The Natural History of Scaphoid Non-Union

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ABSTRACT: We reviewed the clinical and roentgenographic findings of forty-seven non-unions of a fracture of the scaphoid in forty-six symptomatic patients in order to assess the incidence and severity of degenerative changes of the wrist. The duration of non-union ranged from five to fifty-three years. Three roentgenographic patterns were seen: twenty-three lesions had sclerosis, cyst formation, or resorptive changes confined to the scaphoid bone (Group I); fourteen had radioscaphoid arthritis (Group II); and ten had generalized arthritis of the wrist (Group III). The duration of Group-I non-unions averaged 8.2 years; Group-II, 17.0 years; and Group-III non-unions, 31.6 years. Fracture displacement and carpal instability correlated with the severity of degenerative changes. Lunate dorsiflexion of 10 degrees or more was a useful guide to carpal instability. Few of the forty-seven non-unions were undisplaced, stable, or free of arthritis after ten years. Based on the high probability of arthritis, we recommend that all displaced ununited scaphoid fractures be reduced and grafted, regardless of symptoms, before degenerative changes occur. Asymptomatic patients with an undisplaced, stable non-union should be advised of the possibility of late degenerative changes.

Scaphoid non-union occurs in approximately 5 per cent of treated scaphoid fractures9,14 and in an unknown number of unrecognized fractures. Although much has been written about the cause5,8,10,12,14,22,23,24,26 and treatment1,3,7,11,13,15,17,19,20,21,24,26,29-31,33,34 of non-union, and while several authors have stated that non-union leads to degenerative arthritis, the natural history of the ununited scaphoid fracture is not known. In a review of the cases of forty-six symptomatic patients with ununited scaphoid fractures (forty-seven non-unions) of five to fifty-three years' duration, we tried to identify the patterns and prognostic indicators of degenerative arthritis.

Material and Methods

All of the records of patients who were evaluated for non-union of the scaphoid at the Naval Regional Medical Center and the University of California at San Diego from 1972 to 1982 were retrieved. The criteria for inclusion in the study were a scaphoid non-union of at least five years' duration, and personal examination by one of us or review of records that included complete historical and range-of-motion measurements. Patients with prior surgical treatment were excluded. Only patients with symptomatic non-union were included. New roentgenograms of the wrist were made at the time of the most recent examination. Sixty-four patients were identified. Sixteen patients who could not be located were excluded because roentgenograms were not available to us. Thirty-four patients were examined by us. Two were excluded because of associated adjacent injuries: one, a displaced fracture of the radial styloid; the other, an unreduced trans-scaphoid perilunate fracture-dislocation. Adequate records and roentgenograms therefore were available for forty-six patients with forty-seven scaphoid non-unions. Twenty-eight patients were members of the military, including sixteen who were on active duty at the time who had retired from military service.

Thirteen of the patients had sustained the injury prior to entry into the Navy. On careful questioning, however, all admitted having had symptoms at the time of enlistment which became worse on active duty. Two patients had bilateral non-union, but the opposite wrist of one was excluded from the study because of previous operative treatment. In thirty-five patients the dominant wrist was involved.

Only two patients were women, but this may reflect the fact that the population of the military service is predominantly male.

The roentgenograms included anteroposterior, lateral, and oblique projections of the wrist and hand. Fracture location and configuration were determined as described by Russe26. Non-unions with cortical offset of one millimeter or more on any roentgenogram were considered displaced. Instability was determined by measuring the scapholunate angle on the lateral roentgenogram; an angle of more than 70 degrees was considered abnormal16. Because this angle was often obscured by degenerative change, displacement, and angulation of the fracture, dorsiflexion of the lunate
also used to determine carpal instability. This was measured as the radiolunate angle, which is determined by measuring the amount of lunate dorsiflexion with respect to the longitudinal axis of the radius (Fig. 1-A). The normal value is 7 degrees of palmar flexion when the wrist is in neutral position (average range, 12 degrees of palmar to 9 degrees of dorsiflexion). In this study, 10 degrees of lunate dorsiflexion or more was considered abnormal.

To assess the amount of carpal collapse and radial abduction of the distal carpal row, the carpal height ratio and carpal-ulnar distance ratio were determined as described by Byram et al. Abnormal values were a carpal height ratio of 0.50 or less (normal value, 0.54 ± 0.03) and a carpal-ulnar distance ratio of 0.34 or more (normal value, 0.27 ± 0.03) (Fig. 2).

Three roentgenographic groups were established, based on the extent of the degenerative changes. Group-I lesions showed sclerosis of the fracture margins, cyst formation, or resorptive changes confined to the scaphoid (Figs. 3-A and 3-B). Group-II lesions showed radioscaphoid arthritis, involving joint-space narrowing or pointing of the radial styloid (Figs. 4-A and 4-B). Patients with a Group-III lesion had advanced generalized arthritis of the wrist (Figs. 5-A and 5-B).

For each roentgenographic group, we determined the average duration of the non-union and the incidence of abnormal roentgenographic findings (displacement, radiolunate angle, scapholunate angle, carpal height ratio, and carpal-ulnar distance ratio). Each of these specific roentgenographic findings was also correlated with the duration of the non-union.

The symptoms were classified as mild, moderate, or severe. Patients with mild symptoms had pain only with strenuous use of the wrist and rarely required medication. Patients with moderate symptoms frequently had pain that required rest and medication. Patients with severe symptoms had pain at rest, took pain medication regularly, and avoided manual work and sports requiring motion of the wrist.

Results

Roentgenographic analysis showed progressive degenerative changes with time. At between five and ten years almost all non-unions showed cyst formation and resorptive changes within the scaphoid. Degenerative arthritis of the radioscaphoid joint was most common after ten years. Gen-
eralized arthritis of the wrist occurred frequently after twenty years of follow-up.

Twenty-three non-unions were in roentgenographic Group I; fourteen, in Group II; and ten, in Group III. There was a strong correlation between the severity of degenerative changes and the duration of non-union. Group-I non-unions averaged 8.2 years in duration; Group-II, 17.0 years; Group-III non-unions, 31.6 years. The average for all lesions was 15.9 years. The difference was significant between Groups I and II (\( p < 0.005 \)) and between Groups I and III (\( p < 0.001 \)). The majority of the non-unions less than ten years’ duration were in Group I, whereas the non-unions of more than twenty years’ duration were in Group III.

### TABLE I

<table>
<thead>
<tr>
<th>POSITIVE ROENTGENOGRAPHIC FINDINGS IN THE ROENTGENOGRAPHIC GROUPS</th>
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<tr>
<td><strong>Group</strong></td>
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<tr>
<td>-----------</td>
</tr>
<tr>
<td>Total no.</td>
</tr>
<tr>
<td>No. displaced</td>
</tr>
<tr>
<td>Radiolunate angle ( \geq 10 ) degrees</td>
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<tr>
<td>Scapholunate angle ( &gt; 70 ) degrees</td>
</tr>
<tr>
<td>Carpal height ratio ( &lt; 0.50 )</td>
</tr>
<tr>
<td>Carpal-ulnar distance ratio ( \geq 0.34 )</td>
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</tbody>
</table>

Progressive degenerative changes also correlated with displacement, the radiolunate and scapholunate angles and the carpal height ratios (Table I). Only nine of twenty-three Group-I lesions had a displaced non-union, whereas all patients in Groups II and III had a displaced non-union. The radiolunate and scapholunate angles both were abnormal in only eight of twenty-three wrists in Group I, compared with all of the wrists in Groups II and III. The average radiolunate angle was greater in Groups II and III (23.0 \( \pm \) 10.15 and 23.9 \( \pm \) 9.79 degrees, respectively) than in Group I (8.2 \( \pm \) 12.15 degrees). These differences were statistically significant (\( p < 0.001 \)).

Fig. 3-A: In Group I, non-unions demonstrated cystic, resorptive changes or sclerosis at the fracture margins.

Fig. 3-B: A Group-I scaphoid non-union with cystic resorption. Note the absence of degenerative changes in the radioscaphoid joint.
Group-II non-unions are characterized by degenerative changes in the radioscaphoid joint. Figure 4-B: Note the pointing of the radial styloid. The distal fragment is displaced and appears on this roentgenogram to abut the styloid.

The radiolunate angle correlated with the scapholunate angle of forty-one of forty-five wrists and correlated with degenerative arthritis throughout the wrist. In addition to generalized arthritis there is radial migration of the distal carpal row. Apparent carpal collapse was not significant in this group.

Twelve patients had an abnormal carpal-ulnar distance ratio. Five were in Group II and five, in Group III. There was a significant difference between the mean ratios of Groups I and II (p < 0.05) and those of Groups I and III (p < 0.01).

Fracture location and configuration did not correlate with degenerative changes or other roentgenographic findings.

The duration of non-union was five to nine years for twenty-two lesions, ten to nineteen years for nine, and twenty years or more for sixteen. Before ten years, only

![Fig. 4-A](image1)

![Fig. 4-B](image2)

![Fig. 5-A](image3)

![Fig. 5-B](image4)
of the non-unions showed additional roentgenographic abnormality. After ten years, however, more than 85 per cent of all of the non-unions were displaced and unstable. There was also a trend for carpal collapse (carpal height ratio of 0.50 or less) and radial migration of the distal carpal row (carpal-ulnar distance ratio of 0.34 or more) to be more common with increasing duration of non-union (Table II).

### Table II

<table>
<thead>
<tr>
<th>Percentage of Abnormal Roentgenographic Findings Correlated with Duration of Non-Union</th>
<th>5 to 9 Yrs.</th>
<th>10 to 19 Yrs.</th>
<th>20 Yrs. or More</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total no.</td>
<td>22</td>
<td>9</td>
<td>16</td>
</tr>
<tr>
<td>Displacement</td>
<td>50%</td>
<td>89%</td>
<td>94%</td>
</tr>
<tr>
<td>Radiolunate angle &gt;10 degrees</td>
<td>41%</td>
<td>89%</td>
<td>88%</td>
</tr>
<tr>
<td>Scapholunate angle &gt;70 degrees</td>
<td>41%</td>
<td>89%</td>
<td>88%</td>
</tr>
<tr>
<td>Carpal height ratio ≤0.50</td>
<td>18%</td>
<td>33%</td>
<td>50%</td>
</tr>
<tr>
<td>Carpal-ulnar distance ratio ≤0.34</td>
<td>18%</td>
<td>22%</td>
<td>50%</td>
</tr>
</tbody>
</table>

Thirty-five patients had mild or moderate symptoms. In these patients, no correlation was seen between the symptoms and the roentgenographic findings or the duration of the non-union. Eleven patients had had severe symptoms for six months to six years. All had a displaced non-union, and ten had instability of the wrist (a radiolunate angle of 10 degrees or more and a scapholunate angle of more than 70 degrees).

Thirteen patients attributed their symptoms to a recent injury. There was no significant difference, however, in the percentage of patients with mild, moderate, or severe symptoms in the group of patients with a reinjury and the group that attributed the symptoms to the original injury. For both groups, the average age of the fracture when the patients were referred to us was sixteen years.

### Discussion

The natural history of scaphoid non-union and the incidence of subsequent arthritis have not been clearly established. Dickison and Shannon found arthritic changes in 30 per cent of seventy late fractures, but did not specify the age of those injuries. London reported on sixty non-unions, with degenerative arthritis in thirty-six, and observed that the severity of arthritis increased with time. Twenty-five of the lesions in his series, however, were of unknown duration.

The present study was designed to determine the natural history of the scaphoid non-union. The findings were limited, however, to patients who were seen for evaluation of a symptomatic non-union. A prospective longitudinal study of individual patients would be required to determine if degenerative arthritis also occurs in asymptomatic patients with a scaphoid non-union. It is possible, for example, that an undisplaced non-union in a sedentary patient is less likely to displace, slower to undergo degenerative change, and less likely to cause symptoms that our data suggest. Because we found the statistical incidence of displacement and degenerative change to increase so greatly after ten years, however, we would expect the effect of this bias to be slight.

The data in this study suggest that many untreated symptomatic scaphoid non-unions undergo a specific sequence of degenerative changes, and that arthritis is likely to occur if sufficient time elapses after the non-union develops. Cyst formation, radioscaphoid arthritis, and generalized arthritis of the wrist — hallmarks of the process seen in Groups I, II, and III — occurred in the first decades after injury. In the first decade, all but one patient had cystic resorptive changes within the scaphoid, and three quarters showed only Group-I changes. Further deterioration appeared to occur in the second decade in most patients. After nineteen years, radioscaphoid arthritis was present in all but one patient. Extensive arthritis of the wrist is developed, and by thirty years severe changes were present in all of the wrists. It thus appears that few symptomatic wrists can be expected to be free of degenerative change for more than a decade after injury, and most will have established arthritis by twenty years.

The most significant factors associated with arthritis were displacement of the fracture and instability of the wrist. Both were present in more than 90 per cent of the patients with Group-II or III changes in our series. This was predicted by Fisk, who thought that instability was the cause of non-union and early degenerative change. He postulated that instability was due to perilunar ligament damage from the original injury. In our series, however, the majority of non-unions in Group I, and less than ten years old, did not show these findings. Because the incidence of displacement, instability, and degenerative change is so high in later years, it appears that not only does displacement lead to degenerative change, but also that displacement and instability can occur as late phenomena in previously undisplaced non-unions.

Because displacement and instability correlate strongly with arthritis, we would expect that in untreated fractures that are initially displaced arthritis will develop much earlier than the data in this series indicate. We could not show this statistically due to the retrospective nature of our study because only old injuries were included. Projected rates of degenerative change may also be underestimated because the age of the non-union in most patients was probably greater than the time at which the observed changes occurred.

In scaphoid non-unions, lunate dorsiflexion is a useful guide to fracture displacement and carpal instability. It has generally been agreed that displaced injuries are unstable. Displacement may be obscured, however, by degenerative changes. Instability is usually measured on the lateral roentgenogram by means of the scapholunate angle, which is increased by lunate dorsiflexion and palmar flexion of the scaphoid. In scaphoid fractures, however, angulation or displacement of the fragments disrupts the longitudinal...
of the scaphoid. In a scaphoid non-union, degenerative changes further obscure the scaphoid outline. In our experience, the lunate silhouette is easily visualized on a true lateral roentgenogram, even in the presence of degenerative arthritis. For these reasons we prefer to measure both the lunate angle and the scapholunate angle to assess the stability in a scaphoid non-union. Sarrafian et al. determined the normal range of the radiolunate angle to be $-12 \pm 9$ degrees when the third metacarpal is parallel to the first.

In the absence of extension of the wrist and ulnar deviation, which increase lunate dorsiflexion, higher values are seldom seen in normal wrists. In our study, use of the radiolunate angle to assess instability is supported by its correlation with the scapholunate angle and displacement of the fracture. When displacement and instability do not correlate it may be helpful to make roentgenograms of the opposite wrist for comparison.

Based on the high probability that degenerative changes will occur, we recommend that a scaphoid non-union that demonstrates displacement and instability be reduced and grafted before degenerative changes occur. An asymptomatic patient with an undisplaced non-union and no evidence of instability of the wrist should be advised of the possibility of late degenerative changes.

References


GUY'S HOSPITAL REP., 92: 52-59. 1943.


