-quarter amputations for malignant tumours of the pelvis; four of these were in the part of the ilium that had been left behind and the remainder were in the soft tissues.

CASE REPORT

Case 12—This forty-seven-year-old road worker of low intelligence complained of a constant gnawing pain in the region of his right hip for nine months and a swelling in the front of the hip joint which he alleged he had noticed only six weeks previously. Clinical examination revealed a hard mass attached to the pelvis about nine inches in diameter, which occupied the groin and the adductor region of the right thigh. Radiography disclosed a large, heavily calcified tumour arising from the ischial and pubic rami, and extending almost to the symphysis pubis; the appearances were typical of a peripheral chondrosarcoma (Fig. 53). Hind-quarter amputation was performed without a preliminary biopsy; part of the left pubic bone was removed with the limb in order to keep clear of the tumour. The patient is well without recurrence or metastases five years after operation. Examination of the amputation specimen showed the typical appearances of a lobulated hyaline cartilage tumour with central calcification (Fig. 54). Numerous blocks taken from the periphery of the tumour revealed only occasional small foci of plump or double nuclei. Neither cells containing more than two nuclei nor mitotic figures were seen. The appearances were those of a "borderline" tumour.

This type of lesion has been described as an extensive or giant osteochondroma and some are said to show no capacity for malignant activity (Aegerter and Kirkpatrick 1958). However, Lindblom and his colleagues (1961) found that if these tumours were untreated they behaved with low grade malignancy and might eventually metastasise (Sherman 1955, Ghormley and colleagues 1946, Coley and Higginbotham 1953). Their malignant potentialities have also been emphasised by O'Neal and Ackerman (1952).

PROGNOSIS AND RESULTS OF TREATMENT

The prognosis in chondrosarcoma is mainly influenced by the degree of malignancy of the tumour and the treatment. Recently, the results of treatment in two large and well documented series of chondrosarcomata have been reported (Dahlin and Henderson 1956, McKenna and colleagues 1966). They are in broad general agreement. In the latter series the
five-year survival rates were: low grade tumours 78 per cent; moderate grade tumours 53 per cent; high grade tumours 22 per cent.

Long-term survival rates are a little lower than this because metastases may appear at least up to ten years after treatment.

No patients were cured in either series by radiotherapy alone, confirming that irradiation has no place in the treatment of surgically accessible tumours.

The percentage of patients alive without recurrence five years after treatment is much higher when the surgical management is correct (Morton and Mider 1947). By this is meant wisely chosen amputation or resection, without undue delay and preceded if necessary by biopsy. In the series of McKenna and his co-workers, the five-year survival rate after ideal treatment was 48-6 per cent and in Dahlin and Henderson’s series the ten-year survival rate was 41 per cent; however, when treatment was inadequate it fell to 3-7 per cent.

In the series of McKenna and his colleagues, the results of radical resection were not as favourable as those of amputation. At five years there were 31-7 per cent of survivors after resection and 47-6 per cent after amputation. However, some of the tumours, for instance those of the chest wall, could only be treated by resection and it does not follow, therefore, that resection would be less satisfactory than amputation for small low grade tumours in the distal part of the limb.

The prognosis in secondary chondrosarcoma arising from an exostosis in diaphysial aclasis is exceptionally good. Seven of the eight patients treated by amputation by McKenna and his colleagues were alive and well five years later.

These results confirm that chondrosarcoma has a relatively good prognosis when compared with other bone sarcomata, and that a long-term survival of approximately 40 per cent of patients can be anticipated after correct surgical treatment.

**MESENCHYMAL CHONDROSARCOMA**

For the sake of completeness this unusual tumour is worthy of mention.

In 1959 Lichtenstein and Bernstein described twenty-five unusual bone tumours, all having an apparent relation to cartilage. Two of these, to which they gave the name
mesenchymal chondrosarcoma, consisted of a compact, richly cellular spindle-cell stroma with scattered islands of chondroid differentiation. In each case the tumour presented in a single bone and then eventually spread to other bones, visceral involvement being minimal. Three years later Dahlin and Henderson (1962) published a description of ten more tumours of similar histological appearance and Dowling (1964) reported further progress on one of these and added another case. The initial sites involved were vertebra, rib, maxilla, parietal bone, ilium, scapula, and tarsal and metatarsal bones. Dowling's patients had primary tumours in the temporal muscle and meninges. The patient's ages ranged between twenty-one and fifty-eight years and eight men and five women were affected. The symptoms were of pain, swelling or of pressure on neural structures and varied in duration from a few months to several years. In only a few instances were radiographs available and these usually showed sclerosing, calcified lesions though metastatic bone foci in one case were chiefly lytic. The tumours were well defined and appeared on naked eye examination to consist of a partly calcified fibrocartilaginous mass. Microscopy revealed a highly cellular tissue rich in small, delicate, spindle cells with a variable number of mitotic figures. Sometimes cells were clustered around capillaries in a manner reminiscent of haemangiopericytoma (Dahlin and Henderson 1962). Islands of chondroid differentiation were scanty or numerous, the homogeneous matrix containing lacunae with cells having small, rather uniform nuclei, more regular than those seen in the usual form of chondrosarcoma. The cartilage-like matrix was often calcified and sometimes converted to bone. The clinical outcome in this small group of patients was very variable but there was a tendency to involve several bones sometimes after a considerable delay. In some cases a multicentric origin has been suggested (Lichtenstein 1965). The failure of local surgery or irradiation to control the tumours suggested that radical surgery offers the best hope of cure.

**CASE REPORT**

**Case 13**—This twenty-nine-year-old housewife had suffered some swelling of and discomfort in the right knee for ten years. In the last two years the pain had become almost continuous and increased

![Fig. 55](image)

*Case 13—Mesenchymal chondrosarcoma. The radiographs show the blotchily calcified tumour behind the knee.*

in severity so that it kept her awake at night. There had also been a gradually increasing block to full flexion of the knee. Radiological examination revealed a blotchily calcified mass attached to the posterior aspect of the lower end of the right femur (Fig. 55). A biopsy showed the lesion to consist of a mass of small spindle and rounded cells with some plaques of chondroid matrix, partially calcified. A tentative diagnosis of mesenchymal chondrosarcoma was made and a mid-thigh amputation was
Case 13—Mesenchymal chondrosarcoma. In the slab radiograph erosion of the periosteal surface of the cortex is seen in relation to an uncalcified part of the tumour.

Case 13. Figure 57—A plaque of chondroid tissue with round lacunae is surrounded by fibrous tissue in which there are collections of small spindle cells. (Haematoxylin and eosin, ×42.) Figure 58—The chondroid matrix contains lacunae, some empty, others with pyknotic nuclei. The small spindle cells of the tumour here show intercellular vacuoles. (Haematoxylin and eosin, ×120.)
performed. The lesion consisted of a lobulated glassy tumour, with irregular areas of yellowish calcification which appeared to have arisen beneath the periosteum, and was invading the underlying cortex (Fig. 56). The undifferentiated small spindle and round cells in places had a high mitotic rate and there was invasion of periosteal vascular channels, probably dilated veins. Some zones of chondroid matrix were calcified, patchily acellular and partially converted to bone by a process of endochondral ossification. The cells in the cartilaginous matrix were small with uniform, rather pyknotic, nuclei (Figs. 57 and 58). These histological appearances justified the description of mesenchymal chondrosarcoma. The patient is alive and well nearly two years following amputation with no evidence of local recurrence or of metastases. However, in view of the published cases with metastases occurring as late as twenty-two years after initial treatment the prognosis must remain guarded.

**SUMMARY**

1. Chondrosarcoma is a malignant tumour of bone with clinical and morphological features which distinguish it from osteosarcoma.
2. Cartilage tumours present an unbroken spectrum in their clinical behaviour and histological appearances from the entirely benign to the frankly malignant.
3. A few chondrosarcomata, particularly those in children and young adults, run a rapidly fatal course but in general they metastasise late and some kill by local extension of the tumour.
4. "Secondary" chondrosarcomata arising from a pre-existing osteocartilaginous exostosis or enchondroma are mostly low grade tumours.
5. The first appearance of an osteocartilaginous exostosis after skeletal maturity, renewed growth, or pain unassociated with a fracture, should arouse suspicion of malignancy in any cartilage tumour.
6. Cartilage tumours of the trunk and upper end of femur and humerus are especially liable to sarcomatous change.
7. Although most benign cartilage tumours occur in the hand and foot they rarely become malignant with the exception of those in the calcaneus.
8. If biopsy is necessary it should be of the incisional type, a generous amount of material being removed from the edge of the tumour. Calcified, degenerate areas must be avoided.
9. In low grade tumours microscopic fields judged to be malignant by Lichtenstein and Jaffe's well established criteria may be scanty and many paraffin sections should be examined. Absence of mitotic figures, heavy calcification and poor vascularity are no guarantee of benignity.
10. Information as to the site of the tumour and age of the patient must be available to the pathologist if a useful report is to be given.
11. In "borderline" tumours or where any difficulty in diagnosis arises the clinical, radiographic and histological features must all be taken into account and treatment based on the most unfavourable features.
12. Chondrosarcoma is a radio-resistant tumour and treatment is by radical excision or amputation.
13. Malignant cartilage cells implanted in the tissues at operation will often continue to grow and in all instances the biopsy wound and surrounding tissues must be removed en bloc with the tumour.
14. Small, low grade, readily accessible, peripheral tumours may be successfully treated by excision with a wide margin of healthy tissue.
15. In the limbs or pelvis large tumours and those of high grade malignancy should be treated by amputation. Since marrow permeation is often greater than the radiograph suggests amputation should, as a rule, not be performed through the bone in which the chondrosarcoma is situated.
16. Recurrence carries the danger that an initially accessible tumour becomes inaccessible and inoperable and, less frequently, a low grade tumour recurs in a metastasising form.
17. Recurrence is frequent after inadequate surgery; it indicates that the tumour is at least locally malignant and a cure can usually only then be achieved by more radical surgery.
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