Radiolunate arthrodesis

The procedure of radiolunate arthrodesis was suggested by spontaneous radiolunate arthrodesis that resulted in painless, satisfactory function. Ulnar translation down the inclined slope of the radius is accelerated by dorsal dislocation of the ulnar head, ulna minus variance, and triangular fibrocartilage resorption and may be an inducement to increased ulnar deviation of the fingers as well as disintegration of the proximal carpal row. Twenty-two radiolunate arthrodeses were performed, 16 by a corticocancellous slotted graft and six by a modified Laeunstein procedure in 17 rheumatoid and five traumatic cases. Nineteen wrists were available for follow-up at an average of 28 months. Average range of motion was 25° of extension, 30° of flexion, 5° of radial deviation, and 15° of ulnar deviation. Subjective evaluation was good in 14 wrist, fair in three, and poor in two. Relief of pain was generally satisfactory, and preoperative grip strength was slightly improved. Progressive degeneration of the midcarpal joint tends to be minimal. If further spontaneous arthrodesis occurs, the wrist remains in satisfactory position. Carpal ulnar translation, midcarpal angulation, and radial angulation are corrected. Loss of carpal height is partially corrected in most instances. (J HAND SURG 10A:821-9, 1985.)

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The wrist is a complex joint with interrelated kinematic movements among the eight carpal bones. These bones are generally considered to be arrayed in proximal and distal rows, with the scaphoid forming a unique linking mechanism between them. For practical purposes, movements at the radiocarpal joint can be interpreted as biaxial: Flexion-extension occurs in the sagittal plane through a perpendicular axis passing through the articular cortex of the head of the capitate, and radioulnar deviation occurs through an axis in the head of the capitate and in the frontal plane.1, 2 The synchronous and conjunct motions of these elements are necessary for normal movement. Interference with the motion of any of these elements by necessity alters the normal motion relationship in the rest of the carpus.

Interest has recently been renewed in partial radiocarpal and intercarpal arthrodeses in the management of various carpal disorders.3

Spontaneous radiolunate arthrodesis occurring in rheumatoid arthritis of the wrist led to our interest in using this as a surgical technique in selected carpal disorders (Fig. 1). Patients with radiolunate arthrodesis generally had minimal pain, a functional range of motion (ROM), and stabilization of the progressive deterioration of the wrist. Although the procedure initially seemed best reserved for rheumatoid arthritis, experience suggested that it might also have applicability to selected traumatic and developmental arthritides.

Material and methods

Radiolunate arthrodesis was performed in 22 wrists of 20 patients over a 12-year period from 1971 through 1983. Thirteen women and seven men, whose ages ranged from 17 to 69 years, participated. The proximate cause for the arthrodesis was rheumatoid arthritis (15), juvenile rheumatoid arthritis (two), and traumatic arthritis (five). In traumatic arthritis, intra-articular damage at the radiocarpal joint occurred at the time of a distal fracture of both bones (one), distal radial fracture (one), perilunar dislocation (one), and a severe sprain (two). The duration of symptoms ranged from 6 months to 11 years. All patients had a trial of conservative measures, including casts, splints, steroid injections, and anti-inflammatory medications.

Symptoms included pain and weakness in all and limitation of motion in 20 of the 22 wrists. The patients with rheumatoid deformities usually had complaints re-
Fig. 1. Spontaneous radiolunate arthrodesis has occurred on the left. A, Stabilization of tendency to ulnar translation is seen on the right. Key: JRA, juvenile rheumatoid arthritis. B, Spontaneous fusion usually results in symptomatic improvement and increased strength. Motion through midcarpal joint usually persists indefinitely despite progressive joint deterioration. C-D, Spontaneous arthrodesis has occurred in optimal position in another instance.

Fig. 2. Rheumatoid arthritis in a 50-year-old woman with progressive deformity and increasing functional deficit. A, Posteroanterior view of the wrist. Carpal height (L3) ratio (Youn et al.1) is measured along the longitudinal axis of the third metacarpal (L3). Ulnar translational index (Chamay and Della Santa2) is measured from the radial styloid to the center of the capitate head (L2). The slope of the lunate fossa is measured as an angle between a tangent to the lunate fossa and a perpendicular to the longitudinal axis of radius. B, Capitoluminate angle is measured as an angle between the longitudinal axes of the capitate and lunate; midcarpal dorsiflexion is +, and palmar flexion is −. Widened scapholunate gap (−, +, and ++) is noted if present on the posteroanterior view.

lateral to the hand as well as to the wrist and frequently in other joints.

Preoperative examination of the rheumatoid group disclosed limitation of motion in both planes, with retained motion of approximately 60% of normal in flexion and extension, 80% in radial deviation, and 50% in ulnar deviation. Thirteen of the 15 wrists showed dorsal prominence of the lunate head. This appeared to be instrumental in limiting supination in 10. In addition, tenosynovitis primarily involving the fourth dorsal compartment and the usual palmar subluxation and ulnar drift deformities were seen to varying degrees in the metacarpophalangeal joints of 10 patients. Only one tendon rupture was noted in this group. Grip strength, as measured with the Jamar dynamometer, was diminished in all hands and averaged 40% of normal.

Secondary deformities were absent in the traumatic arthritis group. Motion was compromised about 50%, and grip strength averaged 35% of that of the contralateral hand.

Radiographic assessment

Standard posteroanterior and lateral films were obtained in each wrist. The criteria of assessment were somewhat different in the two groups and are, therefore, discussed separately.

Rheumatoid group. The primary radiologic indications for radiolunate arthrodesis were: (1) preservation of a midcarpal joint space of at least 1 mm with minimal erosions, (2) radiocarpal joint space narrowing and erosions, (3) ulnar translation of the carpus down the inclined articular plane, (4) carpal collapse patterns that is, dorsal intercalated segment instability (DISI) or volar intercalated segment instability (VISI) angulations, and (5) dorsal subluxation of the ulnar head.

In an effort to evaluate the factors that may predispose
Table I. Radiographically determined factors in rheumatoid wrist deformity

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Articular slope (degrees)</th>
<th>CHI</th>
<th>UTI</th>
<th>CL angle (degrees)</th>
<th>SL*</th>
<th>Ulnar variance (mm)</th>
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</table>

(legend: CHI, carpal height index; UTI, ulnar translation index; CL, capitulonate; SL, scapholunate relationship. *scapholunate dissociation: −, <2 mm; +, 2 to 4 mm; ++, >4 mm.

patients to the rheumatoid deformity and to identify wrists that would benefit from earlier partial stabilization, we assessed five areas on the radiographs (Fig. 2).

1. Slope of lunate articulation relative to the longitudinal axis of the forearm: A line tangential to the lunate fossa is drawn, and the angle between this and a perpendicular to the longitudinal axis is measured. The sine of this angle is presumed equal to the vector component of the joint compressive force initiating ulnar translation.

2. Carpal height index: This measurement provides an indication of the loss of length of the carpus secondary to cartilaginous diminishment, mechanical collapse, and ulnar translation.

3. Ulnar translation index: This index uses the radial styloid rather than the longitudinal axis of the ulna (proposed by Youm et al.1) as the point from which to measure the transverse distance to the center of the capitum. Measurement from the ulna is often inaccurate in rheumatoid disease because of distal radioulnar joint involvement.

4. Midcarpal angulation: This is a measure of the capitulonate angulation to assess the degree of angular collapse.

5. Scapholunate relationship: Whether the two bones are dissociated may have a long-term effect on the response of the capitulonate joint to the new stresses associated with the procedure.

6. Ulnar variance: This is a measure of the relative length of ulna to radius.

The results of this assessment are shown in Table I. In general, an increase in slope angle appeared to predispose wrists to ulnar translation. Dorsal subluxation of the ulnar head was indicative of radioulnar destabilization. The ulnar minus variance may predispose to slipping of the lunate over the ulnar edge of the lunate fossa. The VISI deformity, defined by positive capitulonate angle >15°, was noted in 11 wrists, whereas a DISI deformity, defined by a negative angle >15°, was noted in only one wrist. In the remaining five wrists, the midcarpal angulation was ≤15°.

Traumatic group. In this group, ulnar translation and carpal collapse were of less importance than the status of the articular surfaces (Fig. 3). Therefore, motion films to assess relative motion in the radiocarpal and midcarpal joints and tomograms to assess the joint contours were more reliable. Trispiral tomograms with cuts at 2 or 3 mm intervals were especially helpful in following the articular cortices (Fig. 4). Radiocarpal damage with relatively normal intercarpal joint space was the primary indication for radioulnare arthrodesis. Radioscaphoid degenerative changes were not a specific contraindication, for reasons to be discussed.

Surgical procedure

Two different surgical procedures were performed to obtain a radioulnare arthrodesis. In all of the traumatic
arthritid group and in 11 of the rheumatoid arthritis group, a slot, or key, graft was done. This procedure was performed through a dorsal approach with reflection of the finger extensors after incision of the dorsal retinaculum at Lister’s tubercle. The dorsal capsule was then reflected to assess both the radiocarpal and the intercarpal joint spaces. Synovectomy was performed in patients with rheumatoid arthritis. The lunate was transposed back onto the lunate fossa and transfixed with a 0.625 Kirschner wire driven obliquely through the radius onto the palmar aspect of the lunate. A slot was then made by parallel cuts with a small sagittal saw across the radioulunate joint. A strip of bone was removed with fine osteotomes. The slot was deepened to the palmar cortex of both bones. Care was necessary to avoid breaking the radial cortex of the lunate or the ulnar cortex of the radius. A cortico cancellous graft of the same dimensions as the slot was removed from the iliac crest in such an orientation that cancellous facets were present on all but the dorsal surface. The graft was cut long so that a slight amount of distraction was possible. Any remaining articular cartilage was removed from the lunate and the lunate fossa without disturbing the cortices. The wrist was then slightly distracted, and the graft was impacted into place (Fig. 5).

An additional one or two Kirschner wires were drilled through the radius obliquely into the lunate and triquetrum (Fig. 6). Motion at the midcarpal joint was tested passively. The proximal scaphoid pole was ex-
Fig. 7, A-B. Modified Lauenstein procedure incorporates radioulnar arthrodesis. Ulnar head is fixed in sigmoid notch with cancellous screws after decortication of surrounding articular surfaces. Ulnar head is used to displace and hold the lunate radially. Kirschner wires and bone graft from ulnar osteotomy site are added.

Table II. Changes in carpal height and ulnar translation indices

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<th>Patient No.</th>
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<th>Ulnar translation index</th>
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was usually required for an additional 4 to 6 weeks. Progressive active, assisted exercises were continued until maximum motion was obtained. A slight variation on this procedure was performed in the first two cases in the series when a radial sliding graft was used to augment decortication and local interarticular cancellous grafting.

In four wrists, a variation on this procedure was...
## Table III. ROM

<table>
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<th>Patient No.</th>
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<th>Radial deviation (degrees)</th>
<th>Ulnar deviation (degrees)</th>
<th>Grip strength (degrees)</th>
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*Traumatic cases.

Performed because the distal radioulnar joint was markedly involved by the rheumatoid disease. A combination of the Lauenstein procedure and radiolunate arthrodesis was performed by decortication of the sigmoid fossa and the contiguous ulnar head and lunate. The ulnar head was then secured to the radius with Kirschner wires or a cancellous screw while the lunate was held reduced within the radial fossa (Fig. 7). Additional Kirschner wires or screws (or both) were used for fixation through the complex.

### Results

Of the 20 patients, one died before an adequate assessment was possible and two were lost to follow-up. The remaining 17 patients had follow-up ranging from 6 months to 14 years, with an average of 28 months. Each of the wrists was examined by one of the authors for final assessment from 6 months to 12 years after surgery. A follow-up telephone interview was obtained in six instances in which more than a year had elapsed from the time of the examination.

The patients were asked to assess the subjective relief of pain, the improvement of function, and the appearance. ROM and grip strength were compared with preoperative values. Radiographs were compared with preoperative films (Table II).

In the rheumatoid group, 11 patients rated 13 wrists as good. Two rated the results as fair and one as poor. In the traumatic group, two patients rated the results as good, one as fair, and one as poor.

The examination results were rated as either satisfactory or unsatisfactory because no attempt was made to achieve a status of near normality in either ROM or strength in these severely afflicted wrists. The results of ROM and strength were compared with preoperative status (Table III).

There was one significant complication, a forearm compartment syndrome occurring on the second post-
operative day in a 20-year-old woman. This required fasciectomy, skin grafting, and secondary scar revision. This condition undoubtedly developed because an ulnar recession was carried out simultaneously with a small dynamic compression plate. This procedure was added to de- compress the distal radioulnar joint (Fig. 8). An- other ulnar recession was performed without incident. A minor complication was produced by a Kirschner wire that caused a painful lump in the first web space. This and two other instances of loose or inflammation-producing Kirschner wires necessitated premature wire removal, which did not otherwise compromise the results.

There was one unsuccessful arthrodesis in a 17-year- old girl with severe juvenile rheumatoid arthritis. She rated her result as fair. The wrist was painless and more stable, and there was no significant loss of motion.

One poor result was in a patient with traumatic arthritis originally treated for a confirmed lunatotriquetral tear in whom an ulnar carpal translation subsequently developed. The radiolunate arthrodesis done to correct this was symptomatically unsuccessful. The patient followed a progressive Münchhausen course, finally re- quiring wrist arthrodesis. The second patient had residual effects from a severe perilunar dislocation. His persisting discomfort interfered with his career as an aircraft mechanic and pilot, although the wrist was stable and regained 75% of its strength. The third patient with severe rheumatoid disease had progressive deformity, and a total wrist arthroplasty was performed.

Compared with preoperative status, ROM of the wrist was diminished in both groups, although for the most part it was still within a satisfactory and functional range. In the rheumatoid group, no wrist deteriorated to total spontaneous arthrodesis, although mild progressive deterioration at the midcarpal joint occurred in three instances.

Grip strength showed modest improvement in a few instances; overall, however, this was marginal in both groups.

X-ray film findings showed that arthrodesis had oc- curred in all but one patient. Evidence of union was evident by 8 to 12 weeks in the others. Carpal height index showed a modest improvement, from 0.05 to 0.01, in six of 10 patients, no change in three, and a loss of 0.03 in one. Carpal translation index, particularly in the rheumatoid group, showed improvement from 0.08 to 0.02 in 10, no change in three, and a loss to 0.02 in one. Improvement in the radiolunate angle was obtained in eight of the 11 patients in whom there was a measured VISI deformity >15° (Fig. 9). Two wrists lost a small amount of angulation, and one remained unchanged. Three patients continued to have a significant radial deviation stance, which would ideally be corrected by adequate replacement of the lunate radially in its fossa.

To date in this group, there has not been a secondary need for ulnar head resection. Thus, stabilization of the radiocarpal joint may have a beneficial effect on further deterioration of the distal radioulnar joint.

Discussion

The primary use of radiolunate arthrodesis appears to be a reasonable treatment for selected rheumatoid wrists. A recent report of seven cases by Chamay and Della Santa suggested that encouraging results can be obtained. We adopted their method of measuring the ulnar translational index, which, as they pointed out, avoids the error that erosion of the ulnar head into the sigmoid notch of the radius often introduces into the method of Youm et al. They also were led to consider this method of treatment by observing the apparently satisfactory response associated with spontaneous radiolunate arthrodesis occurring in rheumatoid arthritis.

The pathomechanics of the typical rheumatoid deformity appear to involve the following processes. A synovitis loosens the capsule and ligamentous inclusions. A loss of cartilage height is induced by enzymatic reaction and pannus intrusion (Fig. 10). The component of the joint compressive force acting in an ulnar direction tangential to the articular surface of the lunate fossa causes the ulnar translation allowed by the processes just mentioned. The radial buttressing effect exerted normally to varying degrees by the triangular fibrocar-
Fig. 10, A-C. Rheumatoid arthritis (RA) in a 55-year-old woman. Progressive ulnar translation, carpal collapse, and radial deviation occurred during an 8-year period.

Fig. 11, A-B. Five years after operative arthrodesis in a 25-year-old woman with radioulnar traumatic arthritis. Relief was excellent until recent reinjury by a 5-year-old child. On reexamination, cysts were noted in the proximal pole of the scaphoid (arrow) and in the lunate. These probably represent degenerative cysts secondary to altered joint mechanics; attention may be required later.

tilage complex is lost to the same processes. Rotation of the carpus about the longitudinal axis occurs in supination as the ligamentous slinglike constraints are weakened and secondary erosion of the radiolunarp lip of the radius occurs. There is often a concomitant dorsal subluxation of the ulnar head as synovitis within the distal radioulnar joint loosens its constraints. The forces acting during pronation and the compressive action against the palmar aspect of the ulnar head by the sliding carpus augment the normal dorsal translation of the ulnar head occurring with pronation. As this occurs, there is usually a concomitant radial angulation of the hand relative to the forearm. This may well be induced by two factors. The most important is probably the increased moment arm of those tendons lying radial to the center of rotation as the carpus translates ulnarily. By the same token, the ulnar moment of the other factor is supplied by the ulnar deviation of the fingers when these are involved in the rheumatoid process. Although there has been considerable speculation about radial deviation at the wrist inducing ulnar drift at the fingers, it is readily apparent by free body analysis that the reverse case must also be valid. When this situation continues, dislocation of the lunate from the radius may occur. This is sometimes hastened by ulnar head resection. Rupture of the finger extensors by the process described by Vaughan-Jackson often occurs as a late result of this process.

When spontaneous arthrodesis of the radioulnar occurs, the wrist has usually settled in such a way that persistent deformity is present. We reasoned that if one could identify the wrist in which the present deformity was likely to progress significantly and in which present symptoms were already sufficient, a directed radioulnar arthrodesis might accomplish the following: (1) relocate the lunate within the fossa of the radius to prevent further slide, (2) correct midcarpal malalignment if present, (3) correct radial deviation at the wrist, and (4) maintain carpal height. This, in turn, should help prevent further changes at the distal radioulnar joint and by maintaining an optimal skeletal length allow the musculotendinous units to function at their optimal length.
Such a procedure would obviously interfere with the
kinematics of a normal wrist by placing undue stress
around the lunate with all wrist motions. Even in the
abnormal wrist, this obviously represents a compromise
by which one hopes to obtain symptomatic relief and
a prophylaxis to further deformity for a period of time.
The results of this procedure suggest that there is
modest loss of motion and little change of strength. It
is possible to improve both the carpal height index and
the translational index, although there were four cases
in which this index was slightly worse. Three involved
the modified Lauenstein procedure, and the fourth did
not include an impacted key graft. If the carpus settles
as it did in these instances, the proximal pole of the
scaphoid is compressed. Fig. 11 shows a cyst that de-
developed in the proximal pole of the scaphoid after 5
years in a patient with early traumatic arthrosis. Slight
distraction of the lunate would probably have prevented
this. If the lunate is distracted slightly, the scaphoid is
more free to rotate about the lunate. Distraction should
allow greater midcarpal motion particularly in rheu-
matoid cases, in which the interosseous membrane be-
tween the two bones is often attenuated. On the basis
of these results, if the combination Lauenstein-radio-
lunate fusion is performed, we recommend adequate
distraction of the lunate combined with secure fixation
of the ulnar head fragment with cancellous screws.
Kirschner wires do not provide sufficient holding power
to prevent proximal collapse in the soft metaphyseal
bone of the radius.

In the event of progressive rheumatoid deformation,
either spontaneous or assisted arthrodesis offers a sat-
sfactory solution.

The small number of patients in whom we attempted
this procedure for traumatic arthritis does not as yet
allow us to determine its worth. All the patients ada-
mantly refused wrist arthrodesis, and all had received
prolonged conservative care. Although the initial re-
results appear to be worthwhile when compared with pre-
operative status, a realistic appraisal will probably re-
quire a significantly longer period for assessment of the
effect of altered kinematics.

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