REVIEW ARTICLE

THE WRIST

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A proper understanding of the anatomy and physiology of any part of the body is essential for effective treatment, whether conservative or operative; this applies to the wrist no less than to other parts of the body. The bony structure of the wrist and hand has been well known to anatomists and surgeons since Vesalius first described and illustrated its structure in 1543 (Fig. 1). The

**PRIMA FIGVRA EARVVM
QVAE VIGESIMOQVINTO
CAPITE PRAEPONVNTVR.**

Fig. 1

The carpus as illustrated by Vesalius in *De humani corporis fabrica*.

ligamentous structures binding these bones together have also been described in anatomy textbooks. It is only relatively recently, however, that the delicate and complicated nature of the wrist has been fully appreciated; indeed we are still only in the early stages of understanding the unique design of this compound joint, which allows movement in all directions in different combinations, while remaining a stable mechanism, and

at the same time providing a rigid support for the prehensile hand. Sir Charles Bell in his *Bridgewater Treatise* (1833) was charged to discuss "The hand: its mechanism and vital endowments as evincing design" but quite failed to appreciate the amazing complexity of the wrist and dismissed the carpus in one sentence: "In the human hand, the bones of the wrist (carpus) are eight in number; they are so closely connected that they form a sort of ball which moves on the end of the radius".

ANATOMICAL CONSIDERATIONS

Every student of anatomy knows (or should know) that the carpal bones are arranged in two rows and that the scaphoid bridges the midcarpal joint (Fig. 2); that there are two levels of movement with different arcs; and that these joints are essential for free side-to-side movement of the hand on the forearm. In addition, a small degree of rotation of the carpus on the radius is normally possible. However, movement which can be displayed in the anatomical specimen is not necessarily that which is employed in the living body; Capener (1956) and others have shown that the true axis of movement in the wrist passes along a line joining the dorsiflexed and radially deviated hand to the palmar flexed and ulnar deviated hand, this movement being commonly performed with the forearm semi-pronated.

Despite the complexity of wrist action, the centre of all movement is located in the neck of the capitate, so that with extension of the wrist the proximal row, in addition to rotating upon the lower end of the radius, moves forwards upon its articulation; the reverse is true in flexion. Again, in side-to-side movement radial flexion* is a function of the midcarpal joint, the scaphoid flexing upon its long axis within the carpus, and at the same time a reciprocal extension occurs within the ulnar column. In ulnar flexion the carpus rotates around the central capitate axis, the scaphoid extends and the hamate performs a rotatory screw-like action at its articulation with the triquetrum.

An alternative and equally apposite concept of the carpus is to regard the bones of the wrist as being

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0301-620X/84/3099 \$2.00

* The terms radial flexion and ulnar flexion are sometimes preferred to radial or ulnar deviation.

arranged vertically in three columns, proximally mobile and distally rigid, each of which subserves a particular carpal function. The *lateral column* is the most freely mobile and consists of the scaphoid and the trapezium-trapezoid articulation. This column is chiefly concerned with prehension and the precision grip of the thumb and index finger. It is in this column, from the first metacarpal to the radius, that degenerative changes are most commonly seen.

The *central column* consists of the lunate and capitate and is concerned with flexion and extension. It is the site of carpal instability or zig-zag deformity which pro-

foundly affects the position and function of the rest of the wrist. The action of powerful gripping compresses the central column and is an important factor in the causation of Kienböck's disease. As the vertical force is directed along the axis of the capitate, its proximal pole tends to insinuate itself between the scaphoid and lunate if the joint between them becomes lax.

The third or *medial column* comprises the triquetrum and the hamate, and it is upon this axis that rotation of the forearm is extended into the carpus. Carpal dislocation, which is almost always sustained by forced supination, causes avulsion and fissure fractures, but only rarely displacement of this column. Occasionally the opposite force of flexion and pronation induces posterior carpal dislocation and ulnar instability.

A third concept is to consider the wrist as a dynamic ring; this accords with the disposition of the intrinsic ligaments. The distal half of the ring is fixed and the proximal half mobile. Distortion or rupture of the mobile segment in relation to the rigid part serves to explain both instability and dislocation.

Ligaments. The ligaments of the carpus are arranged in three layers. The *antebrachial fascia* is the most superficial; its importance has only recently been appreciated in the study of the rheumatoid wrist. The volar and dorsal carpal ligaments, which are localised thickenings of the antebrachial fascia, not only retain the tendons (particularly extensor carpi ulnaris) in their correct position, but also have a "wrap round" effect over both sides of the carpus and the ulnar head. The *transverse carpal ligament* is chiefly concerned with retaining the flexor tendons and acts as a pulley when the hand is used in wrist flexion, but it also provides a shock absorber for falls on the outstretched hand. Its division appears to have little or no effect upon the function of the carpus, but its volar concavity is lessened and in some cases a tangential radiograph shows the pisiform subluxated ulnar-wards (Fig. 3).

The second layer is the group of extrinsic ligaments so well described by Taliesnik (1976). The *radial collateral ligament* partly supports the distal pole of the scaphoid and this ligament merges with the *volar radio-carpal ligaments* which are chiefly responsible for the stability

Fig. 2

Diagram of the bones and ligaments of the carpus. (Reproduced by kind permission of the Editor, *Medical Radiography and Photography*, Eastman Kodak Company.)

Fig. 3

Tangential (skyline) view of both wrists. The transverse carpal ligament has been divided on the right side; note the ulnar subluxation of the pisiform upon the triquetrum.

of the carpus. The superficial part of this second layer is shaped like an inverted V, running from the capitate to the radius and the ulna, whereas the deeper portion passes across the concave aspect of the scaphoid from the radius to the capitate; on the inner side of this deeper portion are the radio-lunate ligaments. The radio-scaphoid-lunate ligament of Testut stabilises the proximal pole of the scaphoid but is also concerned with the passage of nutrient vessels and is affected early in rheumatoid disease.

Fig. 4
Fractured scaphoid with Colles' fracture.

The ligamentous structures on the ulnar side of the wrists are more complicated. The ulno-carpal "meniscus" arises from the posteromedial aspect of the ulna and inserts into the triquetrum (Fig. 2), whereas the *triangular fibrocartilage* takes origin from the posteromedial aspect of the radius and is inserted at the base of the ulnar styloid. There is a synovial recess lying between the meniscus and the fibrocartilage. The ulno-lunate ligament arises from the volar aspect to be inserted into the lunate. The thickness and development of the triangular fibrocartilage depends on the relative length of the ulna as compared with that of the radius; its thickness is such that the carpus is always presented with a smooth articular surface from the radius to the base of the ulnar styloid. The *ulnar collateral ligament* is a thin structure which arises from the base of the ulnar styloid to be inserted into the triquetrum; it reinforces the action of the flexor carpi ulnaris distal to the pisiform.

The *dorsal ligaments* fan out from the posterior aspect of the radius and consist of a number of transverse bands, with two main components, one attached to the lunate and the second to the triquetrum. The extensor fibrous sheaths are an important reinforcement here.

The *intrinsic ligaments* constitute the third, or deepest layer of ligaments. They pass between the individual carpal bones in a circular fashion, holding the four distal carpal bones tightly together. The scapho-lunate ligaments are especially important, one volar and one dorsal. Kauer and Landsmeer (1972) have shown that the scaphoid and lunate articulate with the radius with differently curved joint surfaces, so that when these two bones dorsiflex the scaphoid travels twice as far as the

lunate, displacing volarly and tightening the interosseous ligaments. But the radio-carpal joint reaches the limit of dorsiflexion before the midcarpal joint, so that the scaphoid continues to extend with the distal row. Thus forced dorsiflexion of the hand may result in a fracture of the waist of the scaphoid (Fig. 4), rupture of the interosseous ligament between the scaphoid and the lunate, or both injuries.

The support between the capitate and the lunate is frequently absent and this may well predispose to carpal instability, particularly if there is a similar weakness on the dorsal aspect.

CARPAL INSTABILITY

This may be defined as increased laxity of the carpus (Fisk 1970) in a transverse anteroposterior plane with buckling of the "link system" and rotation of the intercalary segment (usually the lunate), as originally described by Gilford, Bolton and Lambrinudi (1943), but all three columns may exhibit changes separately or in combination.

Causes. Carpal instability arises from a variety of causes. These are: first, congenital laxity as part of a general joint hypermobility in which smooth movement of the carpus may be distorted at the extremes of movement (there is some evidence that fractures and dislocations in the presence of congenital laxity may not heal as well as in a more normally stable carpus); secondly, instability may be habitual and induced by constant and prolonged stress upon the normal carpus, analogous to acquired Madelung's deformity, which was once common in washerwomen.

The commonest cause of instability is of course trauma. This may be only ligamentous in nature in which case the term "sprained wrist" is often applied, but full recovery does not necessarily occur. There is usually a rupture of the ligament and capsule between the capitate and lunate associated with damage to all or part of the volar radio-carpal ligamentous complex. If any fracture

Fig. 5

Fig. 6

Figure 5 Injury led to volar intercalary instability (with flexion of the lunate and hyperextension of the capitate). Figure 6—The buckling has been corrected by traction upon the hand: note the re-alignment of the scaphoid. Plaster was applied, but the carpal bones were not impaled and the buckling recurred.

of the carpus displaces, this must imply ligamentous injury and will determine prognosis and treatment. All carpal dislocations must necessarily cause severe capsular and ligamentous rupture; consequently, even after prompt reduction of a dislocation it may be necessary to impale the carpal bones one to another or to the radius for about three weeks with immobilisation in a plaster cast to enable the soft tissue to heal without distortion (Figs 5 and 6).

Instability is also occasionally seen in neuropathic joint conditions and has been observed in chronic

the scaphoid may displace in the carpus (Fig. 8) with a sharp and painful snap and lie completely flexed, returning to a more anatomical position only when the wrist is relaxed again (Fig. 9). In more severe degrees the scaphoid may lie permanently flexed in this position with scapho-lunate diastasis and disruption of the normal carpal movement.

The second variety, less well recognised, is the effect of the concertina deformity on the ulnar column. The triquetro-hamate articulation may become unstable (Figs 10 and 11) giving rise to painful clicking on the ulnar side

Fig. 7

Bilateral scapho-lunate diastasis, with an exostosis and degenerative changes in the right wrist.

alcoholism. Lastly, rheumatoid arthritis, where there is early softening of the capsules and destruction of carpal ligaments, is a common cause of instability.

Varieties. There are four chief varieties of carpal instability. The first is the concertina deformity of the central column, commonly hyperextension of the lunate on the radial articular surface and corresponding hyperflexion of the capitate in the cup of the lunate. This deformity is associated with flexion of the scaphoid within the carpus and sometimes with diastasis of the scapho-lunate joint (Fig. 7). Less commonly (25% of cases) the lunate goes into flexion, with hyperextension at the luno-capitate joint, but the scaphoid again rotates into a flexed position. These deformities have been defined by some authorities (Linscheid *et al.* 1972) as dorsal or volar intercalary carpal instability, with the acronyms of DICI and VICI. The radial column is occasionally severely affected so that the proximal pole of the scaphoid protrudes over the dorsum of the radial articular surface and the distal pole dislocates forwards from the trapezio-trapezoid combination. There is some evidence that the reverse deformity, that is to say extension of the scaphoid, results in scapho-trapezial arthritis, but personal experience suggests that this condition is most commonly seen in healed rheumatoid arthritis.

As the result of concertina deformity the capsular attachments of the scaphoid may become lax at either end. Control by the volar radio-carpal complex becomes inefficient and with compression forces acting in the long axis of the carpus (as for instance gripping movements),

Fig. 8

Fig. 9

Recurrent intracarpal translocation of the scaphoid in the left wrist. Figure 8—Gripping induces the scaphoid to flex within the carpus. Figure 9—The scaphoid returns to its correct alignment when tension is released.

Fig. 10

Fig. 11

Ulnar carpal instability. Figure 10—In ulnar flexion. Figure 11—In radial flexion. Note the overriding of the triquetrum upon the hamate and the diastasis at the triquetro-lunate level.

of the wrist. The force necessary to produce this instability, namely pronation and radial flexion, sometimes results from physical assault.

The third variety is severe capsular injury, which may also cause ulnar translocation of the carpus (Fig. 12), but this condition is most commonly seen in rheumatoid arthritis. The carpus may be conceived as being "suspended" from the radius by the volar ligamentous sling; this takes its origin from the juxta-articular surface of the radius, and from the ulno-carpal complex which arises from the dorsomedial corner of the radius.

As ligaments and capsules become progressively destroyed by the rheumatoid process the carpus comes to articulate increasingly with the triangular fibrocartilage and the ulnar head.

Fig. 12

Ulnar translocation of the carpus: the scaphoid no longer articulates with the radius on its own facet and the lunate lies upon the ulna.

Finally there may be distortion of the plane of the radial articular surface from an unreduced Smith's or Colles' fracture; indeed, the pain and swelling of the wrist which characterises these injuries may in fact be due to unsuspected ligament rupture. The same laxity may be induced by unequal epiphysal growth after fracture in the immature skeleton (Figs 13 and 14), when the carpus must necessarily adjust itself to maintaining the alignment of the hand in relation to the forearm. The appearance in the congenital variety of Madelung's deformity (Figs 15 and 16) with a greatly increased vertical slope of the radial articular surface does not in fact lead to significant deformity, partly because the ligamentous attachments remain intact, but also perhaps because the carpus is trapped in a concavity between the abnormal radius and the ulnar head.

Diagnosis. The diagnosis of carpal instability depends partly on clinical examination, when increased anteroposterior mobility of the wrist can be elicited with painful clicking and a "jumping" of the carpus. Radiographic examination at the extremes of movement will often demonstrate abnormalities in the articulations and particular attention should be paid to the alignment of the long axis of the scaphoid, which normally lies some 30° to 60° flexed to the long axis of the forearm. Examination under the image intensifier may also demonstrate abnormal movement and will frequently display separate arcs of movement at the radio-carpal and midcarpal joints, instead of a smooth transition from flexion to extension.

Treatment. The deformity which follows an acute injury can sometimes be reduced by applying light traction to the hand and immobilising the wrist in a padded plaster cast, moulding the plaster carefully around the carpus. It is of course important to ensure that any signs of pressure

Fig. 13

Fig. 14

Figure 13 - Anteroposterior view. Figure 14 - Lateral view. Note the gross dorsal tilting of the radial articular surface, caused by a fractured forearm in childhood with involvement of the lower radial epiphysis, which has induced hyperextension of the luno-capitate articulation.

Fig. 15

Fig. 16

Madelung's deformity with unaffected carpal alignment in the lateral view.

from the plaster are quickly relieved. Conservative care is, however, likely to be unsuccessful if the instability from ligamentous and capsular laxity has become established. Suture by non-absorbable material such as stainless steel has proved uncomfortable for the patient. Attempts are being made to devise a reliable method of repairing or grafting the volar carpal ligaments. Linscheid *et al.* (1972) have attempted repair by tendon grafts placed through drill holes in the appropriate carpal bones, but this has not proved uniformly successful. "Purse string" repair of the scapho-capito-lunate ligamentous complex has been attempted (Figs 17, 18, 19 and 20) by threading a free palmaris tendon graft through the capsular and ligamentous remnants; but in one personal case a further fall on the outstretched hand two years later reproduced the original deformity. With intra-carpal subluxation of the scaphoid, however, reinforcement of the dorsal ligaments has been worth while as a

Fig. 17

Fig. 18

Fig. 19

Fig. 20

Stabilisation of the carpus and correction of scapho-lunate diastasis by a purse-string suture using palmaris longus graft. Figures 17 and 18—Before treatment. Figures 19 and 20—After treatment.

method of preventing subluxation of the proximal pole of the scaphoid over the dorsal radial articular surface.

ARTHRODESIS AND ARTHROPLASTY

Arthrodesis. Many varieties of *partial arthrodesis* of the carpus have been advocated to improve stability and comfort, though at the cost of sacrificing some carpal movement. As would be expected, those articulations most commonly in need of such treatment are those in which free movement is most essential. This particularly applies to the scapho-lunate joint where rotatory movements are necessary in achieving full flexion and extension. Scapho-capito-lunate arthrodesis limits the

wrist to radio-carpal movement only. On the other hand, triquetro-hamate arthrodesis is certainly worth considering in cases of instability of the medial column, where there is often pain, clicking and weakness of grip. There is of course some loss of movement, but this is quite acceptable.

The most promising partial fusion for scaphoid translocation is that advocated by Watson and Kempton (1980); this consists of fusion of the distal pole of the scaphoid to the trapezium and the trapezoid. This certainly corrects malposition of the scaphoid within the carpus but it limits radial flexion of the carpus, in which scaphoid flexion is essential.

Radio-lunate fusion has been advocated in cases of gross instability, particularly ulnar translocation of the carpus from rheumatoid arthritis. It is not only a difficult fusion to achieve but also limits wrist movement to the midcarpal joint only.

of choice in manual workers. The formidable complexity of wrist function and movement taxes the ingenuity of the designer. At the present time the Swanson prosthesis is the most widely used; it induces a stable pseudarthrosis in the same manner as do prostheses in the joints of the

Fig. 21

Fig. 22

Fig. 23

Fig. 24

Figures 21 and 22 Unusual posterior perilunate carpal dislocation occurring in a roofer and tiler. Figures 23 and 24 -The same patient after a successful open reduction and fixation with a Kirschner wire for three weeks. There has been restoration of normal alignment and he returned to his full work.

Pan-arthrodesis of the wrist from the second or third metacarpal to the lower radius, but not including the inferior radio-ulnar joint, is such a satisfactory operation that attempts to preserve a small range of uncomfortable movement with weakness of grip are hardly worthwhile. It has been advocated in the past that the wrist should be fused at some 20° of dorsiflexion in order to retain correct balance between the flexors and extensors of the digits, but more recently it has been suggested that fusion in the mid-position gives equally good function and improves the usefulness of the hand for feeding and personal toilet. **Arthroplasty.** Arthroplasty of the wrist is undoubtedly the operation of the future, especially in rheumatoid arthritis and other serious deforming conditions; but it is likely that arthrodesis will continue to be the operation

hand. Attempts to design a universal joint for the wrist have been made by Meuli (1973) and Volz (1976), but the durability and effectiveness of these models are not yet fully rationalised and their future development is awaited with interest.

CARPAL DISLOCATION

Injuries causing carpal dislocation are uncommon. The diagnosis is not always clear, nor is it always recognised by the surgeon or the radiologist. It behoves the neophyte to retire with the films and study them intensively on a viewing box until some analysis of the injury has been accomplished. Perhaps 90% of carpal dislocations are produced by forced dorsiflexion and supination of the carpus upon the radius, so that the whole hand "swings

round" the medial column of the carpus. The proximal carpal row may be protected by the dorsal lip of the radius and the volar ligaments, and the result is perilunar, periscapho-perilunar, or trans-scapho-perilunar dislocation of the carpus. As the hand swings back to its normal alignment all or part of the proximal row may be displaced forwards resulting in anterior dislocation of the lunate, or the lunate and the proximal pole of the scaphoid, or the lunate and the entire scaphoid, or even the lunate and the scaphoid and the proximal pole of the capitate. Mayfield (1980) has postulated progressive dislocation of the carpus as the force exerted upon it is increased, but this cannot be the only explanation as different injuries arise from a variety of forces.

The reverse mechanism of a fall onto the dorsum of the hand will force the hand into excessive pronation with similar fractures and dislocations of the proximal carpus onto the dorsum of the wrist.

Reduction of complicated dislocations and fracture-dislocations may be achieved by traction and manipulation. If necessary the carpus may be impaled with Kirschner wires inserted with the aid of an image intensifier. Where such manoeuvres prove unsuccessful, immediate open reduction should be considered (Figs 21 to 24), particularly from the volar aspect, where division of the transverse carpal ligament may preserve the median nerve from permanent damage.

In cases seen late or undiagnosed, manipulative reduction may still be successful if there is not excessive oedema or haemarthrosis, but open reduction will become increasingly necessary, and is of course essential when manipulation has been unsuccessful. With delay there is an increasing incidence of avascular necrosis of one or more of the carpal bones (Fig. 25).

THE FRACTURED CARPAL SCAPHOID

Rationalisation and treatment of this difficult fracture is now well advanced. Much has been written in the past about the importance of repeating radiography of those wrists in which a fractured carpal scaphoid is suspected, and this advice is ignored only at the peril of the doctor and the patient. Nevertheless, high quality radiography will detect virtually all such fractures and the usual source of error is that the patient fails to attend hospital for radiological examination or neglects to return for further review when advised to do so.

In the uncomplicated case adequate immobilisation for six to eight weeks will bring about bony union in 90% of cases, and in the presence of a stable carpus even fibrous union may be symptom-free. There has been a recent revival of the controversy concerning the position in which the wrist should be immobilised. Like the vast majority of injuries on the radial side of the carpus the scaphoid is fractured by dorsiflexion and supination forces; it would seem logical therefore to immobilise the wrist in neutral rotation of the forearm, radial flexion and possibly slight palmar flexion. The position of

supination and ulnar flexion advocated by Squire (1959) and his successors does not appear logical, particularly as the published experimental evidence to support this position involves the division of important ligaments of the volar radial complex (King, Mackenny and Elnur 1982). There is also some difference of opinion as to whether the thumb should be included in the plaster and it is claimed that a Colles' type of cast gives equally good results. However, in a personal series of some 40 patients coming to grafting for non-union of uncomplicated carpal scaphoid fractures three startling features emerged: first, that the series was composed entirely of young men; secondly, that almost without exception the diagnosis was made late or not at all; and thirdly, that even in those young men attending for treatment there was poor toleration of continuous and prolonged immobilisation in a plaster cast or lightweight splint.

Fig. 25

Avascular necrosis of the lunate, the proximal pole of the capitate and the proximal part of the scaphoid after incomplete reduction.

Internal fixation. Primary internal fixation of the fractured carpal scaphoid by a cannulated screw or by Herbert's device (Herbert and Fisher 1984) has been advocated as a routine measure, but this is not necessary. Discrimination should, however, be exercised by the surgeon early, and if there are social, athletic or other personal reasons, or if it is evident that a plaster cast or other form of splintage is not being properly maintained by the patient, then internal fixation should be undertaken promptly; this would undoubtedly diminish the residuum of cases which proceed to non-union.

Internal fixation of the fractured carpal scaphoid is sometimes mandatory: first, when there is displacement of the fracture, since this must imply capsular and ligamentous injury, and rigid support of the scaphoid not only ensures immobilisation of the fracture but also minimises permanent soft-tissue damage; secondly, where there is clear evidence of associated carpal instability; and thirdly, where the fracture is part of a complicated fracture-dislocation. Internal fixation can be satisfactorily achieved with a cannulated screw, by

either closed or open methods, with the aid of an image intensifier. The ingenious and successful double-ended screw described by Herbert and Fisher (1984) requires an anterior exposure of the scaphoid and the present instrumentation demands some capsular and ligamentous division which might be better avoided.

Internal fixation should also be employed where there has been delay in commencing treatment, or if, after six to eight weeks' immobilisation, there are persisting clinical signs of non-union. This applies even in the presence of threatened avascular necrosis of the proximal pole, since rigid fixation may allow revascularisation across the fracture and limit later collapse.

Fig. 26
"Nesting" of an avascular
scaphoid into an eroded cavity
in the lower radius.

Non-union. The ununited scaphoid usually undergoes resorption of the fracture surfaces, either primarily from ligamentous injury, or secondarily from shortening of the bone which induces a degree of carpal laxity. Indeed, there is some evidence that where congenital joint laxity is present union of a scaphoid fracture is more difficult to achieve. Resorption occurs principally over the antero-lateral aspect of the fracture so that the scaphoid becomes "hump-backed". A dorsal exostosis may be induced and the tuberosity of the scaphoid impacts against the radial styloid, producing pain, degenerative changes and even a pseudarthrosis. In time the misplaced scaphoid will "nest" itself in an eroded cavity in the radial articular surface (Fig. 26).

Many methods of bone grafting have been advocated to achieve union. At first sight it would appear logical to place the graft (with or without internal fixation) down the long axis of the scaphoid, but this disregards the shortening and deformity of the bone which have occurred; it also does nothing to correct the associated carpal laxity, and it puts an unreasonable stress upon the mechanical support of the graft itself.

Anterior grafting, as described by Matti (1937) and Russe (1960), is the contemporary standard method and requires an approach from the front. The fracture line is curetted, packed with bone crumbs, and a strip graft

taken from the volar surface of the radius is inlaid. Since the operation is performed from the front, this method may (inadvertently) overcome the flexion deformity of the scaphoid. It is, however, more logical to insert an anterolateral wedge graft; this is cut from the radial styloid, which has been removed during the approach to the fracture. Such a graft not only corrects the deformity in the scaphoid, but it also brings the bone out to length and immediately tightens the lax carpal ligaments. In a recent series of 41 non-unions treated in this way, some 75% achieved good or excellent function with only slight loss of movement.

Other complications. Malunion or avascular necrosis may cause pain and local arthritic changes. This can be treated by excision of the radial styloid which gives excellent results, though it is contra-indicated in established non-union of the scaphoid. Excision of the proximal pole of the scaphoid or of the proximal carpal row has its advocates, and published results suggest that restoration of good function can follow; nevertheless, these operations are not to be recommended as a routine.

Prosthetic replacement of part or all of the carpal scaphoid is at present being widely used, but the vital function of the scaphoid cannot be substituted by an inert foreign-body. Its use in active young men with non-union of the carpal scaphoid is to be deprecated, and the long-term results of those which have already been done are awaited with some trepidation. The occasional replacement is certainly justified if the bone has fragmented as in Preiser's disease (Preiser 1911) or other local conditions. Arthrodesis of the wrist is to be advocated in the presence of degenerative changes around the scaphoid, if other operations have failed or are contra-indicated.

THE CARPAL LUNATE

This bone is the "lynch pin" of the wrist; the mobility and stability of the carpus depend upon its integrity. It is not surprising therefore that dislocations of the carpus most commonly affect the lunate and the luno-capitate articulation. Perilunar dislocation of the carpus, or its second stage, dislocation of the lunate, is often regarded as an isolated carpal injury, but ligamentous damage is widespread, and although reduction may be achieved (by manipulation or open operation) and may appear successful, not infrequently the position of the scaphoid in the carpus is prejudiced and its proximal pole may be subluxated dorsally. This malposition is further aggravated if the surgeon immobilises the wrist in flexion in the hope that reduction of the lunate will then be more stable; this flexed position, however, only increases the flexion deformity of the scaphoid. Failure to recognise that the scaphoid is flexed, with its proximal pole protruding over the dorsal lip of the radius, results in extreme limitation of dorsiflexion of the wrist. If flexion is recognised early, the wrist should be immobilised in a

neutral position with ulnar flexion, or should be gradually extended by means of a turnbuckle. It may be possible, even after some months' delay, to expose the carpus from the dorsum, remove intruding capsule from around the proximal pole of the scaphoid, carefully mobilise the bone and reduce it under direct vision.

Rarely the lunate is dislocated dorsally from forced volar flexion of the wrist.

Kienböck's disease (lunatomalacia)

Much has been written about this uncommon condition, but its exact aetiology remains in doubt. It closely resembles Perthes' disease of the hip except that it occurs in the mature bone, commonly in the second and third decades of life. The likeliest cause, as with Perthes' disease, is repeated episodes of transient ischaemia. Variations of blood supply to the lunate have been much discussed but there can be no certainty that any particular arterial pattern is constantly seen in lunatomalacia; there is, however, some evidence that the pronated and ulnar flexed position seen in spastic conditions prejudices the blood supply.

Some authorities maintain that the cause of Kienböck's disease is a fissure or compression fracture which cuts off the intra-osseous circulation, but recognisable fractures of the lunate are in fact extremely rare. The condition does not resemble the total avascular necrosis seen after major carpal dislocations nor does the totally necrotic bone undergo the resorption and flattening characteristic of lunatomalacia. A further hypothesis concerns the intra-osseous pressure. This is at its maximum in the lunate or the proximal pole of the capitate during such actions as gripping, and avascular necrosis of the proximal pole of the capitate, similar to that in the lunate, has been reported on several occasions.

Ulnar "variance". Hulten in 1928 was the first to draw attention to the apparent frequency of shortening of the ulna in association with Kienböck's disease. He estimated that only 8% of the normal population had such shortening (called "ulnar minus") whereas 10 of his 19 cases of Kienböck's disease exhibited this feature. On the assumption that shortening was the cause, Persson (1950) lengthened the ulna, while Moberg (1970) and others recommended shortening the radius; both apparently had successful results. It is estimated that about one quarter of the longitudinal compression in the forearm passes through the ulnar head and it is postulated that a short ulna leads to defective buttressing of the lunate and this predisposes to Kienböck's disease. However, the assumption that with a short ulna there is a step in the surface with which the lunate articulates is incorrect. It has been shown that there is in fact no "step" since the triangular fibrocartilage is thicker with a short ulna and thinner with a long one, and that lengthening the ulna or shortening the radius disturbs this anatomical adjustment. Furthermore, the actual diagnosis of ulnar variance is open to question, as there is a slight difference in the

comparative length of the radius and ulna according to whether the forearm is supinated or pronated; in supination the forearm bones lie parallel, whereas in pronation the radius has rotated around the axis of the forearm to lie obliquely in relation to the ulna. Moreover, unless the x-ray beam is directed exactly at right angles to the wrist, the projection of the ulna on the film cannot be relied upon. There is no certainty that these exact criteria were satisfied in many of the series reported. The standard view suggested by Palmer, Glisson and Werner (1982) requires 90° abduction of the shoulder and 90° flexion of the elbow, with the hand resting flat on the x-ray table and the forearm in neutral rotation; only if such standard views are taken can ulnar variance be estimated with any certainty.

We should also consider the great variation in symptoms exhibited by patients whose radiographs reveal changes in the lunate. Some patients never have any symptoms and the condition is discovered only by chance. Dornan (1949) in his series reported that 63% of patients with Kienböck's disease who were treated conservatively returned to full work, and of those undergoing excision of the lunate 69% were little disabled. Gillespie (1961) reported that 80% of patients in whom the lunate was excised early had good or excellent results. It remains to be shown that these figures can be improved upon by adjustment of the length of the radius or ulna. It has also to be demonstrated that there are not other less well understood mechanisms at work in the relief of symptoms, not the least of which is the "McMurray effect" of para-articular osteotomy.

Other methods of treatment. It appears to be generally agreed that once the lunate has lost height and the capitate has protruded between the scaphoid and the triquetrum, the results of treatment will be poor whatever is done, and this must be due to the altered mechanics of the carpus and not to the lunatomalacia alone. Good results are reported from early excision of the lunate and its replacement by a prosthesis such as Swanson's new silicone model (1970) or by a rolled-up tendon or other material. Once the wrist has stabilised then, if the prosthesis subluxates or fragments, it can be removed, and the wrist is likely to remain comfortable.

FRACTURED TRIQUETRUM

This injury is surprisingly common in association with complicated fracture-dislocations of the carpus (Figs 27 and 28). The injury can be readily understood when it is appreciated that forced supination, dorsiflexion and dorsal displacement of the carpus is the commonest way of sustaining fracture-dislocations and that the rotation effect is exerted upon the ulnar column of the carpus. Fissuring, comminution and some displacement is not uncommon but reduction of the fracture-dislocation on the radial side restores the shape of the triquetrum and uncomplicated union occurs.

Fig. 27

Fig. 28

Trans-triquetral perilunar dislocation of the left carpus.

FRACTURE OF THE HAMATE

Nisenfield and Neviasser (1974) have drawn attention to a fracture through the base of the hook of the hamate; this may not be seen on a routine radiograph but requires a "skyline" view for its demonstration. The wrist will remain painful, weak and tender until union has been achieved by internal fixation or grafting.

THE TRIANGULAR FIBROCARILAGE

There has been a revival of interest in this structure over the last few years and it is now regarded as much more complicated than was previously thought. Palmer and Werner (1981) regard the fibrocartilage as being com-

posed of five different parts: the articular disc proper, the dorsal and volar radio-ulnar ligaments, the meniscus homologue, the ulnar collateral ligament, and the sheath of extensor carpi ulnaris. It has two main functions: it is a cushion for the ulnar carpus, and it is a major stabiliser of the distal radio-ulnar joint. It is a structure subject to degenerative change and 53% of the cases examined showed perforation with damage or erosion of the lunate or the distal ulna. Some three quarters of these had, in addition, a rupture of the luno-triquetral ligament. Degenerative change seems to be age-related and, once it has occurred, injection of radio-opaque fluid into the ulnar side of the wrist joint shows a communication with the inferior radio-ulnar joint. Palmer and Werner (1981) estimate that in the neutral position of the forearm and wrist some 40% of the load crossing the joint is carried through the disc and the lower end of the ulna.

In 1960 Coleman reported a series of 14 cases which had undergone excision of the articular disc; five types of tear were found. He suggested that the mechanism of injury was forced dorsiflexion and pronation, which produced pain over the inferior radio-ulnar joint, weakness of grip and a painful clicking. He did not, however, specify exactly how much of the fibrocartilage was removed and, although the operation has had a moderate popularity, it is now felt that the results are disappointing and that instability of the inferior radio-ulnar joint is almost inevitable. It is likely that some patients with symptoms suggestive of injury to the triangular fibrocartilage had in fact instability of the medial column of the carpus.

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