Radial Shortening for Kienböck Disease*

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ABSTRACT: The cases of twenty-nine consecutive patients (thirty wrists) who had radial shortening for the treatment of stages I through IIIB Kienböck disease were reviewed to assess the results of this procedure. Thirteen patients (45 per cent) had a history of trauma, and all thirty wrists had a negative ulnar variance (average, 2.8 millimeters) on radiographs.

All wrists were re-examined after an average follow-up of 3.8 years (minimum, two years). At that time, the pain had decreased in 87 per cent of the wrists. Extension of the wrist had improved an average of 32 per cent; flexion, 27 per cent; radial deviation, 30 per cent; ulnar deviation, 41 per cent; and grip strength on the affected side, 49 per cent. Analysis of the radiographs by computer digitization showed no significant changes in the amount of collapse of the lunate at the latest follow-up. In two wrists, there were complications at follow-up (excessive shortening of the radius and non-union of the radial osteotomy).

Radial shortening is an effective treatment for Kienböck disease in wrists that do not have degenerative changes in adjacent carpal joints. Pain, range of motion, and strength can be expected to improve, but the radiographic appearance of the lunate changes little, if any;

Kienböck disease, or avascular necrosis of the lunate, causes major disability because of pain and loss of function in the wrists of young, productive patients. Numerous treatments have been described. Immobilization in a plaster cast was advocated by Stahl in 1947, but other authors have reported low rates of long-term improvement of symptoms after such treatment. Excision of the lunate, with or without an interpositional arthroplasty, was popular at one time; however, more recently, progressive carpal collapse, observed after soft-tissue interpositional arthroplasty, and synovitis complicating silicone implants have dampened enthusiasm for these approaches. Intercarpal arthrodesis to provide osseous support around the lunate has been advocated recently as a way to reduce compressive forces on the lunate. Several types of limited arthrodesis of the wrist have been described, but the efficacy of these procedures remains to be established.

So-called joint-normalization procedures to make the lengths of the radius and ulna the same, either by lengthening of the ulna or shortening of the radius, are based on the observation that patients who have Kienböck disease have an increased frequency of negative ulnar variance (the articular surface of the distal part of the radius is located distal to the articular surface of the distal part of the ulna). On the basis of this finding, it has been postulated that elimination of the negative ulnar variance will reduce the compressive forces on the lunate. (Fig. 1).

The purpose of this study was to evaluate the results of radial shortening in patients who had Kienböck disease and no evidence of intercarpal degenerative changes. These patients were treated at The Johns Hopkins Medical Institutions and the Raymond M. Curtis Hand Center over a seven-year period.

Materials and Methods

From 1981 to 1988, twenty-nine consecutive patients (thirty wrists) who had Kienböck disease without degenerative changes in the joints were treated by shortening of the radius. The procedures were performed and were reviewed for this study by all four of us. The patients were classified according to the stage of the disease by the method of Stahl, as modified by Lichtman et al. (Fig. 2). Only patients who had stages I through IIIB disease were treated by radial shortening. The two patients seen with stage-IV disease during the time of this study were treated by other methods.

The ages of the patients ranged from seventeen to forty-one years (average, twenty-nine years). There were eighteen male patients and eleven female patients. Twenty-eight patients had unilateral involvement and one had bilateral disease. Nineteen right wrists and eleven left wrists were affected, sixteen being on the dominant side and fourteen, on the non-dominant side.

The pain in the wrist had been present for an average of fifteen months (range, five weeks to ten years) before the patients were admitted to our institutions. Thirteen patients (45 per cent) had sustained an injury to the wrist before the onset of pain, and sixteen had no recollection of any specific
Posteroanterior, oblique, and lateral radiographs of the wrist in a patient who has stage-IIIA Kienböck disease. Note the negative ulnar variance.

A traumatic event that involved the wrists or hands. Of the thirteen patients who had had an injury, seven had noted the onset of pain after an injury at work (all were laborers), three had first felt pain during sports activities (racquet sports in two and soccer in one), and three had first felt pain after a fall that had caused hyperextension of the wrist. Of these three patients, one had sustained an acute fracture of the lunate that had been treated by immobilization in a plaster cast for six weeks, and two had had a fracture that was noted only on retrospective review of the radiographs made immediately after the injury. They had not received any treatment after the injury. Of the sixteen patients who had

Radiographic classification of Kienböck disease according to the method of Lichtman et al.²⁴. Stage I — no change visible in the lunate; stage II — sclerosis of the lunate; stage IIIA — sclerosis with fragmentation or collapse of the lunate, or both; stage IIIB — stage-III A changes combined with fixed rotation of the scaphoid; stage IV — stage-IIIA or IIIB changes combined with degenerative changes in adjacent intercarpal joints.
Radionuclide bone scan of both wrists of a patient who has unilateral stage-I Kienböck disease, showing increased uptake of tracer in the region of the involved lunate.

The stage of the disease in each of the thirty wrists was determined from the posteroanterior radiographs. Three wrists had stage-I disease; seven, stage II; sixteen, stage IIIA; and four, stage IIIB. The lunate index, an expression of the extent of collapse of the lunate, was calculated from the lateral radiographs by a modification of the method of Stahl. The modified index was determined by dividing the proximal-distal diameter of the lunate, as measured on the posteroanterior radiograph, by its anterior-posterior diameter, as seen on the lateral radiograph (Fig. 5). The preoperative lunate indices for the thirty wrists ranged from 0.30 to 0.59, the mean being 0.41 ± 0.09. This value contrasts with the normal lunate index, which Stahl found to be 0.53 ± 0.03 in his series of eighty-four control wrists.

We calculated a lunar-perimeter index and a lunar-area index as additional measures of any changes in the configuration of the lunate that were visible on the preoperative and follow-up posteroanterior radiographs (Fig. 6). To make these calculations, we used a digitizing osteoplan (Zeiss; Thornwood, New York) to determine both the digital length of the perimeter and the integrated area of the lunate, as measured on the posteroanterior radiographs. The lunate-perimeter index was calculated by dividing the length of the perimeter of the lunate by the length of the third metacarpal, and the lunate-area index was calculated by dividing the integrated area of the lunate within the digitized length of the perimeter by the length of the third metacarpal. With use of these formulae, the absolute lengths of the perimeters and the absolute areas of the lunate, as seen on the posteroanterior radiographs, were normalized to the lengths of the third metacarpals, thereby eliminating any errors due to variations in the amount of magnification resulting from

![Diagram](image-url)

Diagrams showing the measurements on the lateral radiographs used to calculate the lunate index (modified from Stahl). The lunate index = y/x, where y is the proximal-distal and x, the anterior-posterior diameter of the lunate. This index is an expression of the amount of collapse of the lunate. C = carpus, L = lunate, R = radius, and U = ulna.
possible differences in radiographic technique. The preoperative and follow-up indices could therefore be compared.

Operative Procedure

Radial shortening is performed with the patient under either general or axillary block anesthesia. A pneumatic tourniquet is applied to the arm and is inflated to 100 millimeters of mercury (13.3 kilopascals) more than systolic blood pressure to maintain hemostasis during the procedure. A longitudinal incision, approximately ten centimeters in length and extending proximally from the distal end of the radius, is made in the distal part of the anterior aspect of the forearm, parallel and lateral to the tendon of the flexor carpi radialis. As the incision is deepened, the superficial branch of the radial nerve is identified and is retracted laterally along with the brachioradialis and radial artery, while the flexor carpi radialis and other flexor tendons are displaced medially. With the forearm in supination, the pronator quadratus and flexor pollicis longus muscles are identified where they arise from the anterior aspect of the radius and are mobilized by subperiosteal dissection to expose the distal one-third of the radius circumferentially. A six-hole dynamic compression plate (diameter of the holes, 3.5 millimeters) is then contoured to fit the volar aspect of the radius and is secured with a compression-type clamp. Through the three distal holes in the plate, holes are drilled and tapped in the radius. The locations of the two osteotomies are then marked with brilliant green. The plate is removed and the osteotomies are performed by making two transverse cuts with a thin oscillating saw to remove an appropriate segment of bone. As far as possible, the length of the segment should equal the amount of negative ulnar variance that was measured on the radiographs that were made preoperatively.

After removal of the segment, the proximal and distal portions of the radius are approximated to ensure good contact between the osteotomized surfaces. The six-hole plate is then secured to the radius by the three distal screws, the radial fragments are precisely approximated, and the three proximal screws are placed eccentrically in the holes of the plate to promote compressive loading across the site of the osteotomy as they are tightened. Intraoperative anteroposterior and lateral radiographs are made to establish that the plate is properly placed and fixed, the lengths of the screws are correct, the alignment of the radial fragments is satisfactory, and the compression at the site of the osteotomy is sufficient. Finally, the wound is closed in routine fashion and a sterile dressing with a well padded volar plaster splint is applied.

Active and passive movements through the ranges of motion of the fingers are begun the day after the operation. The sutures are removed fourteen days postoperatively, when an Orthoplast splint is applied. Active motion of the wrist is begun at this time, with the splint removed during exercise periods. Sequential radiographs are made until clinical healing of the osteotomy has occurred, which usually takes two to three months. Patients are encouraged to wear the splint at all times, except during exercise, for four to six weeks postoperatively.

Results

All twenty-nine patients (thirty wrists) were available for follow-up examination at an average of 3.8 years (range, two to nine years) after the procedure. These examinations were performed by each of us independently (fourteen wrists were examined by A.-P. C. W.; five, by A. J. W.; six, by J. R. M.; and five, by E. F. S. W.).

Clinical Evaluation

At follow-up, the ranges of passive motion of the wrist were measured. The average extension was 51 degrees (range, 18 to 71 degrees), an average increase of 32 per cent compared with the average preoperative extension; average flexion, 55 degrees (range, 25 to 82 degrees), an average increase of 27 per cent; average radial deviation, 19 degrees (range, 15 to 32 degrees), an average increase of 30 per cent; and average ulnar deviation, 31 degrees (range, 5 to 36 degrees), an average increase of 41 per cent.

The grip strengths on the affected side ranged from twenty-eight to eighty-six pounds (12.7 to thirty-nine kil-
ograms) (average, sixty-eight pounds [30.8 kilograms]), an average improvement of 49 per cent.

Pain in the wrist decreased in twenty-six (87 per cent) of the thirty wrists. In twenty-one wrists (70 per cent), there was no pain, even during and after strenuous activity; in five (17 per cent), there was mild pain associated only with strenuous activity; and in four (13 per cent), there was no improvement. One of these four wrists was more painful at the time of the latest follow-up than it had been preoperatively.

**Radiographic Evaluation**

Standardized posteroanterior and lateral radiographs of all thirty wrists were made at follow-up. In ten wrists, the radiographs showed evidence of possible revascularization of the lunate, as indicated by decreasing sclerosis and a more normal trabecular pattern; in fifteen (50 per cent), the radiographs showed no change in the appearance of the lunate; and in the remaining five wrists (17 per cent), further collapse of the lunate was evident. The mean lunate index was 0.41 \pm 0.09 before the operation and 0.38 \pm 0.11 at follow-up, a decrease of 7 per cent. The mean lunate-area index was 263 \pm 86 square millimeters preoperatively and 252 \pm 71 square millimeters at follow-up, a decrease of 4 per cent, and the mean lunate-perimeter index was 74 \pm 7 millimeters before the operation and 70 \pm 6 at follow-up, a decrease of 5 per cent.

Statistical analysis of the lunate, lunate-area, and lunate-perimeter indices by analysis of variance showed no significant differences between the preoperative and follow-up values for any of them ($p > 0.05$).

**Complications**

Complications occurred after two procedures. The patient who had had a preoperative negative ulnar variance of six millimeters had disabling pain during ulnar deviation of the wrist preoperatively. This was thought to be caused by excessive shortening of the radius, which was evident on the follow-up radiographs. A modified hemiresection arthroplasty of the distal radio-ulnar joint was performed, but this did not relieve the symptoms. However, after a third operation, to shorten the ulna, the symptoms resolved (Figs. 7-A, 7-B, and 7-C).

The second complication was a non-union at the site of the radial osteotomy, which healed three months after a secondary bone-grafting procedure.

In a third patient, radiographs made twenty-two months after radial shortening showed progressive carpal collapse and degenerative changes in the adjacent intercarpal joints. Two years after the radial-shortening procedure, the lunate was excised and a scaphocapitate arthrodesis was performed. However, this patient still had pain and disabling limitation of motion when last seen, eleven months after the second procedure.
Discussion

The etiology and pathogenesis of avascular necrosis of the carpal lunate have not been established. Recent studies have suggested that fractures of the lunate are associated with the subsequent development of Kienböck disease. In addition, studies of the vascularity of the lunate, using various microangiographic techniques, have continued to be inconclusive with respect to the exact pattern of the blood supply to the lunate. However, it appears that some normal lunates have a tenuous intraosseous vascular supply composed of a single main artery that may be located in different parts of the lunate. Clinically evident or even subclinical fractures of the lunate in patients who have these vascular patterns may, understandably, lead to subsequent avascular necrosis. The extent to which fractures of the lunate play an etiological role in all patients who have Kienböck disease remains unknown. In the current study, plain radiographs demonstrated only three fractures of the lunate that could have been associated with Kienböck disease. Almost half of our patients had a history of trauma before the onset of pain and decreased function of the wrist. Perhaps the routine use of trispiral tomography would show a greater frequency of fractures and microfractures associated with Kienböck disease.

In 1928, Hultén first demonstrated a high correlation between Kienböck disease and the presence of a negative ulnar variance as seen on anteroposterior radiographs of the wrist. Theoretically, this anatomical variant might selectively overload the lunate, compared with the loading in patients who have a neutral ulnar variance, by transmission of a major portion of the compressive forces on the wrist through the lunate during various activities. Several biomechanical laboratory studies have demonstrated high compressive and tensile forces on the lunate during normal motion of the wrist. An osteotomy to shorten the radius or lengthen the ulna is a relatively simple extra-articular procedure that attempts to lessen the presumably increased compressive forces on the lunate in wrists that have a negative ulnar variance. Appropriate leveling of the distal ends of the radius and ulna by radial shortening would be expected to restore the proper anatomical relationships about the lunate, to decrease any abnormal forces, and, theoretically, to permit revascularization of the lunate. Whether a negative ulnar variance can actually cause Kienböck disease or whether it is merely a factor predisposing a patient to progression of the necrosis and subsequent collapse of the lunate is unclear, but the association between the negative ulnar variance and the disease is quite certain.

Our study demonstrated a major decrease in pain in the wrist, as well as improved motion and grip strength, after radial shortening. The procedure itself is relatively simple, with few intraoperative or postoperative complications. The osteotomy must be performed with care to ensure that the amount of shortening is correct and that the amount of compression of the surfaces of the osteotomy needed to encourage healing has been established. Palmer and Werner thought that some radial translation of the distal fragment of the radius during osteotomy and compression-plating might be useful in patients in whom shortening of more than three millimeters is needed to reduce the forces transmitted across the distal radio-ulnar joint during loading of the wrist. Although follow-up of our patients showed substantial subjective and objective improvement in pain and range of motion after the osteotomy, we found essentially no change in the appearance of the lunate when the preoperative and follow-up standardized radiographs were compared with respect to the lunate, lunate-perimeter, and lunate-area indices. Although radial shortening may prevent additional degeneration and collapse of an already compromised lunate, no measurable radiographic evidence was found in our patients to suggest revascularization of the lunate after radial shortening and progressive changes toward a more normal radiographic appearance. In one-third of our patients, the trabecular pattern in the lunate as seen on follow-up radiographs appeared more normal, but this was not measurable.

One issue raised by this study is whether the amount of radial shortening should be equivalent to the amount of preoperative negative ulnar variance, and whether this procedure would benefit a patient who had Kienböck disease and a neutral ulnar variance. In two patients, the amount of radial shortening after the operation was less than had seemed indicated by the amount of negative ulnar variance seen on the preoperative radiographs. Both of these patients — one of whom had stage-II and the other, stage-IIIIB dis-
ease — had an excellent functional outcome and excellent relief of symptoms, with no radiographic evidence of progressive collapse of the lunate (Fig. 8). Therefore, the exact amount of radial shortening may not be as important as the relative unloading of the lunate resulting from the shortening of the radius. This procedure may therefore be useful in patients who have symptoms in the wrist and a neutral ulnar variance, and the amount of shortening needed to be effective may be slight (probably about two millimeters).

Another issue raised by the study is whether radial shortening is an appropriate treatment for patients who have stage-IIIA or IIIB disease, in which the lunate appears to have collapsed, with or without fixed rotation of the scaphoid. The clinical and functional results of radial shortening for these stages of disease were excellent in our patients, despite the pre-existing collapse of the lunate. However, since only four patients had stage-IIIB disease, the findings in these patients must be considered preliminary, although they were promising after follow-up of three, four, and five years. On average, radiographic improvement in the appearance of the lunate cannot be expected, nor does the fixed rotation of the scaphoid in stage-IIIB disease appear to be corrected. However, despite the lack of radiographic improvement, the clinical findings suggest that radial shortening may be appropriate for all stages of Kienböck disease provided there are no degenerative changes in the adjacent intercarpal joints. In patients who have these degenerative changes, a salvage procedure, such as a proximal-row carpectomy or an arthrodesis of the wrist, seems most appropriate. Additional techniques for treatment of this disease involving direct vascularization procedures of the lunate deserve further investigation.

References