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POST-TRAUMATIC LESIONS OF THE LUNATE BONE

By

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Of injuries to the wrist bones, navicular fractures are the most common, followed by lesions of the lunate bone (*Bavendam, Cave, Jensen, Kappis)*. The pathologic change that is variously termed lunatomalacia, Kienböck's disease, post-traumatic malacia, chronic osteitis, and aseptic necrosis has been the subject of comprehensive studies since the end of the last century, when anatomists described such lesions under the designations lunatum partitum, bipartitum, epilunatum, etc.

Of the theories propounded regarding the mechanism of origin, four different categories may be distinguished. (1) *Axhausen*'s theory differs essentially from the others in that he discounts the notion of a traumatic etiology and believes the cause to lie in an aseptic embolus of unknown origin. All other investigators attach major or minor significance to traumata.—(2) *Kienböck,* who in 1910 described in detail the symptomatology and roentgenologic picture of lunatomalacia, attributed the condition to ruptured ligament and vascular injuries attendant upon dorsal subluxation of the semilunar bone. The vascular disturbance, in his opinion, gave rise to malacia of the bone, and subsequent traumata resulted in compression and fragmentation. Opponents of Kienböck's theory have asserted that dislocation of the lunate bone is never followed by malacia (*Hultén* and others) and that ligament ruptures are not demonstrable at microscopic examination of malacia (*Fabricius-Møller, Cordes*).—(3) *Müller,* in 1920, advanced a theory according to which minor traumata lead to pathologic processes of obscure character. This theory was based on the fact that the disease most commonly affects the right hands of manual workers. Although a few other investigators have subscribed to Müller's theory (*Göcke, Esau* and others) the majority believe that a compression fracture is primary.—(4) The fracture theory fortified by the results of microscopic

examinations (*Cordes*) which show that in the majority of relatively fresh cases a fissure is discernible, generally running parallel with the proximal articular surface. These cases exhibit hematomas—indication that the fractures have occurred in living bone. In the course of time these hematomas are resolved and the picture is one of necrotic areas gradually replaced by fibrous tissue. Since this tissue is never observed to contain hematomas or necroses the lesion has manifestly been produced by a single trauma or, possibly, by repeated traumata over a very short period. Traumata repeated at longer intervals should, logically, give rise to every gradation between fresh hematomas and necroses, but in no case did *Cordes* observe any such lesions.—Opponents of the fracture theory point out that roentgen examinations have failed to reveal any malacia following fresh fractures of healthy bone. *Ståhl*, however, in a series of 184 cases, observed four fresh compression fractures which had resulted in typical malacia.

Some authorities contend that the etiology may vary from case to case, but *Persson* has emphasized the absence of any roentgenologic or histologic difference between verified post-traumatic malacia and malacia with no history of trauma. The condition, in his opinion, is a distinct pathologic entity.

The fracture theory is the oldest and most widely accepted of the four. It is supported, moreover, by *Hultén*'s investigations, which demonstrate a statistically significant preponderance of minus variants. In *Hultén*'s study, non-variants are those cases in which the distal articular surfaces of the radius and the ulna show no difference in level. In plus variants the ulna is longer than the radius, and in minus variants shorter.— *Hultén* observed that in plus variants cystic changes may occur in the ulnar portion of the lunate bone. The cause, in his view, is a maximal load on a punctate area.

Köstler, assailing *Hultén*'s hypothesis, attributes the cyst formation to repeated traumata. He has found that the cysts may occur in non-variants too, and is therefore unable to accept ulnar compression of the semilunar bone as a likely cause. The etiologic factor, he believes, is a damaged disc giving rise to an intra-articular lesion of the lunate.

Kappis, in microscopic studies of post-traumatic navicular cysts, noted that they were filled with fibrous tissue—the remains of necrotic tissue or resolved fracture hematomas. In his opinion small necroses develop at the surface of all compression fractures. Compression of the cancellous bone, moreover, may result in the formation of small bone fragments that are completely isolated by fractures and hence undergo

necrosis. If fractures run in the proximity of nutrient foramina they may lead to vascular lesions with the attendant danger of central necrosis. Even intraosseous hematomas may give rise to cystic cavities. *Kappis* considers that although the mechanism of origin may vary somewhat, trauma is the eliciting factor.

MATERIAL

Of a series of approximately 5,000 wrists roentgenologically examined since 1951, pathologic changes of the semilunar bone were observed in a total of 158 patients. Ninety of these returned for follow-up examinations comprising conventional roentgenograms of both wrists and tomograms of the injured hands. For tomographic examination (Polytome, Massiot) a polycycloid movement, with sections at intervals of 2 mm., was applied. The examination generally included both frontal and lateral projections.

TABLE 1
Distribution of the Series by Side and Sex.

	Males			Females			Total
	Right	Left		Right	Left		
I. Sclerosis	1	1	(2)	–	1	(1)	3
II. Dislocations	6	2	(8)	–	–	–	8
III. Avulsion of compact fragments ...	3	1	(4)	–	1	(1)	5
IV. Structural changes without compression	23	23	(46)	20	26	(46)	92
V. Structural changes with compression	23	11	(34)	10	6	(16)	50
						Total	158

Males 94 cases. Females 64 cases. Right hand, 86. Left hand, 72.

The distribution of the series is shown in Table 1. The first three groups with readily definable changes comprise a total of 16 cases. The remaining 142 cases form two groups. In group IV structural changes of the spongy bone are present alone, while in group V they are associated with lunate deformation due to compression. In order to determine whether compression was present the index reported by *Ståhl* was applied:

$$\text{Index} = \frac{\text{Vertical height}}{\text{Horizontal diameter}} \times 100$$

The height was determined by measuring the distance between the proximal and distal articular surfaces on the lateral projection, and the horizontal diameter by measuring the greatest dorso-volar diameter perpendicular to the vertical height. The measurements were made with an accuracy of 1 mm. Control measurements in 100 healthy wrists showed an index range of 50–70 (median 58). On this basis quotients of less than 50 were considered tantamount to compression. Such cases were assigned to group V, consisting of fresh compression fractures and malacia. Group IV is composed largely of lesions designated as "cysts".

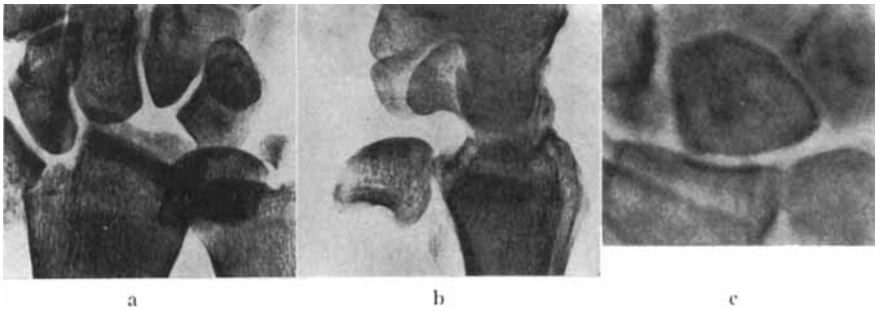
TABLE 2
Age Distribution of the Series.

Age	Males	Females
11–20	4	4
21–30	17	11
31–40	16	9
41–50	29	10
51–60	17	11
61–70	9	12
71–80	2	5
81–90	–	1
91–100	–	1

From the age distribution (Table 2) it will be seen that the majority of the patients were of physically active age. In terms of age distribution the "malacia" and the "cyst" groups do not differ markedly from the total series. Eighty-seven per cent of the males were manual workers.

I. *Sclerosis*

Each of two patients exhibited a central island of compact tissue. One of them was followed up and showed an unchanged picture after five years. The third patient in this group had a well-delineated area of subchondral sclerosis in the distal part of the bone, and a similar lesion was observed in the contralateral hand. In this patient too, the sclerosis was unchanged at follow up. These changes probably constituted developmental defects.



a b c

Fig. 1.
Severe dislocation of lunate bone. (a) Frontal and (b) lateral projection. (c) Tomography in frontal projection 1½ years after the trauma.

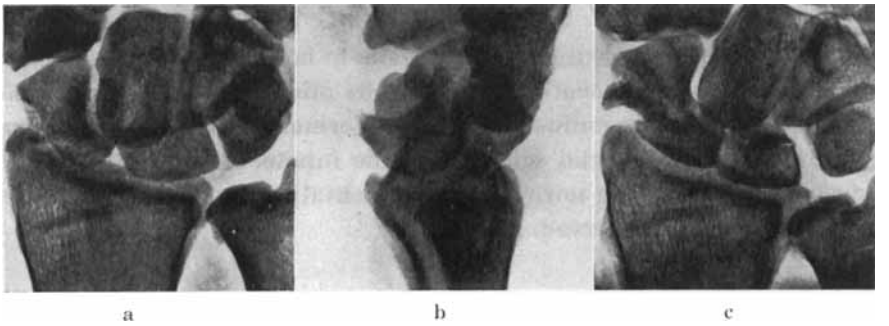


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Fig. 2.
Perilunar dislocation associated with navicular fracture. (a) Frontal and (b) lateral projection. (c) Follow up 11 months after the trauma.

II. *Dislocations*

Lunate dislocations assume two forms: (1) Direct volar displacement in relation to both the radius and ulna and the other carpal bones, and (2) no direct displacement of the lunate relative to the radius and ulna, but dorsal luxation of the other carpal bones. The latter form is known as perilunar dislocation. Lunate dislocations are invariably associated with fractures of adjacent bones. The present series includes three cases of direct luxation (Fig. 1) and three of perilunar dislocation (Fig. 2). Each of these patients underwent roentgen examination at the time of the trauma, then immediate reduction of the dislocation. In none of the three followed-up cases did structural changes develop in the semilunar bone (Fig. 1).

There were also two inveterate cases with a history of trauma about

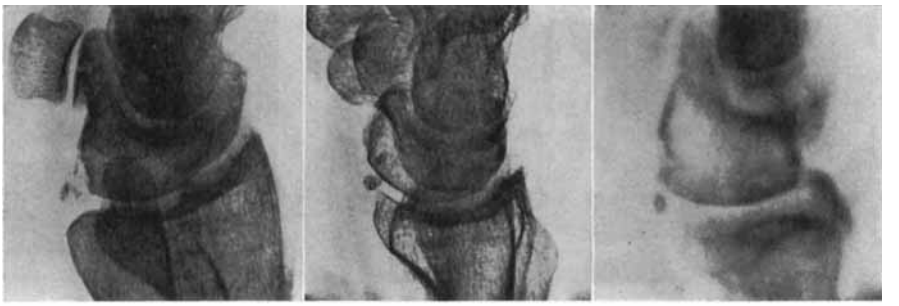

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Fig. 3.
Volar avulsion of compact fragment. (a) Lateral projection at time of trauma. (b) Follow up 10 years later. (c) Tomography in lateral projection shows cortical defect but no structural changes.

twenty years before roentgen examination. In both cases the lunate bone still showed volar dislocation and, like the other carpal bones and the distal portion of the radius and ulna, deformation. Tomographic examination revealed partial sclerosis of the lunate. Although its dorsal border was lower than normal, no fragmentation or cystic rarefaction as in malacia was observed.

III. *Avulsed Compact Fragments*

Only in five cases was avulsion of lunate cortical fragments noted. Avulsion had occurred from the volar aspect in three and from the dorsal aspect in two. In the first-mentioned three the cortical defects were clearly discernible (Fig. 3). At follow up 5–10 years later both the defects and the fragments were still evident. Thus, there was no tendency to resolution of the fragments, which had become rounded and well defined. Neither in these three cases nor in the two with dorsal fragments were structural changes detectable in the lunate bone.

IV. *Structural Changes in Non-compressed Lunate Bones*

This group, comprising 92 cases, consists largely of "cysts". However, tomographic examination shows that the structural changes which on conventional roentgenograms are regarded as cystic correspond to defects and the fragments were still evident. Thus, there was no tendency predilection, one situated proximally towards the radial aspect, the other dorso-proximally towards the ulnar aspect (Figs. 5 and 6).

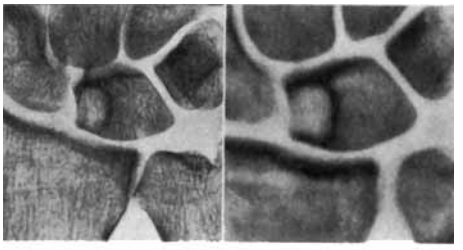

Fig. 4.
(a) Frontal projection showing lunate "cysts". (b) Tomography of same case reveals deep defect towards radial aspect of the lunate.

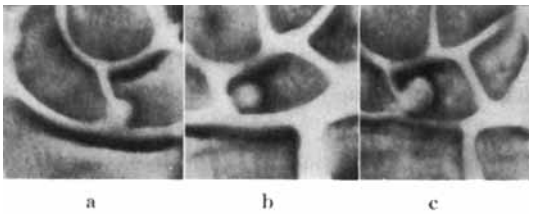

Fig. 5.
Tomography in frontal projection of lunate "cysts" situated towards the radial aspect.

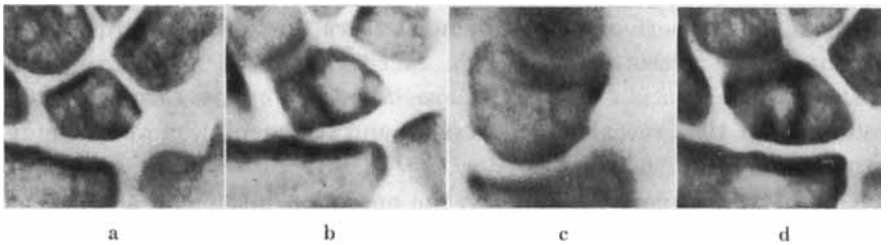

Fig. 6.
Tomography of (a) and (b) cavities in ulnar portion, and (c) dorsal cavity. (d) Large irregular "cyst" with proximal defect in the lunate.

In this group all gradations from shallow depressions to rounded cavities associated with fairly wide cortical defects were observed on the tomograms. The cavities had smooth walls but were usually irregular in shape (Fig. 6 d). In addition to those located near the radial and ulnar aspects, others were situated beneath the dorsal and the volar surfaces (Fig. 6 c). Common to them all, however, was a proximal localization in the lunate bone. Large "cystic formations" sometimes ex-

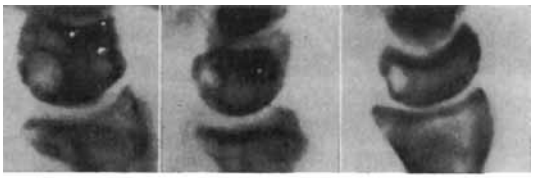

Fig. 7.
Tomography in lateral projection of different cases with subcortical "cysts" and cortical defects at sites of nutrient foramina.

tended some distance distally, but the cortical defects were situated proximally (Fig. 6 d).

Besides these more or less deep cavities, another form of cystic rarefaction was noted, consisting of cystic areas a few millimeters beneath the compact bone. From the "cysts" narrow ducts—possibly corresponding to nutrient foramina—passed through the cortex to the bone surface (Fig. 7). Although the "cysts" were as a rule solitary, some measure of variability was apparent and in extreme cases the entire bone was pervaded with cystoid cavities. In no case, however, was there any deformation of the bone contour.

Eight patients had bilateral lunate "cysts", and 14 showed cystic involvement of other carpal bones as well. In all save one of the followed-up cases (48 patients) the lesions retained their shape and size during the observation period, though in most cases the adjacent bone tissue became more sclerotic. The single exception was a patient who, at roentgen examination in 1957, showed only a cystic rarefaction. A follow-up in 1961 revealed compression and fragmentation of the semilunar bone as in "malacia".

One patient underwent surgery, the operation disclosing a spherical cavity containing a yellowish gelatinous fluid under pressure. A fissure extended through the cortex to the cartilage of the navicular aspect. Histopathologic examination showed cell-deficient fibrous tissue but no inflammatory cell infiltration and no myxoma-like tissue.

V. *Structural Changes in Compressed Lunate Bones*

This group includes both fresh compression fractures and pronounced "malacia", as well as cases intermediate between the two. Tomography of the lunate showed bone densities as well as cystic rarefaction in the same bone. The compression had served to increase the dorsovolar diameter while the radio-ulnar diameter was unchanged. The

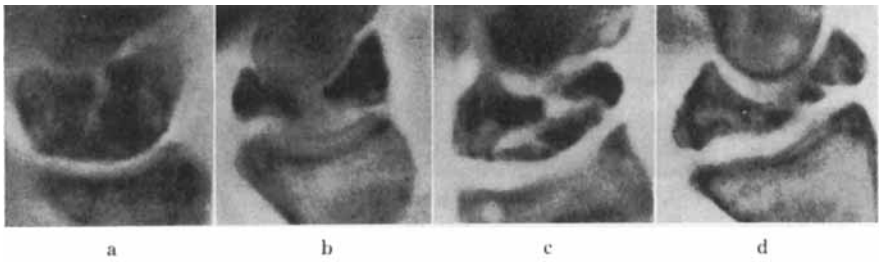

Fig. 8.
Tomography in lateral projection of different malacia cases, showing various degrees of fragmentation and compression.

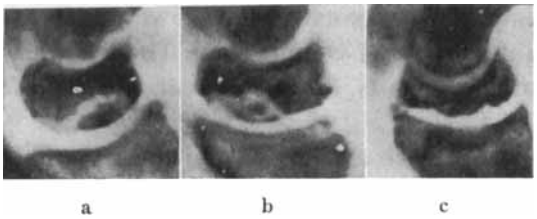

Fig. 9.
Different cases with compression of the proximal portion of the lunate, showing fractures parallel with the articular surface.

degree of compression varied greatly, as did the fragmentation (Fig. 8). No correlation existed between the degree of compression, fragmentation, and the age of the lesion.

A fracture which divided the lunate bone into volar and dorsal fragments was noted in 27 cases (Fig. 8). In ten cases only the proximal part of the bone was compressed, and here a fracture ran parallel with the proximal articular surface (Fig. 9).

Two patients had fresh compression fractures due to severe trauma sustained in accidents. They were treated with fixation and the fractures healed with slight deformation of the bone but no malacia. In another four cases the initial roentgen examination disclosed slight compression, but in view of the relatively mild trauma prolonged fixation was not considered necessary. Follow-up, roentgenograms showed, in all four, a typical malacia picture (Fig. 10). In a further six of 26 cases followed up more than one year after the first roentgen examination the compression had increased.

The minus variant described by *Hultén* (see page 168) was noted in 23 cases (47 per cent), the non-variant in 11 (22 per cent) and the plus

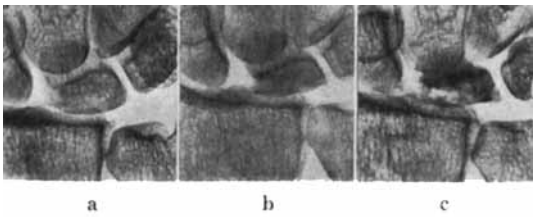

Fig. 10.
(a) Compression fracture in radial portion of lunate bone, due to mild trauma. (b) Four months later the compression has increased. (c) Two years after the trauma, typical malacia picture.

variant in 15 (31 per cent). Thus, there was a definite preponderance of minus variants. The three categories, however, showed no significant differences in the degree of compression. The compression index averaged 35 for minus variants, 34 for non-variants, and 32 for plus variants.

The lesions were twice as common on the right as on the left side. Only one of the patients with left-sided lunate "malacia" was sinistromanual. One patient had bilateral lesions. The group consisted of 34 males and 16 females—a sex distribution which doubtless reflects the occupational disparity.

Anatomic and Mechanical Conditions

Before proceeding to discuss the mechanism of origin of "malacia" and "cysts" I will first recapitulate briefly the anatomic and mechanical conditions to which the lunate bone is subject. Of the dorsal and volar groups of ligaments which extend from the radius and ulna to the carpal bones, only a few fibers are attached to the lunate bone. It is for this reason that avulsion of lunate fragments is rarely observed. Interosseous ligaments, however, unite the lunate with other carpal bones, though only those connecting the lunate and navicular bones permit any major degree of motion. With volar flexion the navicular rotates 90 degrees, whereas the semilunar bone moves only 30 degrees. On dorsal flexion the navicular does not pass the long axis of the radius, while the lunate rotates 10–15 degrees dorsally (Fig. 11). A certain screw-like movement between the navicular and lunate bones also accompanies radial flexion. With ulnar flexion the lunate glides on the articular surface of the radius, its radial portion passing the ridge which divides that surface into two parts corresponding to the articular surfaces of the navicular and lunate in mid-position (Fig. 12).

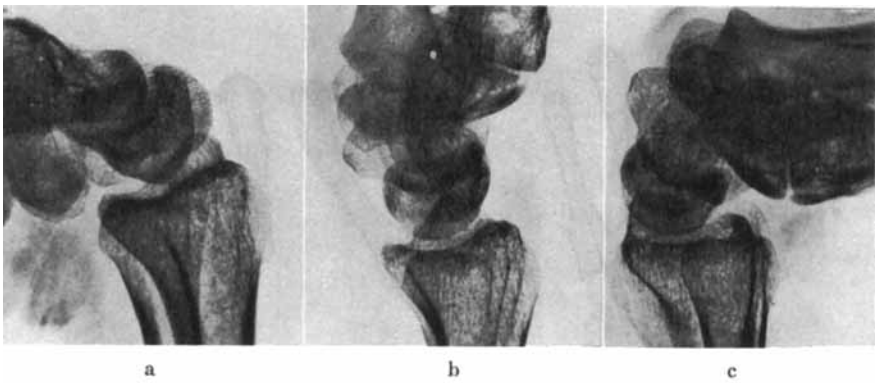

Fig. 11.
Motions of lunate and other carpal bones on (a) volar flexion and (c) dorsiflexion. (b) Mid-position.

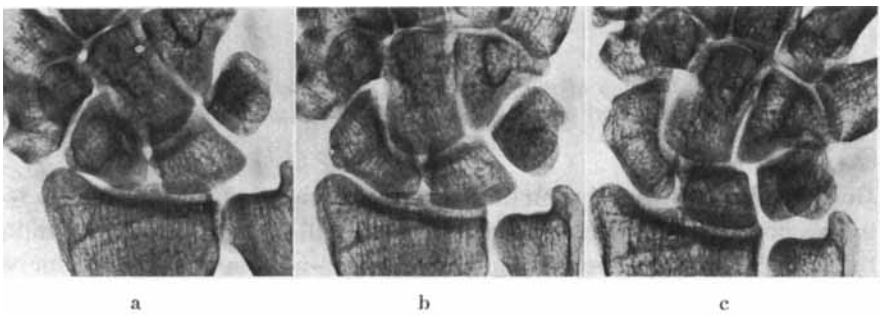

Fig. 12.
Motions of lunate and other carpal bones on (a) radial flexion and (c) ulnar flexion. (b) Mid-position.

Trauma sustained via the capitate bone will, due to the semilunar shape of the lunate, be propagated through the latter's center. Since the radial and ulnar articular surfaces are oblique, lines of force from other carpal bones converge on the lunate (Fig. 13). Thus, the lunate is subject to a greater pressure than any of the other wrist bones, no matter what the position of the hand may be (*Cordes*). The lunate articulates, proximally, with both the radius and the ulna. *Hultén* has shown that, with compression, the distance between the lunate and the ulna decreases but the distance between the lunate and the radius remains constant. The ulnar disc, therefore, is more resilient than the articular surface of the radius. With violence in the long axis of the hand the lunate will be compressed between the carpal bones on one

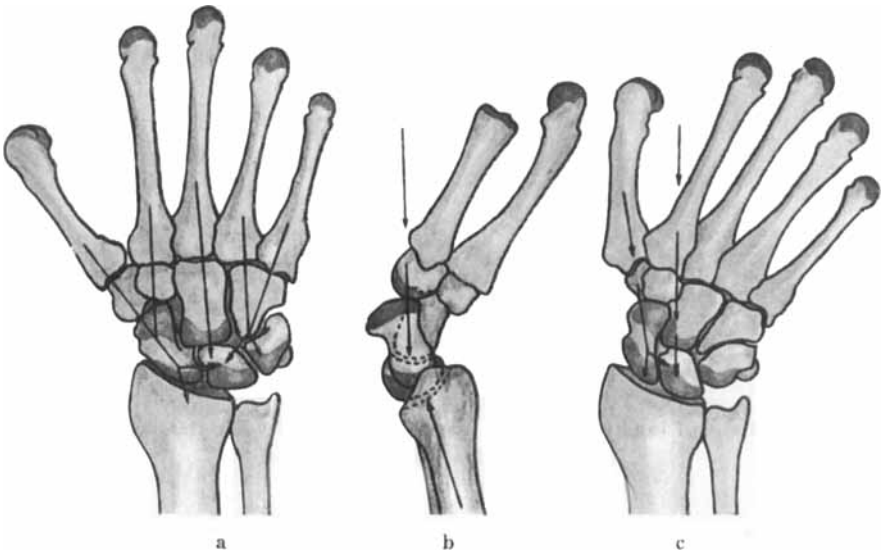

Fig. 13.
Schematic representation of the forces acting upon the lunate. (a) Mid-position. (b) dorsiflexion. (c) ulnar flexion.

side and the radius and ulna on the other. Because of uneven resistance in the proximal articular surface the load will be greater on the radial than on the ulnar portion of the lunate bone—a circumstance conducive to compression fracture. The uneven load will be accentuated if the ulna is shorter than the radius, as in minus variants (*Hultén*).

The lunate bone has been likened to a cartilaginous capsule enclosing a cancellous central portion. Of all carpal bones the lunate has proportionally the largest cartilage-covered area. For this reason it is relatively insensitive, since cartilage itself has no nerve supply and cancellous bone has a lower pain sensibility than periosteum (*Hultén*).

Owing to this discrepancy between cartilage-covered and periosteum-covered surfaces, moreover, the vascular supply of the lunate is readily damaged. Only on the volar and dorsal aspects of the lunate are there small periosteum-covered areas, and here the bone is nourished by a varying number of small vessels—two to four on the volar aspect and one to four on the dorsal (*Cordes, Ståhl*).

Watson-Jones has shown that in fractures the initial hyperemia must subside before calcium deposition can take place in new osteogenic tissue. The hyperemia, which is due to the release of acetylcholine, histamine and similar substances into the tissue, ceases after approximately

ten days. With poor fixation and with repeated traumata the release of these substances continues, the hyperemia persists and decalcification proceeds. A crack becomes a cavity; a linear fracture, a gap fracture.

DISCUSSION AND CONCLUSIONS

"Malacia"

The two principal arguments against the fracture theory have been, first, the frequent lack of any history of trauma in "malacia" cases and, secondly, the fact that fresh compression fractures have not been observed to develop into "malacia". Only 50 per cent of the patients in this series had any recollection of a specific trauma. However, it is evident from the aforegoing that by virtue of the enclosed position of the lunate bone very little violence is required to injure it. Due to the relative insensitivity of this bone the injury may easily escape detection. This accounts for the inability of so many of these patients—most of whom are manual workers and frequently suffer minor injuries—to recall a particular trauma. In the acute stage they make light of the injury and are thus exposed to the risk of defective healing.

Ståhl has shown that in some cases the development can be followed roentgenologically from compression fracture to "malacia". The present series includes four such cases (see page 175). The lunate dislocations, on the other hand, healed without structural changes even though the blood supply must have been seriously affected. Even avulsion of cortical bone fragments is likely to be associated with ruptured vessels, yet in none of five such cases did lunate "malacia" develop. In this series, therefore, nothing has emerged to conflict with the fracture theory. The cases of fresh compression fractures that healed after fixation (see page 175) lend further support to the assumption that lunate "malacia" is not malacia in the strict sense, but merely a defectively healed compression fracture.

"Cysts"

As regards "cystic rarefaction" the mechanism of origin, as *Kappis* pointed out, probably varies, though local compression is a feature common to all cases. At times the trauma may lead to compression of the elastic cartilage. When this cartilage subsequently springs back, a cavity containing blood and compressed bone fragments forms beneath it. The impaired blood supply precludes normal bone tissue regeneration and the cavity fills with fibrous tissue and fluid. In due course

the necrotic area in the cancellous bone becomes larger than the cortical defect.—The fissure through the cortex, observed at operation on one of the present cases, may have corresponded to the fracture. Local subchondral compression fractures of this type usually involve the radial aspect, where the proximal ulnar border of the navicular may be forced against the lunate bone (Fig. 5).

Cystic cavities not situated at the periphery are, as mentioned above, directly connected with nutrient foramina. Injury of the vessel in the cancellous bone gives rise to a hematoma which, on resolution, leaves behind a cystic cavity. That a fracture would, by rupturing vessels, lead to central necrosis—as *Kappis* believes—seems unlikely, for avulsion of cortical fragments with vascular damage does not lead to cystic rarefaction, either peripheral or central.

Both "malacia" and "cysts" thus appear to be post-traumatic changes in the lunate bone. "Malacia" represents a defectively healed fracture after compression of the whole or the greater part of the bone. "Cysts" are residual conditions following local compression by an adjacent bone.

SUMMARY

Of 158 roentgenologically observed cases of lunate bone lesions, 90 were subjected to tomographic follow-up examination. The bulk of the total series consisted of "malacia" (50 cases) and "cysts" (92 cases). In no case did lunate dislocation or vascular injuries of other etiology lead to malacia. Typical malacia did develop, however, from fresh compression fractures. The malacia cases represented defectively healed compression fractures; the "cysts" were residual conditions stemming from local compression.

RESUME

Sur 158 cas de lésions de l'os semi-lunaire constatées radiologiquement, 90 ont été soumis à un réexamen tomographique. La saillie consistait pour la série totale en « malacie » (50 cas) et « kystes » (92 cas). Dans aucun cas la dislocation ou des lésions vasculaires d'une autre étiologie n'étaient cause de la malacie. Une malacie typique s'est néanmoins produite à la suite de fractures fraîches de compression. Les cas de malacie représentent des fractures de compression dont la guérison est défectueuse; les « kystes » étaient de nature résiduelle provenant de compressions locales.

ZUSAMMENFASSUNG

Von 158 röntgenologisch beobachteten Fällen von os lunatum Verletzungen wurden 90 einer tomographischen Nachuntersuchung unterzogen. Der Hauptanteil der Gesamtreihe bestand in „Malacien" (50 Fälle) und „Cysten" (92 Fälle). In keinem Falle führte Lunatumluxation oder Gefässverletzungen anderer Ethiologie zur Malacie. Typische Malacie entwickelte sich jedoch aus frischen Kompressionsbrüchen. Die Malacie-Fälle stellten fehlerhaft geheilte Kompressionsbrüche dar. Die „Cysten" waren Restzustände nach örtlichen Kompressionen.

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