Section of Radiology

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Juvenile Rheumatoid Arthritis (Still's Disease)

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RHEUMATOID arthritis is a subacute or chronic non-suppurative inflammatory arthritis of unknown causation, usually but not invariably affecting many joints. It has long been recognized that it may occur in young persons. In 1897, G. F. Still, while still a Registrar at the Hospital for Sick Children, Gt. Ormond Street, published his observations on 22 cases, on 3 of which autopsies had been performed. He distinguished between two groups—(i) cases of chronic progressive polyarthritis indistinguishable from those seen in adults, and (ii) cases with similar joint changes but associated with enlargement of the spleen and lymph glands, and sometimes with adhesive pericarditis. Since then this latter group has been referred to as Still's disease, though in common parlance many clinicians refer to all cases of juvenile rheumatoid arthritis by that name. A similar condition associated with splenomegaly, hepatomegaly and leucopenia in adults was described in 1924 by Felty.

It is now well recognized that rheumatoid arthritis is a systemic disease; arthritis is not the disease itself, but merely one of its manifestations. In adults the arthritic manifestation is usually clinically the most obvious and symptomatically the most important aspect of the disease. In young persons, however, the bone and joint symptoms may be the least obvious clinical aspect of the condition and may appear late in the course of the disease. In retrospect it seems probable that Still's distinction of two separate groups was artificial, that he was merely describing two extremes, and that we are dealing with one disease in which sometimes the systemic signs predominate, on other occasions arthritis is the predominant sign, while in yet other cases both advance side by side. In children and young persons, the general reaction, the systemic involvement, is often severe, but the acute adult case also occurs as was described by Felty (1924). The occurrence of these occasional acute adult cases, together with the recognition of the less active form in childhood, makes it appear probable "that Still's disease is in reality a special clinical type of rheumatoid arthritis generally encountered at an early age" (Schlesinger, 1938).

The age of onset varies, only 9 cases have been reported in the first year of life (Tho, 1947), and it usually occurs after the age of 2, the peak incidence being in the 2 to 5 year age-group. The sex distribution is roughly equal; Atkinson (1939) stated that of the first 84 cases reported in the literature 48 were males.

The clinical picture obviously varies according to whether the systemic or the arthritic signs predominate. At one end of the scale, the picture of the acute case is one of acute onset, joint pains, fever, a rash, leucocytosis, anæmia and possibly pericarditis, with later an adenitis and splenomegaly. In a recent review of 20 cases of this type Schlesinger (1949) described his own observations as to the onset and the frequency of symptoms and signs. In his experience the commonest presentation was of a child suffering from an arthralgia with some initial fever. In 15 of his 20 cases a widespread rash occurred. Anæmia was always present, and an early leucocytosis of 15,000–20,000 W.B.C. occurred almost invariably, while in some cases the latter passed later to a leucopenia. Pericarditis, if it occurred, did so early and Schlesinger made the point that it may in fact precede all other manifestations and be mistaken for acute rheumatic pericarditis. Pleurisy and pneumonitis may also occur and jaundice has been described. However, not all cases are acute, nor does every case necessarily exhibit all these signs to any marked degree, and at the other end of the scale, the onset may be insidious with gradually increasing joint pains

and joint swellings, the counterpart of the adult onset. Between these two extremes all grades of clinical picture may present. As with many chronic arthritic diseases, iridocyclitis and iritis occur occasionally with the condition. A minor, yet perhaps important, point is the fact that juvenile rheumatoid arthritis occasionally occurs associated with psoriasis.

All observers are agreed that the disease occurs in its most virulent form in the earlier years of life, and that besides being less common in the school years, here it runs a more benign course. Recovery from the disease may be complete, or it may proceed to a chronic polyarthritis; or, it may be arrested at any stage. Many cases, especially those showing the more marked systemic manifestations, end fatally. Tho (1947) has estimated that in those children affected before school age, there is a 30% mortality. In particular, those cases in which a leucopenia develops tend slowly to deteriorate, to become grossly debilitated and to die, usually of intercurrent infection. Amyloidosis has frequently been reported in the later stages of the disease and of course usually ends in death. Many observers have endeavoured to prognose in the condition, but no clear criteria have emerged. As a generalization it is true to say that the younger the afflicted child is at the onset the worse is the prognosis. Similarly Colver (1937) stated that in his experience those cases which survived five years from the onset were unlikely to die from its results in childhood, though this observation has been disputed by other clinicians.

Those cases of chronic polyarthritis but without general systemic reaction do not die; chronic polyarthritis of this type in childhood is not a killing condition.

The joint involvement which, as has already been remarked is often late, does not always follow the adult pattern. Hands and wrists are frequently the site of peri-articular swellings, stiffness and pain; knees are commonly involved but any peripheral joint may be implicated. Sometimes, the condition may present as, and remain, a monarticular arthritis; attention is drawn to this in the literature, and the present writer has seen more than one such case. An interesting feature was first noted by Still (1897) who in his original paper said "the joints earliest affected were usually the knees, wrists and those of the cervical spine". Schlesinger (1938) and other observers have confirmed this early involvement of the cervical spine, and the experience of the present writer has shown frequent clinical involvement of that region but less commonly detectable radiological changes.

Pathology

The ætiology of rheumatoid arthritis in children, as in adults, is still very much open to speculation. Peripheral vascular disease, virus infection, absorption of toxins from focal infections, tissue hypersensitivity, hæmatogenous bacterial infection of the joints, as specific factors have all had their adherents and disciples. An endocrine factor, the suppression of adrenal cortical function or an imperfect utilization of cortisone, the produce of the adrenal cortex, is the ætiological factor now being investigated in many research centres. As yet no clear conception has emerged, but some relationship to the so-called "alarm-reaction" as expounded by Hans Selye (1949), this in turn provoking an abnormality or imbalance in endocrine function, seems likely as a predisposing cause, though in many cases a more specific precipitating or exciting factor may be involved. How the "alarm-reaction" functions in infants of 2 or 3 years of age is a point not yet elaborated.

It does seem possible, however, that the ætiological factor that provides the necessary medium for the morbid changes that occur in this disease will eventually be elucidated in the field of endocrine balance or imbalance.

The morbid changes concern the radiologist more directly. As has been already mentioned this is a generalized disease. In addition to joint pathology, pathological changes occur in muscle, in the subcutaneous tissues, in the heart, and in regional lymph glands, in addition to various changes in biochemical estimations.

In muscle, in addition to atrophy beyond what might be expected as a result of the disability, histological changes in the form of small focal perivascular accumulations of lymphocytes and plasma cells are found.

Subcutaneous nodules are commonly found along the border of the ulna, over the sacrum, and in other sites. These are granulomatous structures, formed of connective tissue cells with necrotic centres, and are characteristic of the disease.

In children adhesive pericarditis is a common occurrence, and it is becoming more widely recognized that organic heart disease is a not uncommon finding in adult cases of rheumatoid arthritis. This subject has recently been examined in detail by Bywaters (1950). The first to draw attention to this feature were Bagenstoss and Rosenberg (1941); in a series of autopsies on cases with rheumatoid arthritis, chronic rheumatic heart disease was found in 53% of cases as compared with 5% in a control series. Such remarkably high figures have not been confirmed by subsequent observers, but in the majority of published series the incidence has been above 25%.

The lymph glands, when involved, show a simple reactive hyperplasia.

The joint changes consist primarily of a marked proliferation of synovial membrane, with hypertrophy of the connective tissue in the marrow spaces in the subchondral bone, and of vascularization and fibrosis of the joint capsule. All other changes in the joints are secondary to these. As the synovial tissue proliferates it forms a very vascular and fibrous granulation tissue which grows over the articular cartilage and then invades it becoming completely adherent to it. If this inflammatory condition resolves, fibrosis follows, the invading granulation tissue forming a thick fibrous membrane. If the destruction of articular cartilage has been extensive and these fibrous adhesions are in contact from opposite sides of the joint, they may ossify, thus producing a bony ankylosis. If the active invasive stage persists articular cartilage may be completely destroyed and subchondral bone invaded and destroyed sometimes to a very considerable extent. Alongside these processes actual bone atrophy takes place.

Vascularization and fibrosis of the capsule together with the associated muscle atrophy may lead to contractures and deformities.

Thus, the condition is primarily a synovitis, and if a spontaneous remission occurs in a joint early in the course of the disease, the cartilage and bone may escape all injury.

Radiological Appearances

In the adult, the first radiological indication commonly described is a regional osteoporosis affecting all the bones. This shows essentially as an exaggeration of contrast in shadowing between the shafts and ends of the bones. At the same time as this, the spindle-shaped swelling of the soft tissues around the affected joints can be seen, and some observers have drawn attention to a slight increase in the joint space due to effusion. As the osteoporosis increases destruction of articular cartilage occurs, producing a diminished joint space on the radiograph.

At this stage it may be possible to detect a localized osteoporosis of articular cortex (Fig. 1A) and, subsequently, destruction of articular cortex and underlying cancellous bone especially at the articular margins (Fig. 1B). As destruction proceeds joints may become completely disorganized, especially as contractures due to muscle changes are occurring at the same time. When all articular cartilage has been destroyed some ossification of the intra-articular fibrous tissue may take place leading to ankylosis, and thence to the more gross manifestations with which all radiologists are familiar. In particular, attention must be drawn to the bony destruction that sometimes occurs at the ends of long bones due to excessive synovial proliferation and invasion (Fig. 2). At any stage the process may be arrested with some return towards normal bone density but without reconstruction of destroyed bone or cartilage.

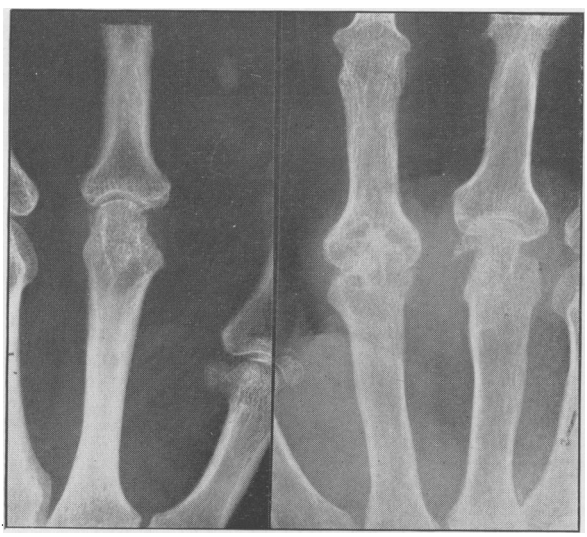


FIG. 1A.

FIG. 1B.

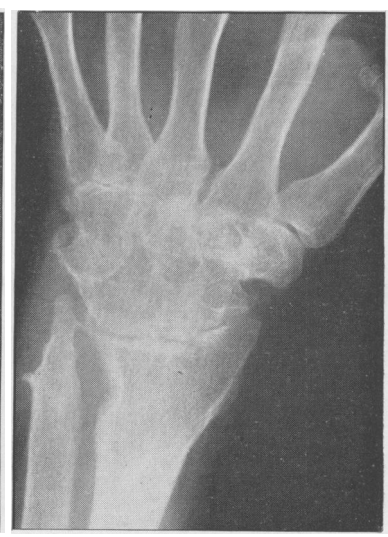


FIG. 2.

FIG. 1 A and B.—Adult rheumatoid arthritis showing: A, Osteoporosis of articular cortex; B, Destruction of underlying cancellous bone.

FIG. 2.—Adult rheumatoid arthritis showing destruction of end of ulna and ankylosis of carpus.

To this description must be added an earlier sign. Tepper and Haspekov (1939) and later Knutsson (1943) drew attention to the fact that it is frequently possible to demonstrate a periosteal reaction along the shafts of bones near an involved joint. In the adult case of insidious onset this is rare but in the more acute adult case of sudden onset, the Felty's syndrome, it is sometimes possible to show this change quite conclusively (Fig. 3).

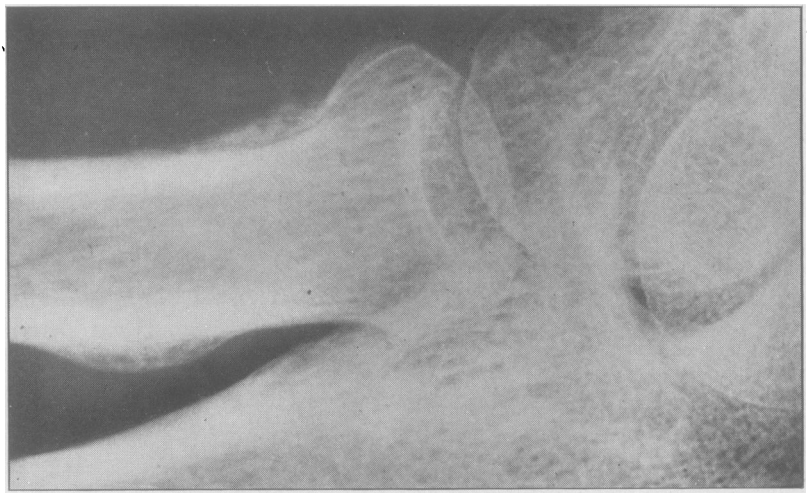
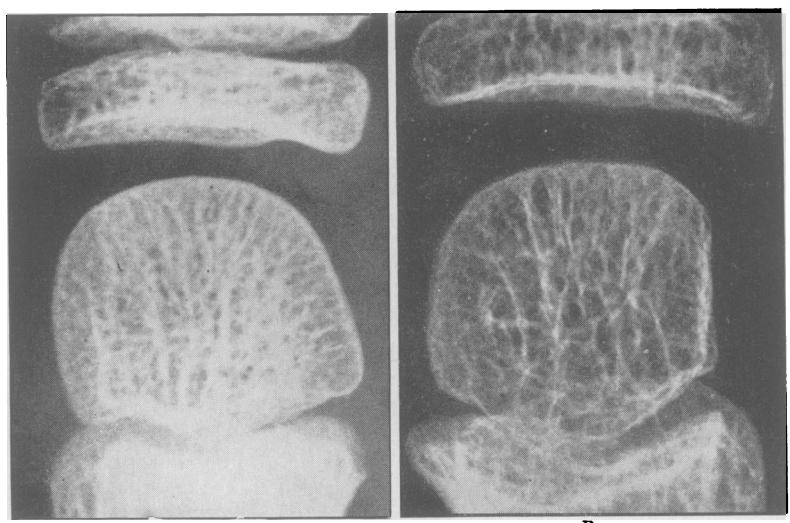


FIG. 3.—Periosteal reaction on neck of radius in a case of Felty's syndrome.

This feature is more common in childhood, and often the first radiological sign to be detected is a periosteal reaction along the shaft of a metacarpal or metatarsal, this, in turn, drawing attention to early changes in the adjacent joint.

Not all cases, however, show this sign and frequently all that can be detected is a generalized osteoporosis involving the bones of hands or wrists.

The subject of osteoporosis is one to which radiologists must pay close attention. Barclay (1947) first introduced the techniques into this country of using fine grain film for micro-radiography. That technique can be adapted to use in the living subject to produce, as it were, a radiograph of living bone histology. Kodaline or Ilford line film can be used for demonstrations of the small joints of the hand. A long exposure of 10 or 12 seconds, and a low kilovoltage, i.e. 45–50 kV., is required. The resultant image can be enlarged up to



A. B.

FIG. 4 A and B.—Fine grain technique showing: A, Normal metacarpal head in a 10-year-old boy. B, Osteoporosis in rheumatoid arthritis in a 10-year-old boy.

10–12 diameters, or examined by means of a dissecting microscope, without interference by film grain. Thus a detailed analysis of bone structure can be made.

Fig. 4A shows the head of the fourth metacarpal of a 10-year-old boy using this fine grain technique and enlarged by about 3 diameters. The detail of the bone trabeculæ, showing as a fine regular meshwork of bony strands, can be clearly seen. Fig. 4B shows the head of the fourth metacarpal of a 10-year-old boy with rheumatoid arthritis. The routine films showed his hands to be osteoporotic. Analysis of the enlarged fine grain film shows the osteoporosis to be due to the actual removal of some bony trabeculæ; some dense strands of bone remain but the intervening strands have been partially removed or destroyed. This osteoporosis, thus, is due not to decalcification, but to actual destruction or removal of some bony trabeculæ: a point worthy, perhaps, of further investigation.

The widened intertrabecular spaces thus produced remain and the bony trabeculæ are not reconstructed even if the pathological process becomes arrested.

An analysis of the radiological appearances that may be seen in cases of juvenile rheumatoid arthritis shows that they fall into four categories: (i) Periosteal changes. (ii) Effect on articular cartilage. (iii) Effect on bone. (iv) Effect on growth, or changes in bony structure due to growth.

In discussing these points certain other factors must be considered, namely: (i) The speed at which the radiological changes progress, and their correlation with the clinical picture. (ii) Whether the condition is monarticular or polyarticular, and, if the latter, the distribution of joints involved. (iii) In particular two features must be examined: (*a*) the common involvement of the cervical spine; (*b*) the association of the condition with psoriasis.

Periosteal changes (*see* Table I).—A periosteal reaction is most commonly seen along a metacarpal or metatarsal. It often involves the whole length of the shaft of the bone, and usually only the medial or lateral border, not both. The adjacent joint is usually, but not invariably, the site of articular changes. It seems likely that the periosteal changes are due not to a hyperæmia of the synovium or capsule of the adjacent joint, but to the connective tissue reaction in the marrow spaces of the bone or to a generalized connective tissue reaction—periosteum itself being composed of connective tissue cells.

TABLE I

COURSE OF PERIOSTEAL REACTION IF PRESENT

Complete resolution	Ossification		
	Remodelling of bone leaving no trace	Persistence as cortical thickening along shaft of bone	Persistence as a periosteal tag of bone

The periosteal reaction may resolve or ossify. If it resolves it usually does so quite rapidly in the course of a few weeks leaving no trace.

Case I.—A girl, aged 10 years, had complained at school of stiffness in the small joints of the hands and wrists for two months. Radiological examination revealed a periosteal reaction along the shaft of the second right metacarpal and some involvement of the metacarpophalangeal joint (Fig. 5A). No other joint showed radiological changes, and in particular her right wrist appeared normal (Fig. 6A). She had no systemic signs and her general health was relatively good. Ten weeks later (Fig. 5B) the periosteal reaction had resolved, but six months later there was radiological evidence of destructive changes in her radiocarpal and mid-carpal joints (Fig. 6B). Twelve months after first being seen there is radiological evidence that the condition is advancing in the small joints of both hands and wrists and both feet, though clinically she is still relatively well, and is maintaining good movement in her joints, and is not deteriorating so rapidly as the radiological picture appears to indicate.

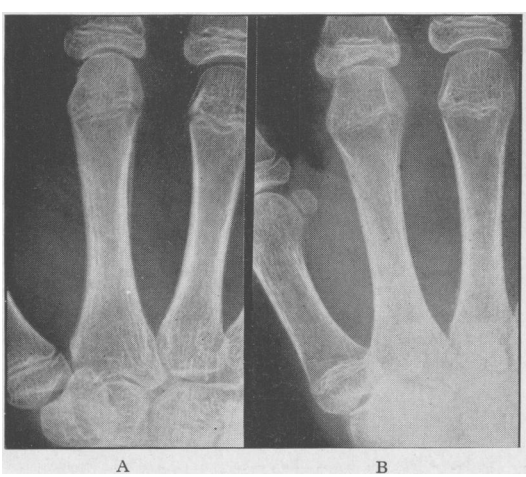


FIG. 5 A and B (*Case I*).—A, Periosteal reaction. B, Ten weeks later.

If the periosteal reaction ossifies remodelling may take place leaving no trace of the subperiosteal bone apposition, or it may persist either as a cortical thickening along the shaft or as a periosteal tag of bone.

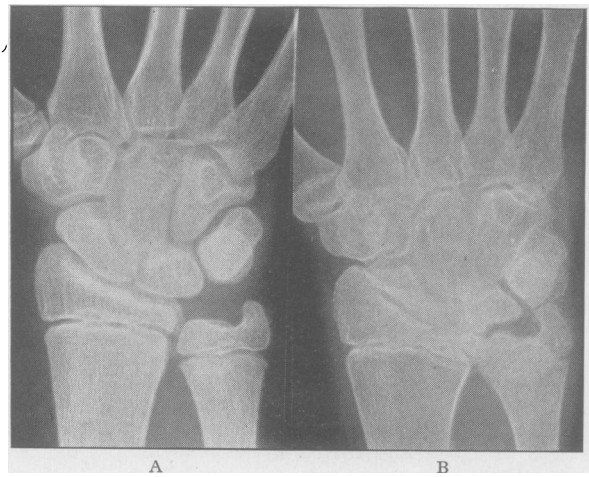


FIG. 6 A and B (*Case I*).—
A, Radiocarpal joint.
B, Six months later.

Fig. 7 shows ossification occurring in the periosteal reaction along the metacarpals of an 11-year-old girl with rheumatoid arthritis. This also resolved leaving no trace six months later.

Case II.—A 4-year-old boy was diagnosed as a case of Still's disease, showing many of the clinical signs of that syndrome, but without any evidence of pericarditis. At that time there were no detectable radiological changes. Two years later his second right metacarpal compared with the corresponding left second metacarpal (Fig. 8 C and D) is shown to have a thickened cortex. In retrospect this was seen to have been present a year earlier (Fig. 8B). Figs. 8 A, B, and C also show gradual destruction of the articular cartilage with narrowing of the joint space, and some destruction of subarticular bone. Clinically his condition has greatly improved, he has started at school and is holding his own with his classmates at work and play. This case illustrates in contrast to Case I how slowly

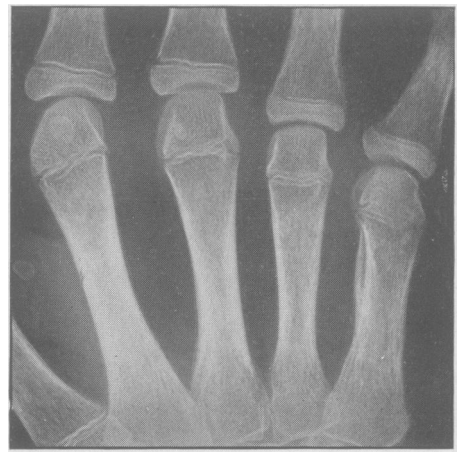


FIG. 7.—Ossification proceeding in periosteal reaction and early joint involvement.

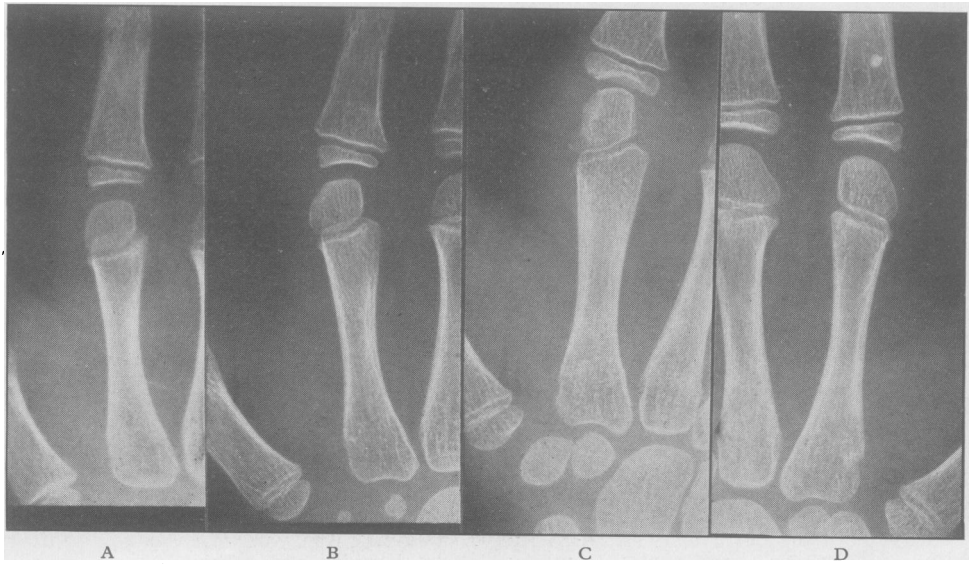


FIG. 8 A, B and C.—Right second metacarpal, 1948, 1949, and 1950 respectively. D, Left second metacarpal, 1950.

the joint changes may progress, how, in fact, the joint changes may be detectable radiologically only two years after the disease has been diagnosed clinically. Both cases demonstrate how little indication of the clinical condition the radiological picture gives.

Fig. 9 shows a periosteal tag of bone on the lateral aspect of the tibia in an adult male patient in whom the disease first became manifest at the age of 8 years.

A periosteal reaction has been noted previously in adults, but there is no reference to its occurrence in children in the literature, though Caffey (1945) has drawn attention to the later result in the form of cortical thickening.

Effect on articular cartilage.—This takes the form of destruction which may be partial or complete, and may progress rapidly, as in Case I or slowly as in Case II.

Fig. 10 shows early alteration in the joint space of a 10-year-old boy with rheumatoid arthritis. One side of the joint space is increased and there is early invasion of articular cortex.

Figs. 8 and 17 show examples of partial destruction and Fig. 11 of complete destruction.

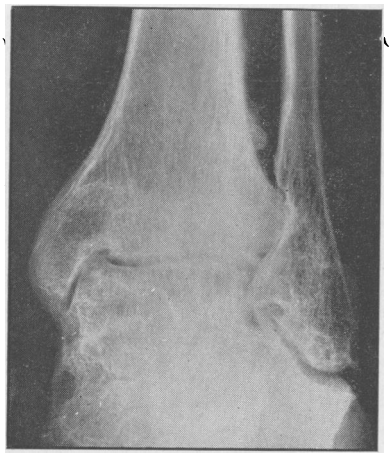


FIG. 9.—Periosteal tag of bone.

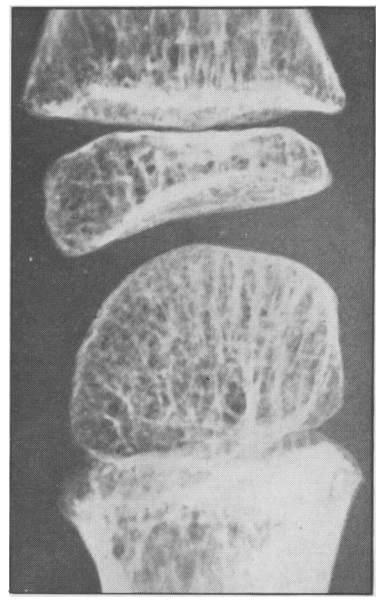
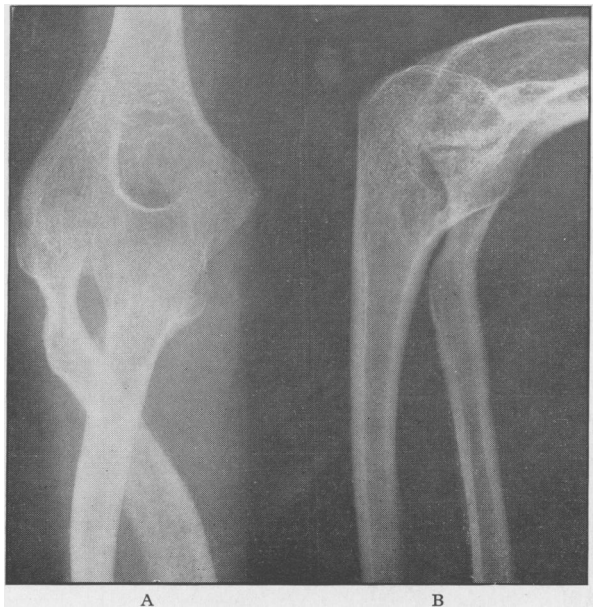


FIG. 10.—Early alteration in joint space and invasion of articular cortex (fine grain technique).



A B

FIG. 11A and B.—Complete destruction of articular cartilage.

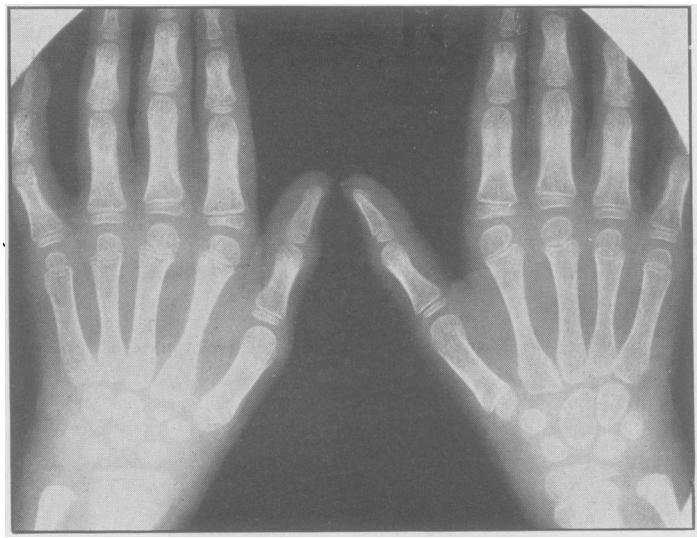


FIG. 12.—Osteoporosis and acceleration of ossification.

Effect on bone (*see* Table II).—The effect on bone is primarily an osteoporosis (*see* Figs. 4 and 12). This may become arrested at any stage, or may progress to active destruction of bone by invasion by granulation tissue from the synovium. If it is arrested the widened intertrabecular spaces persist (*see* Fig. 13).

Destruction may proceed in one of three ways: (i) It may become arrested at any stage with return towards normal bone density but without reconstruction of normal bone; (ii) it may progress with eventual subluxation of the joint as occurs with ulnar deviation of the carpus in adults; or (iii) if all the intervening joint cartilage is destroyed bony ankylosis may take place. Fig. 11 is an example of this in a quiescent case now aged 20 years, in whom the disease commenced at the age of 4.

Effect on Growth

This can be classified simply into four categories:

(i) Acceleration of epiphyseal growth or of the growth of ossific centres. Fig. 12 is an example of this in which seven ossific centres are shown in the carpus of a 4-year-old girl who has had clinical evidence of the condition for eighteen months. In addition there is evidence of osteoporosis, but none of destructive joint changes. The classic example

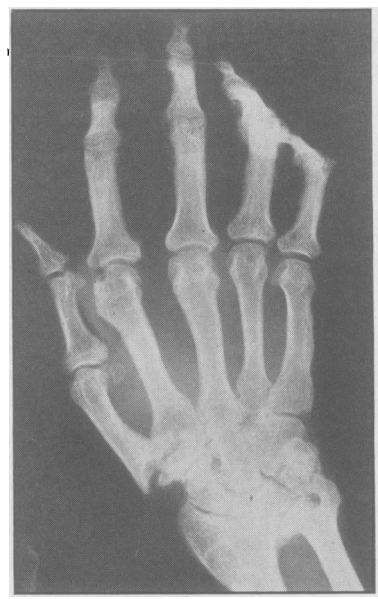


FIG. 13. — Premature fusion of epiphyses causing brachydactylia.

TABLE II

EFFECT ON BONE

Osteoporosis	Destruction by invasion of proliferating granulation tissue from synovium		
Return to normal bone density but with persistence of widened intertrabecular spaces	Arrest at any stage with return to normal bone density but no reconstruction of bone	Progressive destruction with eventual disorganization of the joint	If all the intervening joint cartilage is destroyed some bony reconstruction may take place leading to bony ankylosis

of this was published in 1937 by Francon *et al.* whose case had rheumatoid involvement of one wrist and not the other; the involved wrist had eight ossific centres in the carpus, besides destructive joint changes, whilst the uninvolved wrist had only three ossific centres.

(ii) Premature fusion of epiphyses. This is not a constant feature but may occur in any involved joint. In the hands it may produce a brachydactylia. Fig. 13 is an example of this condition in a 31-year-old male patient in whom the onset was at the age of 10. The condition was slowly progressive for ten years, was quiescent for approximately ten years, since when he has had intermittent recurrences of joint signs and symptoms. Coss and Boots (1946) first drew attention to the occurrence of brachydactylia observing it in 11% of cases in a series of 52. The present writer's experience in a series of more than 40 cases, many of which are early and still progressive, would place the incidence slightly higher. This premature fusion of epiphyses may lead to

(iii) Gross deformity. This occurs where one epiphysis fuses and growth in the epiphyseal cartilage of an adjacent bone proceeds. It may thus occur in hands or feet, forearms or legs. Fig. 14 is an example in a 20-year-old girl in whom the condition started at the age of 4.

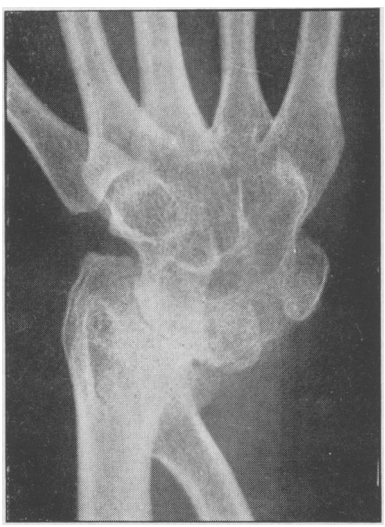


FIG. 14.—Disorganization of joint.

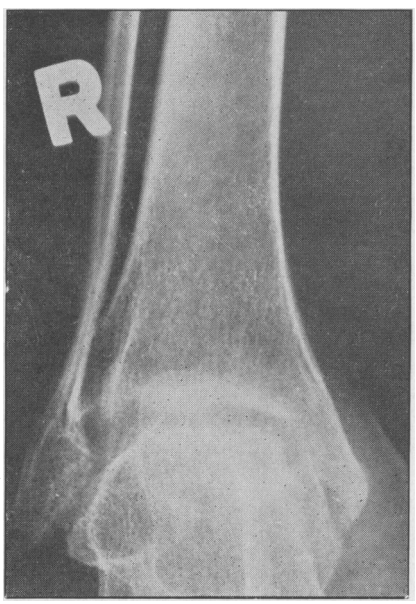


FIG. 15.—Tapering of shaft of fibula.

The epiphysis at the distal end of the radius fused while growth proceeded in the ulna. As is shown, the wrist is partially disorganized, the ulna is bowed away from the joint, and the carpus has moved proximally towards where the distal end of the ulna would normally be. Even more bizarre examples of this process occasionally occur.

(iv) A tapering of the juxta-epiphyseal parts of the shafts of bones may occur. Fig. 15 shows an example of this in the fibula of a 27-year-old man in whom the disease started before the age of 10. This effect is comparable in some respects with the destruction of the end of the long bones that occurs in adults (*see* Fig. 2) and is presumably due to synovial proliferation during the years of growth. It may occur near any involved joint, and sometimes produces particularly gross effects in the metatarsals.

There may be great variation in the speed with which the joint changes proceed (Cases I and II). Similarly these cases emphasize how little correlation there is between the clinical condition and the radiological picture. Many cases show no detectable radiological change other than osteoporosis for two or even three years after the condition has been diagnosed clinically. The writer has seen some cases that have been diagnosed as classical examples of "Still's disease", have run a course of three or four years, have recovered, and yet have shown no radiological evidence of destructive joint changes.

The X-ray demonstration, however, can be regarded as a demonstration of the amount of permanent irreversible joint damage that is taking place.

The condition may be monarticular or polyarticular.

Case III.—A boy aged 4 years was well until in December 1948 he complained of pain in the left knee which became swollen. Pain was severe enough to make him cry out. Tuberculin reaction was negative and has remained so ever since. His B.S.R. at that time was 18 mm. in one hour. He has been apyrexial throughout, his B.S.R. rose at one time to 36 mm., his hæmoglobin was 86%,

his total white cell count 10,000. The condition of the knee has been slowly progressive ever since and no other joint has become involved. Orthopædic treatment has been necessary to correct deformity of the knee. Fig. 16 shows his knee eighteen months after the onset of the condition.

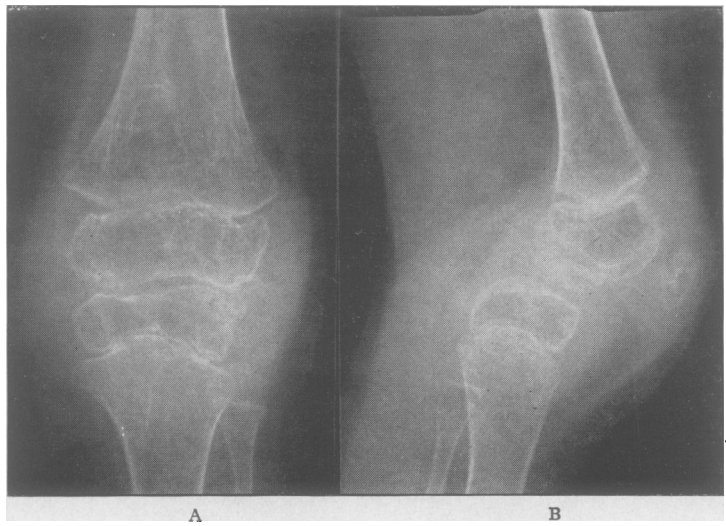


FIG. 16 A and B.—Monarticular arthritis of knee.

This monarticular form of the disease is relatively rare, the present writer has seen 3 such cases. The radiological appearances of the joint are in no way different from the polyarticular form.

The distribution of joints affected in the polyarticular form do not differ materially—except in one instance yet to be mentioned—from that in adult cases. Small joints of hands and wrists, feet and ankles, together with knee-joints are the commonest joints to be affected. The illustrations have shown involvement of all those joints together with an example affecting the elbow (Fig. 11). Fig. 17 shows involvement of the shoulder in a young man aged 22 who had been the victim of a slowly progressive polyarthritis since the age of 12.

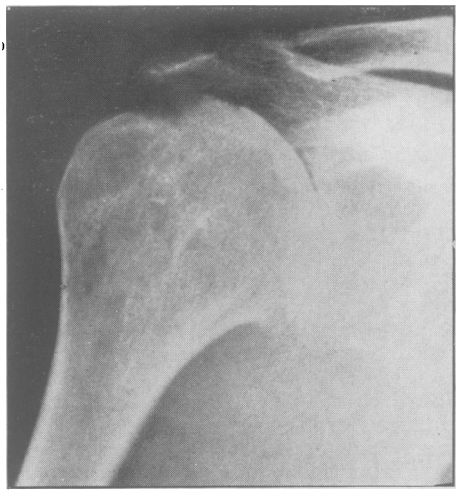


FIG. 17.—Involvement of shoulder.

In contrast to adult cases, however, the cervical spine is frequently affected in children. Still (1897) described early involvement of the cervical spine and in their series Coss and Boots (1946) found clinically a 13% incidence. M. and O. Lucchesi (1950) have put this involvement of the cervical spine forward as a separate problem, but in my experience it is relatively common, occurring at the same time as involvement of the peripheral joints. From an analysis of the radiological appearances the pathological process would appear to be the same as in other joints. It is the apophyseal joint that is affected, and the process may lead to complete obliteration of the joint space with bony ankylosis. Fig. 18 shows a gross example in an 8-year-old boy with a four years' history of both joint and systemic signs.

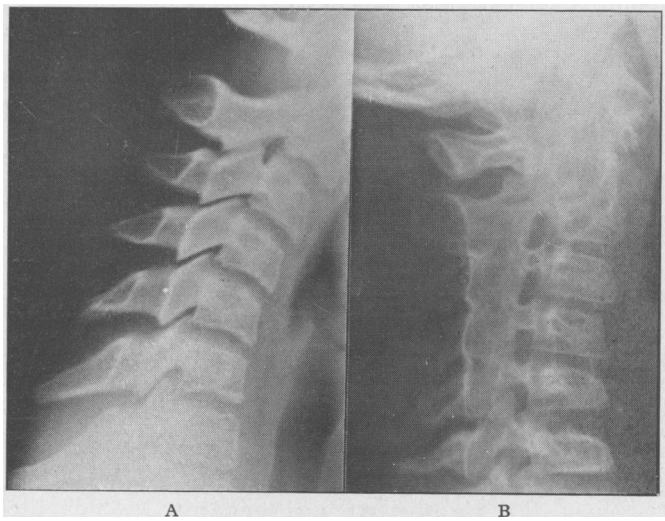


FIG. 18.—A, Normal cervical spine. B, Ankylosis of cervical spine.

Finally, association of the condition with psoriasis must be mentioned. The association of the two conditions in adults is well known and has recently been analysed by Fawcitt (1950). It is less common in childhood, but does occur. Fig. 19 shows a patch of psoriasis on the elbow of an 11-year-old boy who has had psoriasis on his elbows, knees, and finger

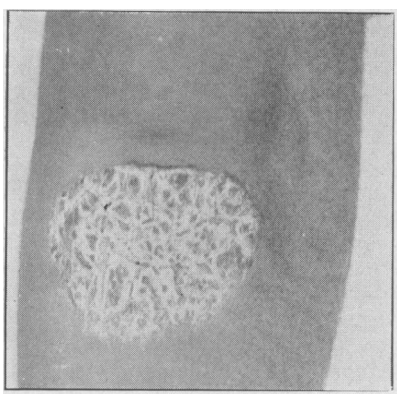


FIG. 19.—Psoriasis of elbow.

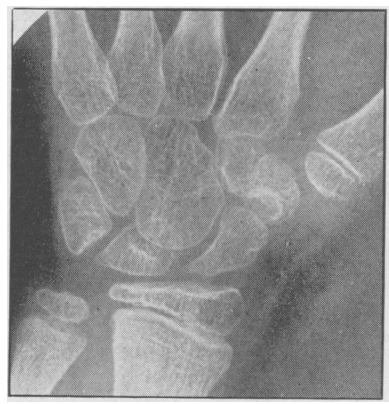


FIG. 20.—Early destruction in trapezium and capitate (same case as Fig. 19).

nails for three years. His joint symptoms started a year earlier, the small joints of both hands and wrists, both feet and the cervical spine being involved clinically. Radiological changes are only just beginning to appear and Fig. 20 shows his right carpus which is osteoporotic and in which a small zone of destruction can be seen in the trapezium and a second on the capitate.

SUMMARY

(1) The clinical manifestations of rheumatoid arthritis in childhood are reviewed, noting in particular that in many cases joint symptoms and changes occur late in the course of the disease.

(2) The pathological processes occurring in the condition with particular reference to those in the joints are briefly mentioned.

(3) The radiological appearances are described and analysed. Attention is drawn to: (i) The frequent occurrence of a periosteal reaction early in the course of the disease. (ii) A detailed analysis of the osteoporosis that occurs using a fine grain radiographic technique. (iii) The involvement of the cervical spine that may occur. (iv) The effect of the condition on growth, and its late results in adult life.

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Colour in Radiography

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INTRODUCTION

Dr. G. E. Donovan: The great advance in photography was the introduction of colour; it began with the formulation of the wave theory of light. Louis Ducos du Hauron had either demonstrated or mapped out, by the end of the last century, the many paths by which the goal of natural colour photography might be reached. His realization of the broad fundamentals was unique at the time. Roentgen discovered X-rays in 1895, and these radiations were immediately applied in medicine. Unfortunately, so far as radiography and colour photography were concerned, the two were never associated. Colour radiography has recently been described in a preliminary report by Donovan (1951); this, as far as we are aware, was the first article on the subject in the literature.

THEORY

The electromagnetic spectrum covers over sixty or more octaves and extends from radio waves to cosmic rays. The visible portion constitutes about one octave and has wavelengths ranging from the red end of the spectrum (7,500 A) to the extreme violet end (about 3,200 A); visible light is only a very small window in the electromagnetic spectrum. The boundary wavelengths of diagnostic X-rays range from about 0·414 A to 0·138 A. The wavelength of visible light determines its colour, and, in the case of X-rays, is the property akin to colour. The kilovoltage of the X-ray tube governs its spectral emission which is not monochromatic but rather a spectral band. The penetrative power of the X-ray beam depends on the wavelength, density of the part and the atomic numbers of the atoms composing the part. The orthodox radiograph is a shadow picture in various shades of grey, and the detail that can be seen is dependent upon the degree of transparency or opacity of the part being radiographed at the particular kilovoltage. Different detail is shown by using different kilovoltages (wavelengths) on the X-ray tube.

Colour photography is based on the trichromatic theory which is not strictly correct but yields in practice very good results. Monochromatic filters are not generally used but red, green and blue filters which cover a wide spectral band of red, green and blue respectively and have a slight overlap. Clerk Maxwell's mixture experiment can be performed nearly as well by using wide-band three-colour filters which between them transmit the whole of the visible spectrum as with three monochromatic lights. In copying colour transparencies and in colour radiography narrow-cut tricolour filters are usually employed. Satisfactory results are obtained in colour radiography by using two radiographs and two colours. It is not necessary to produce pseudo-natural colour effects but rather to choose colours which bring out a particular effect or lesion.