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The venous drainage of the lunate bone

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Abstract One of the theories as to the etiology and pathogenesis of lunatomalacia (Kienböck's disease) is based on the presentation of an osseous compartment syndrome caused by a venous block in the pedicle. This gave us cause to examine the lunate bone more closely and to investigate possible anatomical causes for the disruption. For this purpose, ten hands were removed from cadavers proximal to the radiocarpal articular space. Through an artificial intraosseous canal, which did not touch the vascular structures of the lunate bone, epoxy could be injected under controlled conditions. The venous drainage, from the exit out of the bones up to the entrance into the comitant veins of the distal forearm, was exposed as a preparation under the microscope. In all preparations a dense plexus of small venous vessels was found at the palmar and dorsal periosteal face which has not previously been described in literature. As this wide plexus is woven into the solid palmar as well as into the dorsal connective tissue, it could be, as we suppose, the weak point of the venous drainage we have been looking for. It is easy to imagine that the rheological situation in this venous segment is impaired and an osseous compartment syndrome is induced by systemic factors as well as by local compression.

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Le drainage veineux du lunatum

Résumé L'une des théories concernant l'étiologie et la pathogénie de la maladie de Kienböck s'appuie sur l'hypothèse d'un syndrome compartimental osseux lié à un blocage veineux dans le pédicule vasculaire. Cela nous a amenés à examiner plus précisément le lunatum et à étudier les causes anatomiques possibles d'une telle interruption. Dans ce but, dix mains ont été prélevées sur des cadavres par section proximale à l'articulation radio-carpienne. Grâce à un canal intra-osseux artificiel, qui ménageait les structures vasculaires du lunatum, une résine époxy a pu être injectée dans des conditions contrôlées. Le drainage veineux, depuis sa sortie hors des os jusqu'à sa jonction avec les veines comitantes de la partie distale de l'avant bras, a été exposé après préparation sous microscope. Sur toutes les présentations, nous avons trouvé un plexus dense de petites veines sur les faces périostées palmaire et dorsale. Cette disposition n'avait pas encore été décrite dans la littérature. Ce large plexus, tissé au sein du tissu conjonctif palmaire dorsal et dense pourrait être, nous le pensons, le point de faiblesse du drainage veineux que nous avons étudié. Il est aisé d'imaginer que la situation rhéologique dans ce segment soit altérée et qu'un syndrome compartimental osseux soit induit par des facteurs systémiques ou une compression locale.

Keywords Kienböck's disease · Os lunatum · Compartment syndrome

Introduction

The etiology and pathogenesis of aseptic lunatomalacia (Kienböck's disease) have not been explained. Among other factors, disruption of the circulation has been thought to be responsible. Jensen [7] and Schiltenswolf et al. [14] see a connection between intraosseous hypertension, caused by disruption of the drainage of the

venous pedicle, and osteonecrosis. Also, there are interesting parallels with the theory of aseptic femoral head necrosis. Hungerford [6] was able to show a significant increase in the intraosseous pressure in the femoral head and signs of venous drainage impairment in patients with this disease.

Whereas the extra- and intraosseous arterial vascularity of the lunate bone and other carpal bones has been the target of investigation of authors such as Gelbermann and Gross [2], the demonstration of the venous effluent has been difficult. Schiltenswolf and Martini [15] attempted to show the venous drainage on cadaver hands by retrograde injection into the comitant veins of the ulnar and radial artery and by transcutaneous intraosseous injections into the distal radius. Following this, the material was sheet-plastinated. This method resulted in some very impressive preparations, which had the disadvantage, however, of not allowing any insight into the complete continuity of the venous vessels, especially in the periosteal sector. Simank et al. [16] also reported on this drawback of sheet-plastination in their paper describing the human cruciate ligament.

Handley and Poley [4] explain how retrograde injections can only describe a part of the system due to the location of the venous valves and the resulting distribution of pigments. Therefore they transcutaneously punctured the scaphoid bone directly. The correct position of the cannula was ensured by an injection of saline solution. If the wrist joint did not intumescence and liquid emerged from the comitant veins of the distal forearm, an injection of pigmented epoxy followed. We believe that the problem of this method is that the vascular periosteal tissue of the carpus is inevitably destroyed, which can lead to misinterpretations.

Nyström et al. [12] have also studied in detail the venous system of the hand. By injecting pigmented synthetic material into digital venous vessels they described the venous drainage of the palm and achieved a filling of the veins in their natural (distal to proximal) direction of drainage. Unfortunately, they did not provide an isolated description of the venous drainage of the carpal bones, especially the lunate bone.

A number of authors regard lunatomalacia as a consequence of an osseous compartment syndrome. Our opinion, on the other hand, is that all experiments that have hitherto tried to describe the pathways of the vessels from the bone to the large comitant veins of the distal forearm have not gained optimal insight into the venous circulation pedicle. There are, in particular, few investigations concerning the periosteal region. This zone, however, seems to be particularly susceptible to disruption from systemic as well as under local influences.

It seems to us that the problem in every study to date is the approach to the injection of pigments into the venous system. The aim of this study was to describe in greater detail the venous system of the lunate bone by a modified method of injection and, further, a closer examination of its relation to the periosteal connective tissue.

Materials and methods

Ten fresh hands (4 female, 6 male) aged between 55 and 80 years were removed from cadavers 2 cm proximal to the wrist joint. The main criterion for the choice of preparations was that the region of the carpus and the carpal joints was outwardly intact. Particular attention was paid to insuring that there were no tumescences, scars, malpositioning or passive restriction of motion compared with the contralateral side. During the course of preparation, the intra-articular situation was checked for possible osteoarthrotic transformations.

In order to reach the intraosseous side of the carpal articular surface, the spongiosa of the distal extremity of the radius was removed with a drill at low speed. During this process the compact bone was not affected, so that a hollow piece of bone was left, covered only by a coat of soft tissue.

Afterwards, the interarticular space of the wrist joint was opened by making a window into the carpal articular surface with a small chisel. Thus, the faces of the scaphoid and the lunate bones articulating in the wrist joint could be reached without damage. By flexion and ulnar duction the proximal side of the lunate bone was adjusted so that it could be punctured with a Strauss cannula. Depending on the size of the lunate, the cannula was inserted 5–9 mm into the bone.

To prevent the injected material from running out, the puncture was sealed with cyanoacrylate (Superglue). Then, the synthetic material (epoxy, Biodur) was injected with an ordinary syringe. In order not to damage minute vessels with excessive pressure, we increased the injection time to 4–5 min/ml. Depending on the size of the hand, 3–5 ml were injected per hand.

We observed that the pigment seeped out of the comitant veins of the radial and ulnar arteries already after only 0.5 ml of synthetic material had been injected. The injection process was stopped after the filling of the dorsal subcutaneous veins was clearly visible. For polymerization, the hands were stored at 8°C for 24 h.

After the synthetic material had hardened, the surface was prepared under a magnifying glass. Skin, tendons and connective tissue were removed in layers from the palmar as well as from the dorsal side. In due course, the venous pedicle of the drainage of the lunate bone in its entire length up to its entry into the veins of the distal forearm was documented photographically (Fig. 1). The

Fig. 1 Venous network of the dorsal surface of the lunate bone. Dorsal intercarpal arch

last step was to place the preparation in aqueous potassium hydroxide for partial corrosion in order to remove the soft tissues. Strict control ensured that the bones and the vessels filled with synthetic material were left undamaged.

Results

All examined hands showed a venous plexus that lies on top of the palmar and dorsal surfaces of the lunate (Fig. 2). This plexus continued into the contiguous capsule of the wrist joint. By intraosseous injection of epoxy, the venous drainage of the lunate bone was revealed in detail.

The further drainage ran regularly in a radial direction via the dorsal intercarpal arch into the comitant veins of the radial artery. Furthermore, there was a connection with subcutaneous veins via small connective vessels, which went through the deep dorsal fascia of the hand. A large-caliber vein was frequently visible between the radial veins and the subcutaneous dorsal venous plexus, after these had entered the back of the hand between the two sections of the first dorsal interosseous muscle. Sometimes, also one or two veins stretched along the base of the fourth synovial sheath and discharged into the dorsal interosseous veins.

Upon closer examination of the palmar surface of the lunate bone, the typical venous plexus and its continuation into the contiguous parts of the capsule were visible. Further on, there existed connections with all surrounding venous blood vessels. In most cases, there were two drainages in the ulnar direction. These ran alongside the concavity of the ulnar part of the carpus and reached the ulnar veins where these entered the distal forearm after leaving the proximal hiatus of the ulnar canal (box of Guyon). Several parallel vessels

stretched in the deep palmar fascia towards the deep palmar arch and discharged their blood into the comitant veins leading away radially (Fig. 3).

Before the radial comitant veins swerved in the dorsal direction from the ventral distal radius side under the tendons of the long thumb muscles (abductor pollicis longus, extensor pollicis brevis and longus), they received blood from the palmar vascular plexus of the lunate bone (Fig. 4). These connective vessels ran at the height of the wrist joint in the radial direction. In the proximal direction a single vein ran beneath the pronator quadratus muscle in the direction of a ventral interosseous vein.

Because of the narrowness of the carpal ligaments and their close contact with the joint capsule of the carpal, the topographic attribution of the veins to the complex ligamentous apparatus seemed difficult. Upon closer examination, however, our research showed that after leaving the bone, the small veins filled the connective tissue intervals of the deep, middle and surface carpal ligamentous structures [10] and ran in palmar and dorsal directions in the deep fascia of the hand (Fig. 5).

Discussion

Compared with all previous techniques, the selected method of injection has the advantage of not damaging any soft tissue around the carpus. Our approach to the proximal side of the lunate bone insures the integrity of the vascular structures of the carpus. Of course, as with any method of injection, it has to be taken into consideration that the injection may have been incomplete. But as the results of all preparations examined by us are quite clearly the same, it can be concluded with regard to

Fig. 2 The proximal carpal bones from the distal view after preparation and maceration, and their dense venous plexus

Fig. 3 Parallel veins in the deep palmar fascia stretch towards the deep palmar arch

Fig. 4 Palmar surface of the lunate bone. The venous network is woven in the soft tissue. Typical drainage to the main radial and ulnar veins

Fig. 5 Right lunate bone from its ulnar side. The veins leave the palmar and dorsal poles of the bone

the complexity of the intra- and extraosseous vessel system that no such deficit is present. The similarity of the results also suggests that the number of hands examined was sufficient.

Our intraosseous injections show the venous drainage of the lunate bone. Panagis et al. [13], who performed an exclusively arterial injection and showed the superficial and intraosseous arteries, did not describe this typical vascular situation we found near to the surface of the lunate bone.

To establish the etiology of Kienböck's disease was not the primary aim of this paper, because only anatomical observations are presented. Nevertheless the effect of a disturbance in the venous effluent in the early stage of the disease will be discussed as it contributes to the understanding of aseptic lunate necrosis.

The literature shows that, especially in connection with aseptic femoral head necrosis, much basic knowledge on the genesis of non-inflammatory bone decay has been collected which can also be applied to Kienböck's disease. It can be deduced from this that insuring optimal venous drainage seems to play a role in the origin of aseptic osteonecrosis. Brookes [1] has already discussed in detail how disruption of the venous drainage can lead to problems with intraosseous metabolism and consequently degenerative transformations. He describes in particular the resulting massive decay of the cortex of bone. In his opinion a simple drainage disruption through immobilization of the muscular apparatus after a fracture or through denervation can lead to such results. Thus even the rare diagnosis of aseptic necrosis of the lunate in hemiparetic patients can be explained. Green [3] and Joji et al. [8]. The point to consider is that inactivity of the muscular system leads to a venous blockage and to disruption of metabolism in the intraosseous tissue.

Tsukamoto et al. [18] demonstrated with a dynamic MRI analysis in an animal model a significant decrease in the blood supply of the proximal femur after ligation of the deductive veins of the femoral head. Launder et al. [9] point out the importance of the venous drainage of the femoral head of young rabbits. Tamponade of the joint capsule of the hip produced a disruption of the blood drainage and consequently an increase in the intraosseous pressure was observed.

The peculiarity of the venous drainage of the lunate bone as opposed to other parts of the body consists in the delicate structure of the periosteal vascular plexus, the area of which is restricted to the dorsal and the slightly smaller palmar surface due to the situation of the lunate bone within the carpus. Furthermore, the position of the bone as a central element of the proximal carpus and the resulting great strain, as demonstrated by Navarro [11], have to be pointed out. Together with the scaphoid the lunate takes the main strain in axial pressure transmission on the forearm. Even for quantitative reasons it seems plausible that, as opposed to other regions, minute pathological influences, such as inflammation of a systemic or local nature, together with capsule swelling or recurrent microtrauma, can lead to substantial disruption of the circulation. Because of the position of the small veins in a thick lamina of connective tissue, the risk of circulatory disruption is again increased.

Conclusion

Given that the morphology of structures helps to explain the physiology and pathophysiology, conclusions as to therapy can be drawn. It would seem that

maintaining the continuity of the circulation could be helpful in the early stage of Kienböck's disease. This could be achieved by an anti-inflammatory therapy aiming at the periosteal connective tissue or by an improvement of the rheological situation by heparinization. Furthermore, it is worth considering to what extent the consistent passive mobilization of the carpal joint, and thus the activation of the venous muscular pump, Simons [17] could be helpful. We think that surgical treatment such as opening the carpal tunnel to achieve a decompression of the lunate bone is not helpful in the early stage of Kienböck's disease.

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