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The Structure of the Upper End of the Humerus with Reference to Osteoporotic Changes in Senescence Leading to Fractures

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FRACTURES of the upper end of the humerus are relatively uncommon in young adult life but occur with some frequency in the older age groups, particularly among women. The literature regarding the incidence and treatment of these fractures was reviewed in 1958 by Einarsson.[3] The following statistics were gleaned by him from cases treated at the University, City, and Orthopedic Hospitals of Copenhagen, and hence are likely to reflect a good representation of both age and sex distribution.

Age	*Cases*
7 - 29	28
30 - 59	130
60 - 86	144

Age	*Male*	*Female*
7 - 49	43	39
50 - 79	64	144
80 - 86	6	6

Wentworth[8] found that 76% of his patients with fractures of the neck of the humerus were over the age of 65.

The age and sex incidence alone would suggest that these fractures are associated with an underlying osteoporosis, and usually there is a history of a relatively slight fall on to the outstretched hand. Thus they are on the fringe of the group of pathological fractures, and it is to be expected that there would be a difference in the structure of the bone that has lowered the resistance to injuring forces.

The internal structure of the upper end of the femur has become quite well known, and is demonstrated in most standard anatomy books. That of the upper end of the humerus is, however, not well demonstrated in the English language texts (Morris is an exception[6]), although it is described in detail in the French texts. A wealth of information on the structure and properties of bone is available in the late nineteenth and early twentieth century German literature, which has been briefly reviewed by Disse[2] and critically discussed by Evans.[4] More recent references are given by Schranz,[7] who has described some of the features of older bones and has described Hansen's method of age determination by the degree of porosis found in the upper end of the humerus.

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ABSTRACT

Fractures of the upper humerus occur most commonly in elderly women. Humeri from cadavers of 20 aged individuals were sectioned in one of three planes and examined radiographically. The greater tuberosity was found to be cavitated and the shaft is devoid of cancellous tissue in older bones, but the scar of the epiphyseal plate persists. Cortical bone is very thin at the lower part of the greater tuberosity and humeral head where fracture most commonly occurs. Two major groups of vertical trabeculae are found. The head has its own trabecular system.

MATERIAL

In order to gain further knowledge of the structure of the humerus and the changes that occur in senescence, 20 intact right humeri showing senescent changes, but of undetermined age, were selected from the stock of the Department of Anatomy, University of Toronto. After roentgenograms were made in anteroposterior and lateral planes (Figs. 1 and 2), they were sectioned in one of three ways: (a) sagitally, parallel to the anatomical neck; (b) approximately horizontally and parallel to the central axis of the head and neck; and (c) vertically, in the coronal plane in such a manner that the transverse plane of the section was parallel to the axis of the head, thus compensating for variations in degree of cervical torsion. Roentgenograms were made of these sections, which were about one-eighth of an inch thick. The sections were orientated and mounted on cards for comparison with the roentgenograms (Fig. 3).

DESCRIPTION OF TRABECULAR STRUCTURE

The scar of the epiphyseal plate remains as a dominant feature, clearly separating the epiphysis from the diaphysis in all specimens. The medullary cavity stops well short of the epiphyseal plate in younger bones, but in the osteoporotic material the cavity extends right up to the plate (Fig. 4). Arising from the inner wall of the diaphysis are vertical trabeculae. Although these are usually described as two beams or groups, i.e. medial and lateral, as they would appear in a single vertical section, reference to a transverse section shows that there is in fact a ring of trabeculae running

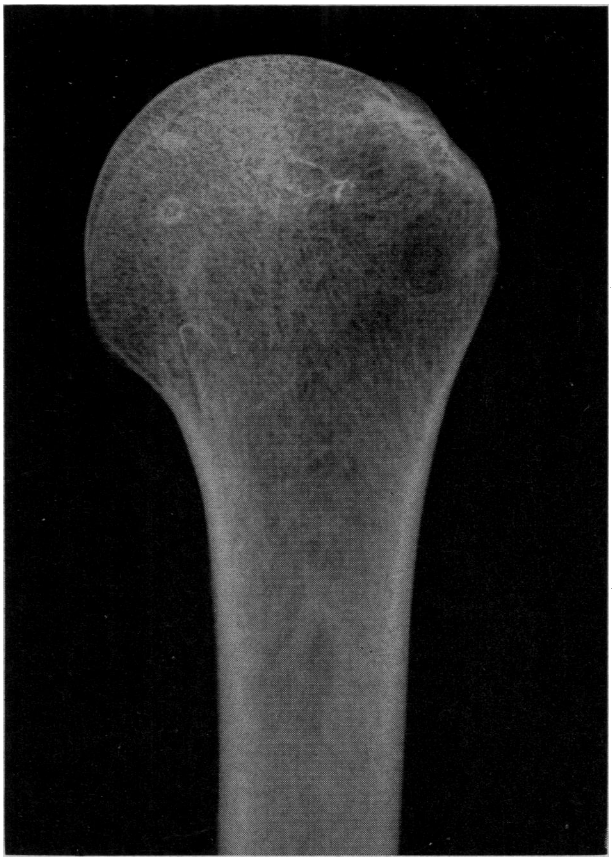

Fig. 1.—Anteroposterior roentgenogram of upper humerus. A cavity can be seen in the greater tuberosity, but the amount of cancellous bone in the shaft cannot be estimated. The epiphyseal plate is not identifiable.

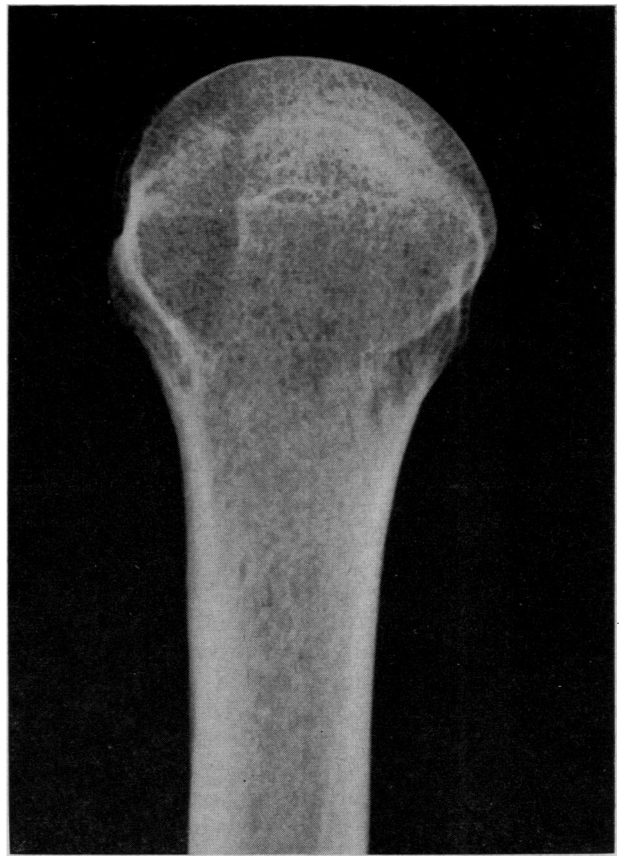

Fig 2.—Lateral roentgenogram of upper humerus.

from the diaphyseal wall, and from both sides of the anatomical neck (Fig. 5). For the greater part these run vertically up to the epiphyseal scar; where any significant amount of bone remains in the central part of the diaphysis there is a crossing over and intersection to form ogives, or a Gothic-arch inverted-V appearance. In most of the bones examined, however, this was not found, and according to Hansen the medullary cavity reaches the level of the surgical neck at 41-50 years, which would destroy these central intersections. The trabeculae seem to be continued through the

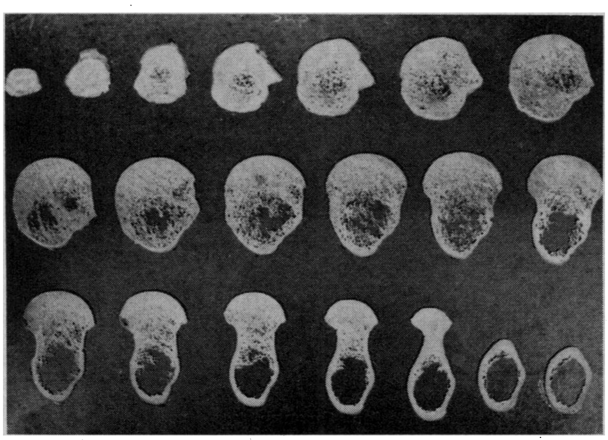

Fig. 3.—Horizontal sections made parallel to the central axis of the head and neck (group c), mounted on card in correct orientation.

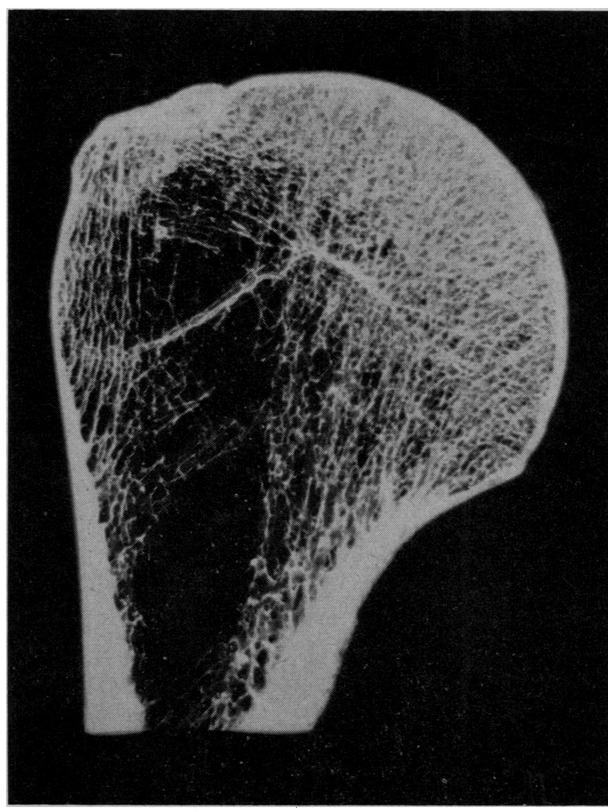

Fig. 4.—Vertical, coronal section. Observe the narrowing in width of the cortical bone at the funnel of the metaphysis, the loss of bone from the greater tuberosity and from beneath the epiphyseal scar, the persistence of the epiphyseal scar, and the vertical groups of trabeculae passing to the greater tuberosity and the inferior part of the head.

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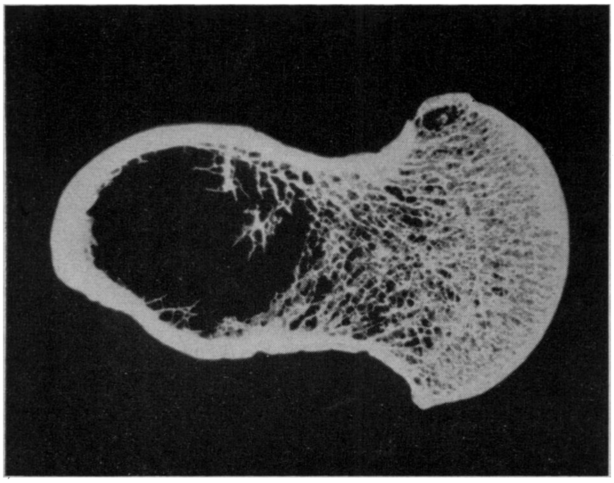

Fig. 5.—Horizontal section showing trabeculae arising from the anterior and posterior surfaces of the anatomical neck of the humerus. The peripheral trabeculae pass through the epiphyseal scar; the central trabeculae end at it.

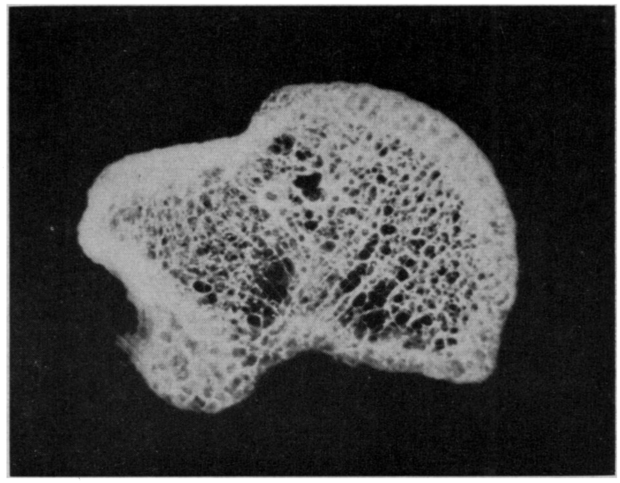

Fig. 7.—Vertical, coronal section through the posterior part of the greater tuberosity of the head. The arborescent pattern of trabeculae in the head is demonstrated.

periphery of the epiphyseal scar (Figs. 4, 5 and 6); laterally they pass upwards to end in the greater tuberosity, and medially they curve gently to pass to the central and inferomedial aspects of the humeral head. The remainder of the trabeculae pass to the epiphyseal scar and seem to end there. It is usually difficult to find trabecular continuity through the central part of the scar although certainly in some places it does occur.

Within the head other trabeculae take origin from the epiphyseal scar. These are rather arborescent in pattern, in that the stems on the epiphyseal plate are few and thick in comparison with the progressive increase in numbers and decrease in thickness of trabeculae as the cortex is approached (Figs. 4, 6 and 7). As in the femur, a coarsening of the trabeculae is found when there is a diminution of total quantity of bone. The honeycomb arrangement of trabeculae in the head, seen best in sagittal sections (Fig. 8), becomes larger-meshed in the more osteoporotic bone, but the trabeculae are of equal thickness, suggesting that there is no primary or secondary division of them and that they are of equal significance in resisting deformation of the head. The head showed no evidence of cavitation in any of the bones examined.

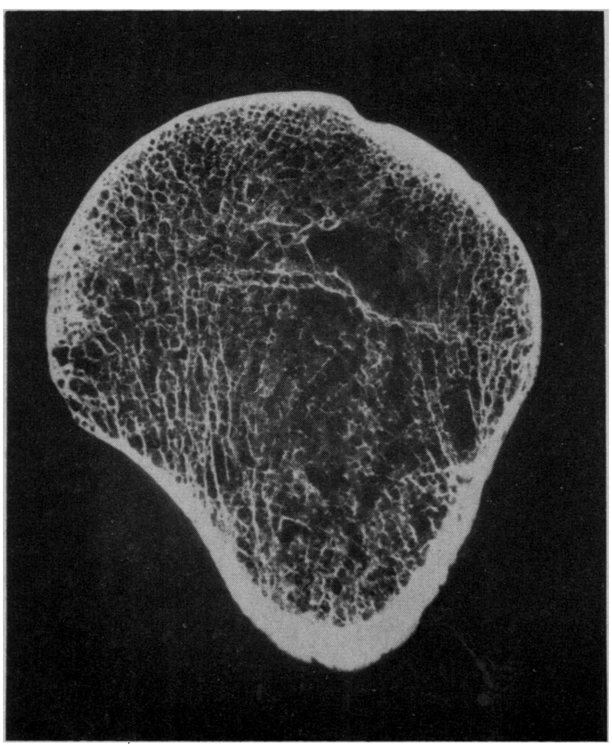

Fig. 6.—Sagittal section parallel and lateral to the anatomical neck, through the upper part of the greater tuberosity. There is a considerable volume of bone in the section. Trabecular continuity is seen through the epiphyseal scar.

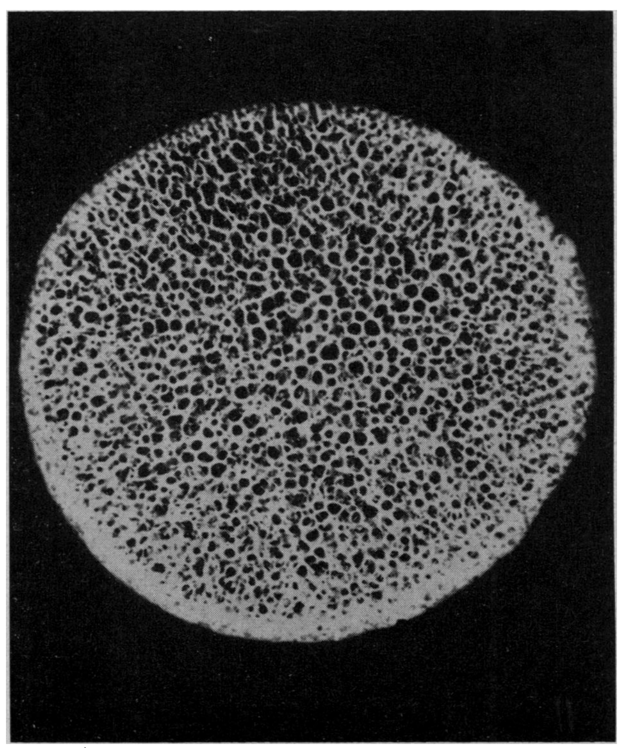

Fig. 8.—Sagittal section through the head, showing the honeycomb arrangement of the trabeculae. The bone is denser inferiorly, where it receives the medial trabecular ray, than superiorly where it is reinforced by the ray from the greater tuberosity.

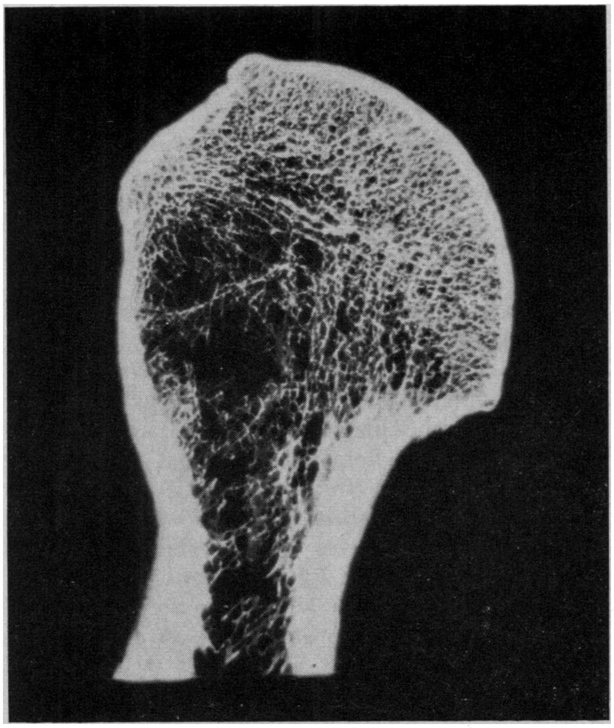

Fig. 9.—Vertical section posterior to the axis of the humeral neck, showing the thick cortical plate where the supraspinatus is inserted, the ray of trabeculae from the greater tuberosity reinforcing the upper part of the head, and the vertical trabeculae from the medial shaft cortex passing to the inferior half of the surface of the head.

Although in younger bones the greater tuberosity is filled with cancellous bone, in all of the specimens examined some evidence of cavitation had occurred. This in the more osteoporotic specimens occupied the greater part of the tuberosity, whose external bone is found to be a thin shell.

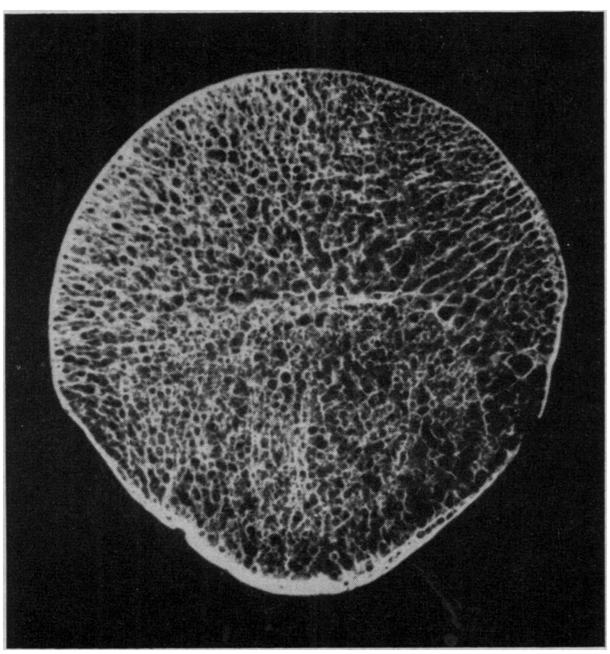

Fig. 10.—Sagittal section parallel to the anatomical neck, through the lesser tuberosity (to the right of the picture) and the posterior part of the greater tuberosity (to the left of the picture. The region of the anatomical neck is filled with cancellous bone, even in an osteoporotic specimen such as this. Trabecular rays pass to the centre of the section from both tuberosities.

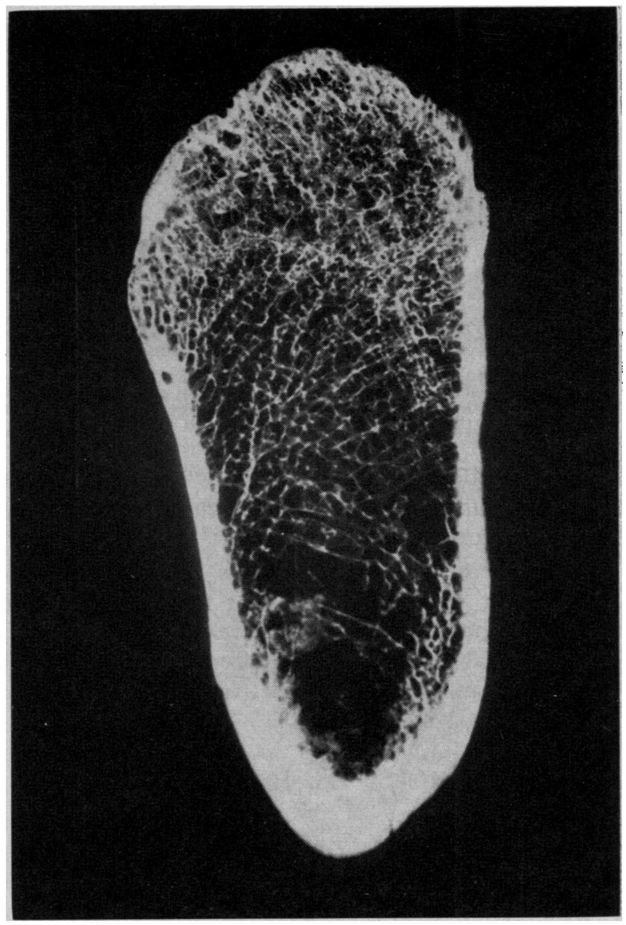

Fig. 11.—Sagittal section, parallel to the anatomical neck, through the lower part of the greater tuberosity (upper part of picture) and the shaft (lower part of picture). Even though the obliquity of the section exaggerates the thickness of the wall, the porous character of the lower part of the greater tuberosity is apparent.

The presence of the cavity can be identified on good-quality clinical radiographs, when its character is known and it is sought. According to Schranz, it never communicates with the cavity of the diaphysis, but in the more porotic specimens examined the lateral extremity of the plate was missing, allowing such a communication. The remarkable persistence of the epiphyseal scar, when there may be no bone on either side of it, is presumably of some significance. The cortex at the superior surface of the greater tuberosity is thickened where the supraspinatus tendon is inserted into it. There is a radiation of trabeculae from below this point that merges medially with the trabeculae of the head (Fig. 9), and is supported below by the vertical trabeculae from the diaphysis. There is also a medial radiation beneath the thickened cortex of the bicipital groove. Trabeculae radiate forwards and inwards from the posterior aspect of the greater tuberosity, and backwards and inwards from the lesser tuberosity (Fig. 10). The cortex of the lower part of the greater tuberosity is often so thin that it appears to be cancellous bone (Fig. 11). The cortex of the head, although it becomes a thin shell, never has this appearance in its upper two-thirds; but at the

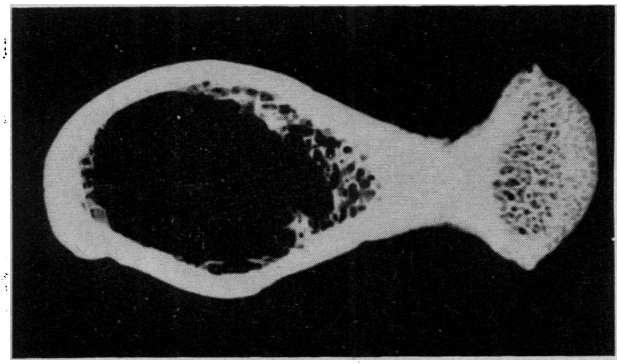

Fig. 12.—Horizontal section, parallel to the axis of the head and neck, passing through the lower part of the head (right of picture) and the shaft (left of picture). The porous structure of the lower part of the head is demonstrated.

lower one-third as the head merges into the surgical neck, a similar cancellous appearance of the bone shell is found (Fig. 12).

The cortex of the diaphysis is of uniform thickness in its upper part, but as it flares into the funnel-shaped metaphysis there is a progressive thinning until the metaphysis merges with the head medially and the greater tuberosity laterally (Figs. 1, 3, 4 and 5).

A Comparison of the Humerus with the Femur

In the upper end of both the humerus and the femur two major rays of trabeculae are seen. In the femur there are a vertically orientated medial ray and a transversely orientated lateral ray.[5] In the upper end of the humerus both rays are vertically orientated. The medial ray, like that of the femur, passes to the head; but in the humerus it passes to the inferomedial aspect of the head, whereas in the femur it passes to the superolateral aspect.

The lateral humeral ray passes vertically to the tuberosity, but from there a second ray passes to the superolateral aspect of the head. These two rays may perhaps be considered one unit.

The medial ray in both the femur and the humerus resists deformation by static loading, i.e. in standing or in leaning on the hand. But whereas the lateral femoral ray is concerned with dynamic distortion, the lateral humeral ray is probably also concerned with static loading, because force is transmitted through it between the supraspinatus muscle and the humeral shaft. Dynamic distortion of the head is resisted by its honeycomb of trabeculae, and probably is also strengthened by the trabeculae that run from the greater tuberosity to the head.

Fractures of the Upper Humerus

A description of these fractures will be found in all standard texts; the literature on this subject has been reviewed by Einarsson. The least common site of fracture in this region is through the head itself, and such a fracture usually occurs in young men after a major injury. Fracture through the anatomical neck of the humerus is also uncommon. In both of these regions the cancellous bone is dense and still persists even in the advanced osteoporotic state.

The commonest fracture occurs at the surgical neck of the humerus. This is usually in the nature of an undisplaced fracture, often erroneously called impacted, and may be associated with a fracture of the greater tuberosity. In the series studied, Einarsson found 136 fractures of the surgical neck compared with two fractures of the anatomical neck. Isolated fractures occur at the greater tuberosity in which it is either struck off, as in dislocations of the shoulder (15% of 500 cases at the Massachusetts General Hospital[1]), or may be squashed by direct trauma.

From an examination of the sections of these bones the existence of an egg-shell-thin cortex which is unsupported by cancellous bone readily explains the ease with which the area is injured. The actual point of fracture at the surgical neck is often hard to determine on the clinical radiographs owing to fragmentation and overlapping of the fragments. It appears, however, to vary between a truly transverse fracture across the mouth of the metaphyseal funnel immediately beneath the head and the greater tuberosity, and a more oblique fracture line passing from the lower half of the greater tuberosity to the inferior surface of the head-neck junction. Both of the latter areas have been found to be particularly thin.

Summary

Twenty upper humeri from cadavers were sectioned in three planes and examined radiologically. The appearance of the trabecular patterns is described. Loss of bone substance with ageing is found in the shaft beneath the epiphyseal scar centrally and in the greater tuberosity. The commonest site of fracture in the region is through the surgical neck, and this has been related to the bone loss described.

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