

SACRO-ILIAC JOINTS*

Observations on the Gross and Histological Changes in the Various Age Groups

G. R. MACDONALD, B.Sc., M.D.† and
T. E. HUNT, B.A., M.D.,‡ Toronto

COLLINS¹ in a discussion of the pathological alteration in the sacro-iliac joints during the course of ankylosing spondylitis (Marie Strumpel type), states: "There appear to be no histological reports on these joints". This is true, in spite of the recent increase of interest in the radiological changes in these structures associated with this disease. Indeed, there is little information available concerning the normal variations in these joints during life.²

This paucity of information may perhaps be excused for two reasons. Firstly, the articular portions of the sacro-iliac joints are inaccessible for biopsy purposes, and few patients with spondylitis die of the disease—at least in the early phases. Secondly, even at post-mortem the complete removal of the joints has been considered to be a formidable and rather mutilating procedure, unwelcomed in most hospital laboratories. Thus, fresh material for study has been generally unavailable.

The challenge of this state of affairs has resulted in an attempt to obtain satisfactory fresh specimens from one or both sacro-iliac joints during routine post-mortem examination. It became possible to carry out an investigation of the so-called "normal variations" in the different ages; thus providing a fitting background for the study of pathological changes should such be presented.

The purpose of this paper is to present our observations of the gross and histological appearances of the sacro-iliac joints in the various age groups. Included as well is a description of the method which has been found to be quite satisfactory for obtaining specimens. It should be emphasized that this report deals only with the true, diarthrodial portions of the joints.

*From the Department of Pathology and the Department of Medicine, Arthritis Service, Sunnybrook Hospital, D.V.A., Toronto, Ont.

†Assistant Resident in Pathology, Sunnybrook Hospital, D.V.A., Toronto, Ont.

‡Canadian Arthritis and Rheumatism Society Fellow in Medicine, Sunnybrook Hospital, D.V.A., Toronto, Ont.

MATERIAL

The material for this study was obtained from 57 unselected post-mortem examinations carried out on males at Sunnybrook Veterans' Hospital, Toronto, Canada. Two further specimens were made available to us through the kind co-operation of Dr. W. L. Donohue and his staff in the Department of Pathology at the Hospital for Sick Children, Toronto. For study purposes, the specimens were grouped according to the ages of the cases, as shown in Table I, below. It will be noted that the majority of these specimens have been obtained from patients in the older age group. This is because cases coming to post-mortem at this hospital are generally advanced in years. Being a veterans' hospital too, there have been few cases in the age group between 40 to 49 years. Only three of the cases were known to have been treated primarily in hospital for arthritis. Two of these had well established severe rheumatoid arthritis, and one had far advanced ankylosing spondylitis with peripheral joint involvement.

The diagnoses in the remaining cases varied greatly as would be expected. A search of their hospital records was carried out after the anatomical observations were made, and any musculo-skeletal complaints recorded. In eight, there were clinical records of osteo-arthritis involving either the spine or hip joints, and in four of these advanced degenerative changes were found in the sacro-iliac joints. Six additional patients were noted to have had x-ray evidence of degenerative joint disease, but there was no correlation between this observation and the changes seen in the joints under study. One other patient's x-rays demonstrated obliteration of the sacro-iliac joints, although, there were no musculo-skeletal complaints. The specimens from this case confirmed the radiological diagnosis. The histories of the remaining 44 cases were non-contributory.

METHOD

Specimens were obtained during routine autopsy procedures. After clearing away the psoas muscle and other soft tissues overlying the alæ of the sacrum and the ilium, the antero-inferior margins of a sacro-iliac joint were easily demonstrated. A sharp chisel was then driven into the bones on either side of the joint for distances of 5 to 6 centimetres. After making parallel cuts of 5 to 8 centimetres in length, in such a manner, a narrow chisel was finally driven from the upper margins of the sacro-iliac articulations, downwards and backwards into the pelvis. The block so produced included the complete diarthrodial joint or the major part of it, as well as some of the adjacent bone. Left behind was only ligamentous

TABLE I.

Group	Age	Number of cases
I.	*Newborn	2
II.	20 - 29 years	7
III.	30 - 39 "	7
IV.	40 - 49 "	2
V.	50 - 59 "	10
VI.	60 - 69 "	10
VII.	70 and over	21
Total		59

* Specimens from the Hospital for Sick Children, Toronto.

portion, but this was sufficient to prevent mutilation. With experience, the whole procedure was accomplished in 5 to 10 minutes.

The gross specimens were first tested for joint stability. Following this any ligamentous portions, if present, were dissected with scalpel or scissors. A sufficient amount of the capsule was then incised so that the joints could be laid open from the posterior aspects, unless there was fusion between the articular surfaces. Both articular cartilaginous surfaces were then inspected as well as significant portions of the capsule and synovial tissues. Examination of the fused specimens had to be carried out primarily on cross sections made perpendicular to the planes of the joints. After microscopic sections were taken, gentle prying with a blunt instrument was found to be sufficient to open the remainder of the joint in most instances. Only two were fused to such an extent that separation was not possible. Representative portions of each specimen were placed in a variety of fixatives. Formalin was found to be the most satisfactory.

Histological sections were prepared from characteristic specimens in each age group, and from every case in which the joint appeared to be fused. A jeweller's saw was found invaluable for procuring blocks thin enough for satisfactory decalcification without tearing off the capsules or synovial tissues. In the case of formalin fixed specimens, a period of dehydration in alcohol, prior to decalcification, was found to be necessary. The method of rapid decalcification with nitric acid was used. In a few instances, decalcification was attempted with electrolysis as well as by the ion exchange resin method.³ Neither proved to have any significant advantage over the nitric acid method. After decalcification, paraffin block sections were prepared and stained with hæmatoxylin and eosin in the usual manner.

OBSERVATIONS

(a) *General anatomical features.*—The joints were found to be roughly crescentic in shape with the curved edges pointing anteriorly and inferiorly. The sacral articular surfaces were found to be somewhat convex while those on the iliac side were slightly concave. This study confirmed the presence of a true synovial diarthrodial joint composed of articulating cartilage together with an enveloping synovial membrane, and anteriorly at least, a fibrous capsule. Capsular tissues were not identified either in the gross or histological preparations between the articular and fibrous portions of the joint, although synovial tissues were present in this region.

Except in early infancy, all of the joints were extremely stable. No significant movements were produced even with pressure of a bench vise, apart from very slight degrees of compression. It will be recalled that occasionally only a portion of the ligamentous union was present in each specimen after removal from the body. With such stability, it would seem very unlikely that any significant degree of subluxation could occur in the sacro-iliac joints of adult males. Indeed, in a suicidal case who had jumped from a fifth storey, both alæ of the sacrum were fractured but the sacro-iliac joints were intact. After removal they only permitted a millimetre of sliding motion. This case was seventy years of age and fusion of the joint spaces was not demonstrated. Sashin² has reported greater mobility in females during pregnancy and in the puerperium. A similar degree of mobility was noted in our newborn cases, where sliding and rotatory movements, ranging through several millimetres, were demonstrated even in the presence of complete ligamentous union posteriorly.

The cartilaginous surfaces were of interest, in that the sacral cartilage was found to be consistently two to three times the thickness of that on the iliac side. This relationship persisted in spite of advanced degenerative changes in some of the older cases. In the younger ages, the surfaces generally were found to be smooth and shiny without interlocking ridges, although these features did become evident in the older age groups. The fine radiating lines on the iliac cartilage, described in many texts,⁴ were evident in adults up to about middle age. Fusion of the cartilaginous surfaces was apparent in eleven cases over 50 years of age. These will be discussed in detail separately.

(b) *The changes occurring in the various age groups:*

1. *In early infancy.*—In the newborn, as noted above, the sacro-iliac joints were found to have considerable mobility. On gross examination, a thin capsule and a very fine membrane-like synovium was recognized along the antero-inferior margins. The cartilaginous surfaces were smooth, shiny and of a pearly-blue colour. No lines, ridges or pitting were evident (Fig. 1). There was little subchondral bone, and that present could be easily cut with scissors or a scalpel.

Microscopically, the capsule although thin was seen to be composed of well-formed, quite cellular, collagenous connective tissue. A moderate number of fibroblasts were present, as were small, thin-walled blood vessels. The synovial tissues consisted of loose areolar connective tissue with an intimal layer three to four cells in thickness. There was a moderate number of small blood vessels scattered throughout the areolar tissue, and in this region metachromasia to toluidine blue dye was demonstrated. In both specimens, small, vascular villi protruded into the joint spaces. The intimal layers (*stratum synoviale*) of the synovium were continuous on both sides with a single layer of elongated cells, which completely covered the cartilaginous surfaces. These surfaces were smooth and regular. The cartilage *per se* presented no abnormality, and, particularly on the iliac side, demonstrated the characteristic transition of cartilage into new bone (Fig. 2).

2. 20 to 29 years.—In this group, the capsules were quite thin and pliable, but the areolar-like membranous synovial tissues were identified much more easily. The joint spaces were clear. No debris was present on either cartilaginous surface. The cartilage, generally, was not as smooth or as shiny as in the infant, and was of a greyish-yellow colour. A few minute depressions were scattered over both the iliac and the sacral surfaces. The cartilages on the sacral side measured 2 to 3 mm. in thickness, while those on the iliac averaged 1.5 mm. The subchondral bone was dense, but did not appear to be sclerosed.

Microscopically, the capsules were found to be composed of a fairly dense, relatively acellular and avascular collagen, which merged gradually into the periosteum at the joint margins. The synovial tissues were also relatively thicker than in the newborn, and much more fibrous in composition. A decrease in the vascularity was also evident. The cartilaginous surfaces were slightly irregular, and only broken portions of the flattened, superficial layer of elongated cells were seen. The usual distinct zone of calcification separated cartilage and subchondral bone. This line was continued with a similar zone of calcification just deep to the periosteum. No abnormalities of subchondral bone and bony cortex were seen.

3. 30 to 39 years.—Generally, the gross features of this group were similar to those observed in the previous age group. Although the cartilagin-

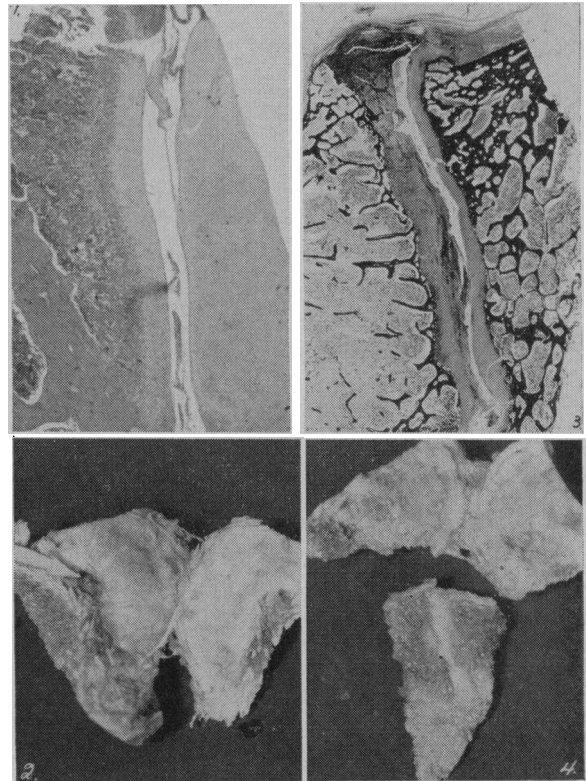


Fig. 1.—Section of the joint from a newborn infant showing from above down (a) the thin capsule; (b) a tongue of synovium; (c) the wide joint space. The articulating cartilage on the left (sacral side) shows the normal transition of cartilage to bone. Fig. 2.—Sacro-iliac joint of a male of 70 years of age showing erosion and pitting of cartilage. Fig. 3.—Section of joint shown in Fig. 2 showing (a) thick capsule; (b) fibrillation and destruction of cartilage; (c) thin subchondral bone. Fig. 4.—Sacro-iliac joint showing articular surfaces. There is marked destruction of the cartilage and large amounts of amorphous debris in the joint space causing a superficial type of fusion.

ous surfaces were still quite smooth, there was a slight increase in the number of the minute depressions, particularly on the iliac side.

Histologically, the capsules appeared to be somewhat thicker and there was an increase in the amount of fibrous material in the synovial tissues. The latter were much less vascular than previously, and the intima were composed of only one or two cellular layers. The layer of elongated cells, on the cartilaginous surfaces, could not be identified, and there was some roughening and minimal erosion of the superficial cartilage. A slight amount of fibrillation was seen in the marginal layers, but the deeper cartilage did not appear unusual. No abnormalities were noted in bone or periosteum.

4. 40 to 49 years.—In this group degenerative changes became apparent upon gross examination. These consisted mainly of superficial irregularities and erosions in the cartilaginous surfaces with collections of flaky, yellow, amorphous debris. In both specimens, the iliac cartilage appeared to be affected more than that

on the sacral side, and the fine radiating lines were difficult to identify. The gross and microscopic appearances of the capsular and synovial tissues were similar to those of the younger adult age group.

Histologically, the surface layers of the cartilage were found to be quite irregular, with considerable fibrillation and erosion. In some of the eroded areas, there were collections of eosinophilic, acellular, amorphous material. On the iliac side, the cartilage cells and lacunæ tended to collect into cellular islands, the intervening matrix being bland, eosinophilic and somewhat fibrillated. In contrast, the sacral cartilage maintained a normal hyaline appearance, deep to the eroded regions.

5. *50 to 59 years.*—Thickening of the capsular and synovial tissues was evident in this age group, and there were more extensive degenerative changes in the articulating cartilage. In one case, the joint space appeared to be obliterated, although, there did not seem to be any decrease in the thickness of the cartilage. (X-rays of the joint taken at post-mortem revealed no obvious abnormalities.) After blocks were taken for microscopic section, the opposing edges could be separated easily by gentle prying with a blunt instrument. The cartilaginous surfaces thus exposed did not appear to be remarkably different from the others in this age group. In another, the joint spaces were completely obliterated, the cartilage irregular, and in several regions there was complete bony bridging. This will be described with fused specimens.

Microscopic examination of the other joints confirmed the thickening of the capsule and synovial tissues, and in addition, there was extensive loss of cartilage on the iliac side of the joint with gross irregularities of the surface layers. The sacral cartilage was somewhat irregular and showed fibrillation and superficial erosion, but the changes were not so marked as on the opposing side.

6. *60 to 69 years.*—The sacro-iliac joints were found to be fused in two of the ten cases studied. These will be described separately with the other joints which demonstrated this condition. Thickening of both the capsule and synovium was noted in a third of the remaining specimens. The cartilage showed further irregularities with erosion of larger areas, up to 4 or 5 mm. in diameter. In some of these larger eroded areas, the articulating surfaces were almost completely denuded of cartilage. The yellowish, amorphous

plaques observed in the previous age groups were much more abundant and covered almost the entire superficial layer on each side. Definite ridging was observed near the anterior margins in two cases, while in another, early lipping could be observed in the sub-capsular regions. The sacral cartilage, apart from the eroded areas, maintained a thickness of 2 to 3 mm. There appeared, however, to be a generalized narrowing of the cartilage on the iliac side of the joints, the average being less than 1 mm. in thickness. Again, the erosions were more prominent on this side, and the usual radiating lines were not identified. Moderate subchondral bony sclerosis was noted in the gross in only one case.

The microscopic examination confirmed the presence of capsular thickening in three cases, and in these there was a slight amount of calcification of the capsular attachments on either side of the joint spaces. In two specimens, there was increased density and vascularity of the synovial tissues with focal accumulations of fibroblasts and small, round cells. The capsules and synovia of the other joints resembled those of the previous groups.

In all cases, there were gross irregularities in the superficial layers of cartilage, with fibrillation extending into the deeper portions. In some areas erosion had occurred almost to the surface of the bone, and the thin layer of remaining cartilage was acellular and necrotic in appearance. Amorphous, acellular, eosinophilic material covered large areas on both surfaces. In one case, the cartilage was completely destroyed immediately deep to the capsule on the anterior aspect of the joint and it appeared to have been replaced by loose, rather vascular, connective tissues. Early subcapsular osteophyte formation with moderate subchondral bony thickening was seen in two cases.

7. *Over 70 years.*—Six of the twenty-one specimens in this age group were fused. In one case, the patient had been known to have had Marie Strumpel's spondylitis for many years, while another had had typical rheumatoid arthritis of over twenty-five years' duration. Ante-mortem x-rays of the former case revealed obliteration of the sacro-iliac joints. Radiological studies of the spine of the patient who had had rheumatoid arthritis were normal. These together with the other four fused specimens will be described along with the others showing this abnormality in a separate section.

The remaining fifteen specimens presented marked degenerative changes with extensive erosion of cartilage and thickening of both capsular and synovial tissues. In all cases there was definite and sometimes marked marginal lipping. Some of the articular surfaces were extremely roughened due to the presence of large areas of erosion and apparently sloughing of necrotic cartilage. In between the eroded areas, there were apparent elevations particularly on the sacral surface. It was felt that these represented less affected cartilage rather than hyperplasia of hyaline cartilage. The thickness of the cartilage on the sacral side as well as that on the iliac was greatly diminished, averaging 1.5 mm. and 0.5 mm. respectively. The subchondral bone appeared to be atrophic (Fig. 3).

The cartilaginous changes were the most remarkable features of the histological observations. The capsule and synovium, although dense and thickened, did not appear to be significantly different to those of the previous two age groups. All sections examined, however, demonstrated marked fibrillation of cartilage with necrosis and breaking off of superficial and deeper layers. The cells in the remaining cartilage were all collected into islands, with fibrillated, eosinophilic, whorled, intervening ground substance. In the subcapsular regions, osteophyte formation was seen in all cases, and in some was quite striking. The subchondral bone was generally much thinner than normal and the bone cortex appeared to be decreased (Fig. 4).

8. *Fused specimens.*—Four different types of fusion were found among the eleven specimens presenting this feature.

In the first group, the opposing articular surfaces were united by a mass of yellowish, amorphous material which was similar both grossly and histologically to that covering the cartilage in the older cases. This fusion would appear to have occurred merely as a result of adhesion of necrotic superficial debris on to both cartilaginous surfaces. This union was broken easily and the two sides then separated without difficulty. After separation, gross and histological studies of the four cases in this group revealed no significant alterations, other than those described in non-fused specimens from the same age groups (Figs. 5 and 6).

The second group, comprising two specimens presented similar gross and histological features to those described above, except that the zone

of calcification was less prominent. In addition, however, extensive areas of cartilage were replaced by loose, vascular, connective tissue. In some regions this tissue was found to be extending into the joint structures from the subchondral bone, while in others, it traversed the adherent cartilaginous surfaces. No inflammatory changes were observed. Post-mortem x-rays were entirely normal in one of these cases. The patient, in the other instance had had rheumatoid arthritis for twenty-five years but the x-rays again demonstrated no abnormalities in the sacro-iliac joints.

In three cases, small slit-like joint spaces were still present, but bony bridging had occurred across the external margins of the articulating surfaces. Microscopically, both capsular and synovial tissues as well as adjacent cartilage had been replaced by bridges of well-formed, dense bone (Fig. 7). Once these structures were fractured, the joints could be opened and they presented features similar to those of other specimens from the older age groups.

The final two specimens were completely fused due to bony ankylosis. In these, there was no evidence of even small portions of persistent joint spaces, and the sacral and iliac bones could not be separated. The most marked changes were seen in the specimens obtained from the case of Marie Strumpel's spondylitis. Here, thin islands of cartilage were the only remnants of the joint tissues (Fig. 8). The intervening structures were composed entirely of bone without inflammation or fibrous replacement. No traces of capsular or synovial tissues were found.

In the other case, although the cartilage was not grossly narrowed, bony invasion had produced marked irregularities and, upon microscopic examination complete bony union was demonstrated in several regions (Fig. 9). The patient, in this instance, had been treated for Hodgkin's disease with radiation to the mediastinum and spleen. Although there had been no musculo-skeletal complaints, x-rays of the abdomen and pelvis revealed obliteration of the sacro-iliac joints.

DISCUSSION

The changes observed in the sacro-iliac joints would appear to conform, generally, with those described by others^{1, 5} who have conducted similar investigations on various peripheral joints. With a few exceptions, these observations

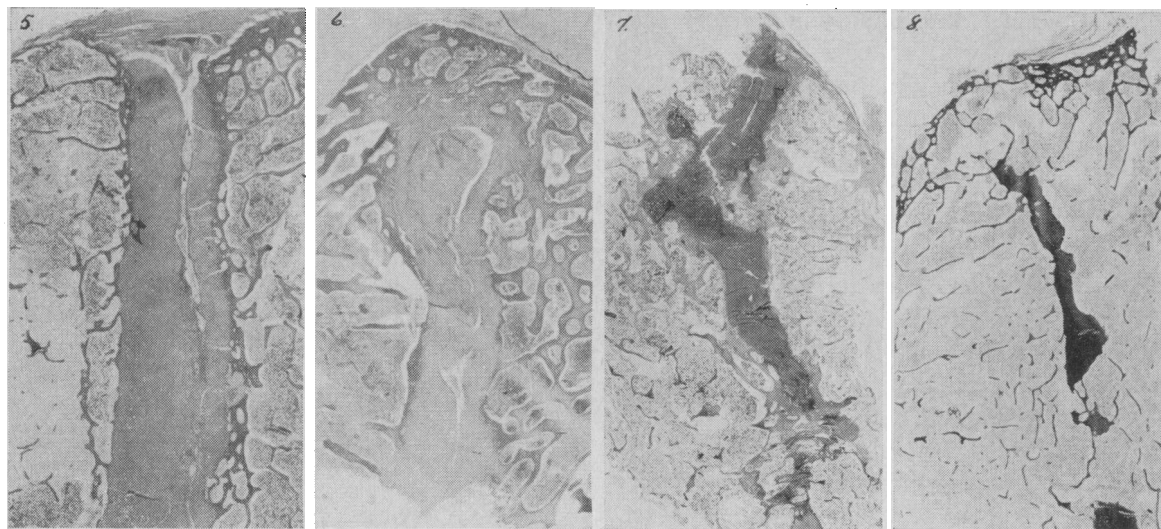


Fig. 5.—Section of the joint shown in Fig. 4. Fig. 6.—Section of a joint showing (a) bony bridge replacing the capsule; (b) partial obliteration of joint space by adherent articular cartilage. Fig. 7.—Portion of an ankylosed joint from a case of old Marie Strumpel's spondylitis showing an irregular remnant of cartilage and joint space and complete bony union in the lower portion of the photograph. Fig. 8.—Portion of a joint showing almost complete bony union.

would also agree with those of Sashin who was the only other writer, to our knowledge, to concern himself with the histological changes in the sacro-iliac joints, in the different age groups. With increasing age, there occurred, primarily, a progressive degeneration of articular cartilage with secondary bony alteration, and, to a lesser extent, changes in the capsule and synovial tissues.

As early as the 4th decade (or even possibly the 3rd) the articular cartilages of the sacro-iliac joints commenced to show evidence of degeneration. At first, this was characterized by only an irregular loss of the most superficial layer of the cartilage, but with increasing age, fibrillation and erosion occur, and gradual loss of large areas of even the deeper structures took place. Some older cases demonstrated filling of almost the entire joint space with amorphous, flaky or granular material which was thought to be necrotic, sloughing cartilage. In the more advanced stages of these degenerative alterations, hypertrophy of bone occurred about the margins of the joint, with the production of lipping and osteophytes. The joint capsules generally became thickened and were composed of dense, acellular, avascular, collagenous tissues while the synovia contained much more fibrous material than in the early age groups.

Unlike the peripheral articulations, the sacro-iliac joints showed a tendency to become fused during later life, even in the absence of clinical evidence of arthritic processes. This feature was present in 11 of the 41 cases over fifty years

of age and was more frequently observed over the age of seventy. With the exception of two of these cases, it was felt that fusion was merely an exaggeration of the degenerative process already described. In some, the opposing surfaces were adherent due to intra-articular adhesion of the necrotic superficial debris, while in others, there was in addition, an invasion by loose, vascular connective tissue without evidence of inflammatory reaction. A third form of fusion due to the marginal bony bridges, perhaps, was indicative of a more advanced state of degeneration or rather another manifestation of the ageing process. Complete, intra-articular bony ankylosis was found in only two cases, and this feature was considered to be the late result of acquired disease rather than to a type of degeneration. Neither the gross nor the microscopic examination indicated the chain of events which had resulted in the ankylosis.

These observations, at first glance do not appear to conform with those of Sashin who reported bony ankylosis in 82% of males over the age of sixty years. However, his report describes merely bony bridging on the anterior margins of the joints without intra-articular ankylosis. These observations—although more frequent in occurrence than indicated by this study—are still in keeping with the hypothesis that such a feature is only a manifestation of osteoarthritic alterations.

The degenerative processes occurring in the sacro-iliac joints would then appear to be very similar to those observed in other joints. With

increasing age, destruction of cartilage occurs, probably, as a result of continued stress and strain. Due to the poor reparative abilities of cartilage, this destructive process is progressive, with resultant severe erosion and necrosis of cartilage, and to a lesser extent reactive bony hypertrophy. It may be that a vicious cycle develops with age. Injury resulting in erosion and necrosis of cartilage produces an amorphous debris filling the joint space. This interferes with nutrition of the superficial cartilage, rendering it more susceptible to further trauma and hence progressive degeneration ensues.

The sacro-iliac joints demonstrate at the most only very slight mobility, and because of this relative lack of motion, it is felt that other more pronounced degenerative features develop in a certain proportion of the older cases. Such is evident by the production of apparent fusion of these joints (20% in this series), an unusual manifestation of degenerative disease in the peripheral articulation. True intra-articular ankylosis has been apparent in only two of our cases and this is felt to be the result of acquired disease rather than a part of the ageing process.

SUMMARY AND CONCLUSIONS

1. A method has been described for procuring

satisfactory specimens of the diarthrodial portions of the joints.

2. The sacro-iliac joints have been studied in 59 unselected post-mortems. In 48 cases, the progression of changes with advancing age was similar to that observed in peripheral articulations consisting of destruction of cartilage and secondary bony hypertrophy with thickening of capsule and synovium.

3. Eleven of the 41 specimens from patients over fifty years-of age demonstrated fusion. In 9 of these, there was evidence that this was merely the result of advanced osteo-arthritis changes in relatively immobile joints. Two specimens were found to have complete intra-articular bony ankylosis, but none of the gross or histological features were indicative of the pathogenesis of the process involved.

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"Parenteral nutrition will succeed only if the caloric demands of the patient who is unable to eat can be met, either parenterally or from his own stores. When such body stores are lacking, as is usually the case in chronic wasting diseases, caloric needs cannot be adequately met by the parenteral preparations now available. Accordingly, the need for a more effective intravenous calorogenic material is urgent. Fat emulsions plainly offer the only practical solution to this problem." (*Nutritional Reviews*, 9: 193, 1951, Caloric Priorities in Parenteral Nutrition.)

"The results of the second survey in Bataan province indicated that after two years of rice enrichment the beriberi incidence had declined from 12.76 to 1.55% of the population in the experimental area and to 8.7 in the control area. Furthermore, the severity of the disease diminished greatly in the experimental area so that cases of frank beriberi had almost disappeared. It was observed, on the other hand, that the severity of the disease actually increased in the control area for no known reason. A decline in beriberi incidence occurred in one control area, but this was traced to infiltration of enriched rice into 20 to 30% of the homes in this municipality." (*Nutrition Reviews*, 9: 218, 1951, Artificial Enrichment of White Rice in the Philippines.)

"One of the marked biochemical effects of the rice-fruit diet was a lowering of the serum cholesterol level from the average control value of 233 to 158 mgm. %

after thirty-three days on the diet. The decrease in the serum cholesterol level from a normal level is not likely to play a specific rôle in the observed lowering of the blood pressure. In the reduction of the blood pressure the salt restriction is certainly important but the specific mechanism remains uncertain and is probably complex. It was observed, both under laboratory and field conditions, that semistarvation alone with no restriction in salt intake reduces blood pressure in both normotensive and hypertensive individuals." (*Nutrition Reviews*, 9: 233, 1951, Blood Pressure and Body Composition on the Rice-Fruit Diet.)

"Milk substitutes have aided greatly in providing adequate nutrition for infants and children allergic to milk. Strained meats and casein hydrolysates are two sources of protein that have been used for this purpose. These same proteins have been used in the feeding of premature infants. The nitrogen absorption in premature infants was 90.6% on formulas consisting of half-skimmed milk plus 10% added carbohydrate. On a similar formula in which meat supplied 30% of the protein intake, the absorption of nitrogen was 86.0%. When meat was the sole source of protein, the nitrogen absorption was 82.2%. Nitrogen utilization, however, was greater in the infants receiving all or part of their protein in the form of strained meat. Consequently, the nitrogen retention was comparable for both groups." (*Nutrition Reviews*, 9: 242, 1951, Protein Supplements in the Feeding of Premature Infants.)