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THE INTRAOSSEUS ARTERIAL PATTERN OF THE CARPAL LUNATE BONE AND ITS RELATION TO AVASCULAR NECROSIS

By

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In 1910, *Kienböck* described an avascular lesion of the carpal lunate bone that had not previously been recognised.

Avascular changes in the lunate may, or may not, also follow dislocation of bone. Although it is generally accepted that necrosis is the result of damage to the blood supply of the bone, a search of the literature reveals only limited and conflicting evidence about the intraosseus pattern of the blood supply. An investigation has therefore been carried out to analyse the intraosseus arterial pattern and to correlate this with the various clinical avascular lesions of the lunate.

MATERIAL

The arterial supply of 53 normal lunates has been examined, using the technique described by *Trueta & Harrison* (1953). These were from patients between the ages of 11 and 79 years of both sexes. In no instances were necrosed or deformed lunates found.

METHODS

After flushing the major vessels from distal to proximal with a warm saline solution, the limb was injected via the subclavian or brachial artery with 50 % Micropaque suspension in water.

After the bone had been stripped of soft tissue it was fixed in 10 % formalin for 4–5 days and then decalcified using 10 % nitric acid.

The decalcified bones were examined by X-ray and then cleared by the Spalteholz method. This made it possible to examine the specimens both by microradiography and by direct vision, and for details to be studied under a dissecting microscope.

RESULTS

14 (26 %) lunates were found to be supplied from either the palmar non-articular surface alone, or from the dorsal non-articular surface alone, by means of a single major vessel, often supplemented by one or more minor vessels. 6 bones were supplied from the dorsal surface alone and 8 from the palmar surface. The single vessels enter the medial or lateral border of the appropriate surface of the bone, and then traverse the bone in a diagonal direction to end near the opposite border of the other surface of the bone.

Figures 1 and 2 are photographs of a Spalteholz preparation of the injected lunate from the right wrist of a man of 64. Figure 1 shows the specimen from its distal surface and shows the main artery of the bone entering towards the medial border of the palmar surface of the bone, and ending near the lateral border of the dorsal surface. Figure 2 shows the same bone photographed from the medial surface. The major vessel is seen to divide into two main branches supplying predominantly the proximal and distal parts of the bone separately.

4 (7.5 %) lunates were supplied by dorsal and palmar vessels that clearly did not anastomose. 2 of these were supplied by a single palmar and a single dorsal vessel; the other two by a single palmar and two dorsal vessels, and a single dorsal and two palmar vessels respectively (Figs. 3, 4 and 5). Figure 3 is of additional interest as it shows pene-

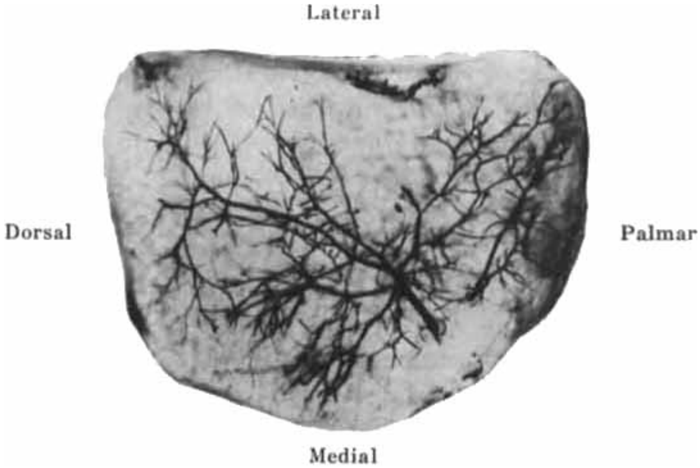

Fig. 1.
Male aged 64. Spalteholz preparation viewed from distal aspect showing arterial supply from palmar aspect only.

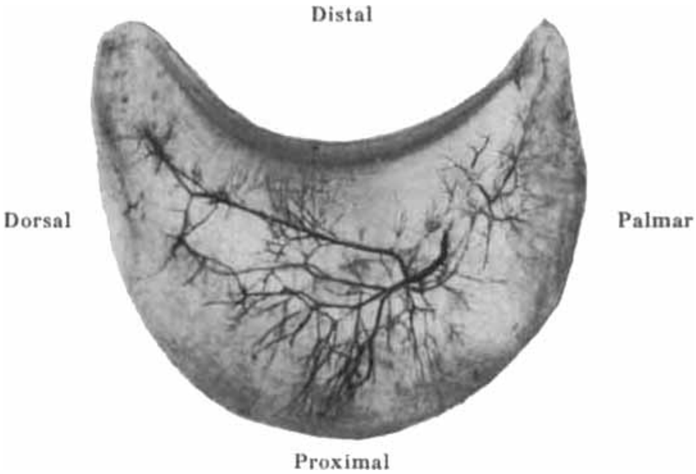

Fig. 2.
Male aged 64. Spalteholz preparation viewed from lateral aspect.

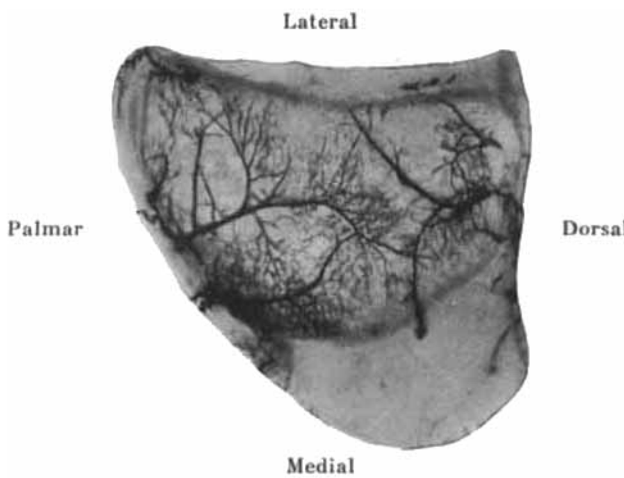

Fig. 3.
Male aged 11. Spalteholz preparation viewed from distal surface showing double palmar and major single dorsal vessels without anastomosis across the midline. Note the vascular sprout penetrating the enchondrium.

tration of the enchondrium by a vascular sprout prior to the laying down of bone, indicating the association between vascularity and osteogenesis described by *Trueta* (1957).

The remaining 35 (66.5 %) lunates were supplied by dorsal and pal-

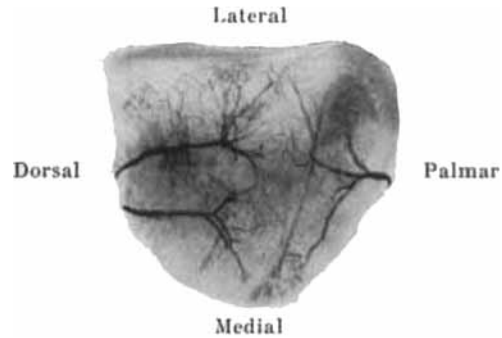

Fig. 4.
Male aged 11. Radiograph from distal aspect showing double dorsal and single palmar vessels which do not anastomose.

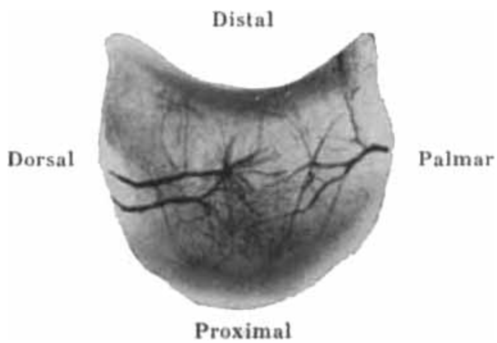

Fig. 5.
Male aged 11. Radiograph from lateral aspect showing double dorsal and single palmar vessels which do not anastomose.

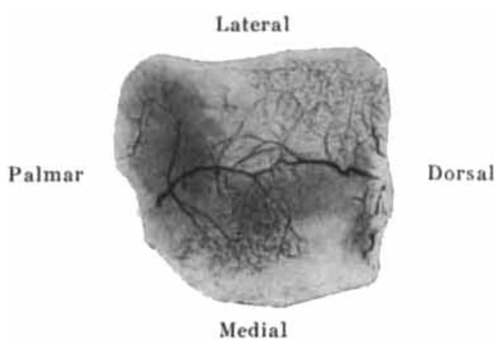

Fig. 6.
Male aged 18. Radiograph from distal aspect showing single dorsal and palmar vessels anastomosing.

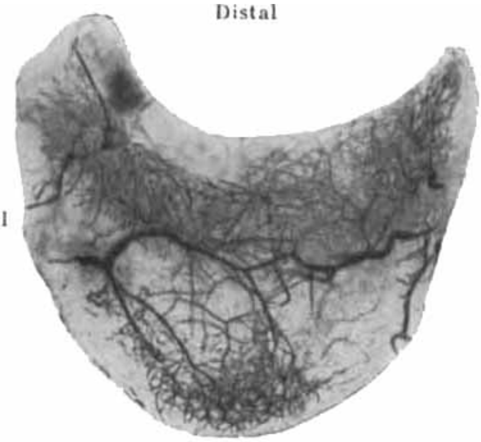

Fig. 7.
Male aged 18. Spalteholz preparation viewed from lateral aspect showing anastomosis between single palmar and dorsal vessels with branches to proximal part of lunate ending in a subchondral network.

mar vessels of varying numbers which anastomosed across the midline of the bone in various patterns as follows:

21 (40 %) bones had a main single dorsal and a main single palmar vessel: 16 (30 %) with a single central anastomotic channel (Figs. 6 and 7); and 5 (10 %) with a ring anastomosis in the centre of the bone from which branches were given off to the rest of the bone (Fig. 8).

14 (26.5 %) bones had varying numbers of dorsal and palmar vessels, all anastomosing across the midline (Fig. 9), the commonest pattern being one dorsal with two palmar vessels which occurred in 5 (10 %) specimens. In one specimen only, in which the supply was by one palmar and two dorsal vessels, was there a ring anastomosis between the palmar and dorsal vessels (Fig. 10).

When there was a simple anastomosis between dorsal and palmar vessels, this was usually in the centre of the bone. In a few instances it was found to lie distal to the centre of the bone; it was never found to lie proximal to the centre of the bone.

All 6 (11 %) lunates in which there was a central ring anastomosis between palmar and dorsal vessels also showed a characteristic pattern of distribution. This vascular anastomotic ring invariably lay obliquely within the bone so that one half of the ring lay nearer to the distal surface and one half nearer to the proximal surface of the bone (Fig. 8).

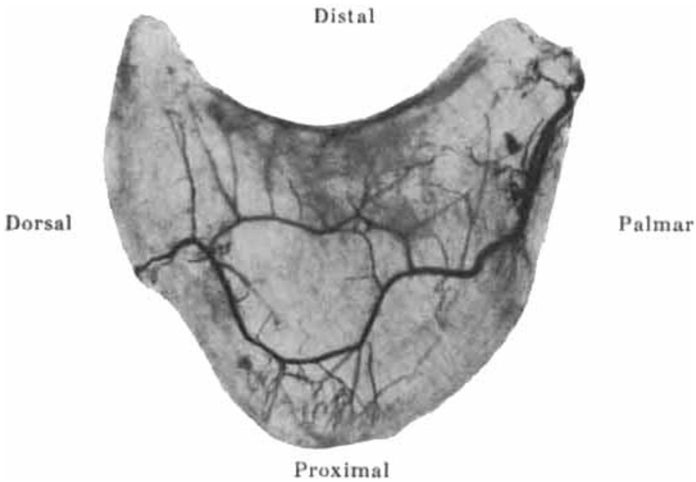

Fig. 8.
Male aged 40. Spalteholz preparation from lateral aspect showing single palmar and dorsal vessels anastomosing by an obliquely placed ring.

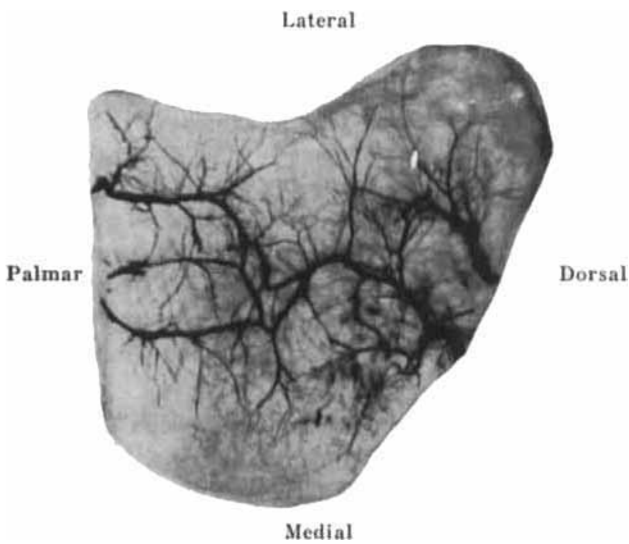

Fig. 9.
Male aged 21. Spalteholz preparation from distal aspect showing triple palmar and double dorsal vessels with good cross anastomosis.

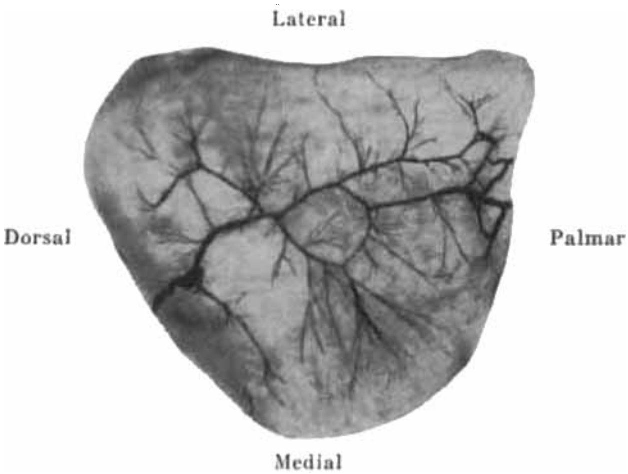

Fig. 10.
Male aged 55. Spalteholz preparation from distal aspect showing ring anastomosis with typical "right angle" branches from ring and main vessels.

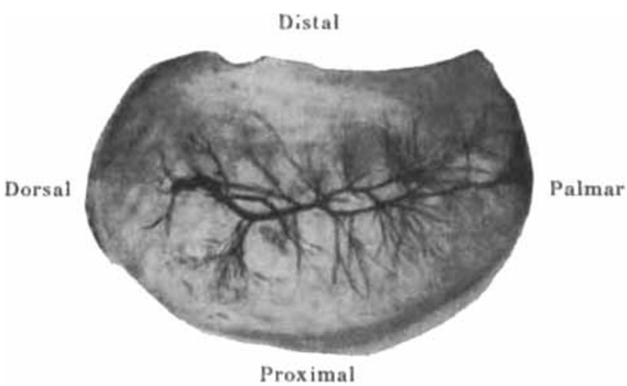

Fig. 11.
Lunate of Figure 8 viewed from lateral aspect showing horizontally placed major vessels with branches leaving at "right angles".

From each half of the ring major transverse branches were given off to the appropriate proximal or distal half of the bone, supplying a major part of these portions of the bone.

It was found that within the lunate, the main artery gave off branches at regular intervals which often left it at a right-angle to run towards the surface of the bone (Figs. 3, 6, 7, 8, 9, 10 and 11). At a variable

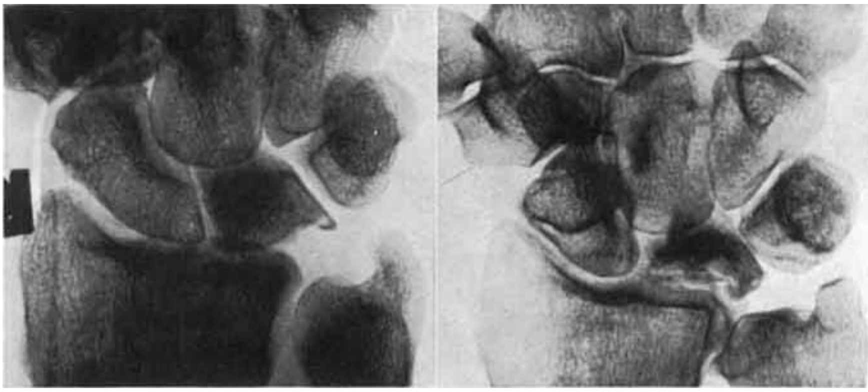

Fig. 12. *Fig. 13*
Collapse of the proximal part of the lunate.

distance from the main vessel, these branches divide obliquely and continue to subdivide until they end in a fine subchondral network (Figs. 6 and 7).

REVIEW OF THE LITERATURE

In a comprehensive study of Kienböck's disease, *Ståhl* (1947) discusses the main aetiological theories, and offers considerable evidence in favour of the fracture theory. This postulates a primary transverse compression fracture which damages the intraosseus circulation, leading to avascular necrosis of the bone. Secondary vertical fractures and resorption and transformation processes within the bone produce the typical X-ray changes.

The theory is supported by *Persson* (1950) who discusses the value of operative lengthening of the ulna as a method of treatment, believing that disproportion in length of the radius and ulna is a factor which predisposes to a compression fracture of the lunate.

Mouat, Wilkie & Harding (1932) also considered that the necrosis was the result of damage to the vessels in the lunate by a fracture, though *Durbin*'s (1951) opinion, based on three cases in which the lunate showed total necrosis, was that every case of Kienböck's disease could not be the result of a compression fracture. *Marek* (1957), however, suggested that the vessels entering the palmar aspect of the bone were damaged before they entered the bone, by a hyperextension injury. In 1938 *Logròscino & de Marchi* described in detail the extra-osseus origin, from the palmar and dorsal arterial complexes, of the arteries supplying the lunate. They found intraosseus anastomoses between the vessels entering the dorsal and palmar surfaces of the bone, as described by *Köstler* in 1936. The supply of the bone by a single palmar or a single dorsal vessel was suggested by *Cordes* (1930) and *Ståhl* (1947) who found the lunate supplied from the palmar surface alone in twenty-nine out of thirty injected specimens.

DISCUSSION

This investigation indicates that the lunate is supplied via the dorsal and palmar interosseus surfaces alone and that the interosseus vascular pattern falls into one of three groups:

Group A. A single palmar or dorsal vessel crossing the bone obliquely (26 %);
Group B. Palmar and dorsal vessels which do not anastomose (7.5 %);
Group C. Palmar and dorsal vessels which anastomose (66.5 %).

From the horizontally running anastomotic channels large branches are given off to the proximal and other surfaces of the bone.

It is usual in Kienböck's disease to find the proximal part of the bone necrotic and deformed whilst the distal part is rarely affected (*Kienböck* 1910, *Ståhl* 1947) Figs. 12 and 13.

This investigation shows that it is impossible for a dorsal or palmar capsular lesion with associated extra-osseus damage to the vessels entering the bone, to lead to proximal necrosis of the lunate. Damage to the dorsal or palmar capsule alone would lead in group A to either total necrosis of the bone or to no change at all, depending on whether or not the vessel supplying the bone lay in the damaged capsule. In group B it should theoretically produce palmar or dorsal necrosis alone, a lesion which does not appear to have been described. In group C it should lead to no necrosis at all owing to the wide anastomosis between dorsal and palmar vessels within the bone.

It is easy to see how a transverse compression fracture across the proximal parts of the lunates illustrated in Figs. 2, 5, 7, 8 and 11, will deprive the proximal part of the bone of its blood supply leading to the typical proximal necrosis of Kienböck's disease. This fracture will cross and interrupt the arterial branches as they run between the anastomotic vessels and the proximal surface of the lunate. It is also perfectly reasonable for this fracture line to leave intact the anastomotic vessel, so preserving the blood supply to the distal part of the bone.

If the transverse compression fracture line lay a little more distally it would interrupt the main vascular anastomotic vessel and produce total necrosis of the lunate. *Ståhl* (1947) found that the compression fracture did indeed cross the bone concentric with the proximal articular surface, and at varying distances from this surface.

In traumatic dislocation of the lunate it is usual for the dorsal capsule to rupture and for the lunate to hinge forward on the intact palmar capsule (*Eggers* 1933). Necrosis of the lunate following dislocation is rare (*Russell* 1949). This is as expected when one considers the blood supply of the bone, as it can only occur in the lunates that fall into group A, and only in those whose single artery of supply enters the dorsal interosseus surface.

SUMMARY

The intraosseus pattern of the blood supply of the carpal lunate bone has been examined by microradiography and Spalteholz preparations after injection of a Micropaque suspension.

Three main patterns are described:

Group A. A single palmar or a single dorsal vessel crossing the bone obliquely (26 %).

Group B. Supply by palmar and dorsal vessels which do not anastomose within the bone (7.5 %).

Group C. Supply by palmar and dorsal vessels which anastomose within the bone (66.5 %).

The anastomosis lies in the centre or slightly distal to the centre of the bone, supplying major branches to the various parts of the bone.

Kienböck's necrosis of the lunate commonly affects the proximal part of the bone alone and can be caused by a proximal horizontal compression fracture crossing the vascular branches to the proximal part of the bone. A more distally placed fracture will interrupt the anastomotic channel or the main vessels within the bone causing necrosis of the whole lunate.

Necrosis of the lunate rarely follows dislocation of the bone. This is apparent when one realises that only those supplied by the group A pattern and whose sole vessel of supply lies in the ruptured dorsal capsule will be affected.

RESUME

Le dessin intraosseux de l'alimentation sanguine de l'os du carpe lunaire a été examiné par microradiographie et préparations Spalteholz après injection d'une suspension micropaque.

Trois dessins principaux sont décrits:

Groupe A. Un seul vaisseau palmaire et un seul dorsal croisant l'os obliquement (26 %).

Groupe B. Alimenté par vaisseaux palmaires et dorsaux qui ne forment pas anastomose dans l'os (7,5 %).

Groupe C. Alimenté par des vaisseauv palmaires et dorsaux qui forment anastomose dans l'os (66,5 %).

L'anastomose se trouve au centre ou à une légère distance distale du centre de l'os, alimentant les branches principales des différentes parties de l'os.

La nécrose Kienböck de l'os lunaire touche en général la partie proximale de l'os et peut être causée par une fracture de compression horizontale proximale croisant les branches vasculaires de la partie proximale de l'os. Une fracture placée plus distalement coupe le canal anastomosique ou les vaisseaux principaux à l'intérieur de l'os, causant une nécrose de tout l'os lunaire.

Une nècrose de l'os lunaire suit rarement une dislocation de l'os. Cela semble évident lorsqu'on réalise que ce sont seulement les vaisseaux d'alimentation du dessin du groupe A et dont le seul vaisseau d'alimentation se trouve dans la capsule dorsale où il y a rupture qui se trouvent touchés.

ZUSAMMENFASSUNG

Die intraossäre Anordnung der Blutversorgung des os lunatum wurde mittels Mikroradiographie und Spalteholz Präparaten nach Injektion einer Mikropaquesuspension untersucht.

Drei Hauptandordnungen werden beschrieben:

Gruppe A. Ein einzelnes Gefäss, das den Knochen palmar oder dorsal überquert. (26 %).

Gruppe B. Versorgung mit palmaren und dorsalen Gefässen, die innerhalb des Knochens nicht anastomosieren. (7,5 %).

Gruppe C. Versorgung mit palmaren und dorsalen Gefässen, die innerhalb des Knochens anastomosieren. (66,5 %).

Die Anastomose liegt im Zentrum oder ein wenig distal vom Zentrum des Knochens und versorgt die verschiedenen Teile des Knochens mit grösseren Ästen.

Kienböcks Nekrose des os lunatum greift im Allgemeinen nur den proximalen Teil des Knochens an und kann durch eine proximale, horizontale Kompressionsfraktur, die die Gefässäste zum proximalen Teil des Knochens überkreutz, hervorgerufen werden. Ein weiter distal gelegener Bruch wird die Anastomosekanäle oder das Hauptgefäss innerhalb des Knochens unterbrechen und eine vollständige Nekrose des os lunatum verursachen.

Lunatumnekrose entsteht selten als eine Folge der Luxation des Knochens. Das ist verständlich wenn man sich vergegenwärtigt, dass nur jene Knochen die gemäss Gruppe A versorgt sind und deren Versorgung in der geborstenen dorsalen Kapsel liegt, betroffen werden werden.

ACKNOWLEDGEMENT

My thanks are due to Professor *J. Trueta*, who has given me advice and encouragement. I am grateful to Mr. *J. H. S. Scott* and to Mr. *H. V. Crock* for their help in the collection of material. I also wish to thank Mr. *D. W. Charles* for his assistance with the photography of the specimens.

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