COLLES' FRACTURE

A STUDY OF TWO THOUSAND CASES FROM THE NEW YORK STATE WORKMEN'S COMPENSATION BOARD

BY ROBERT W. BACORN, M.D., AND JOHN F. KURTZKE, M.D., NEW YORK, N. Y.

Colles' fracture, a common injury, is usually considered to be rather trivial and is often delegated to the orthopaedic neophyte for treatment. It is the purpose of this paper to survey a large number of such fractures, with the emphasis being placed on final results and their contributory factors.

We have defined Colles' fracture as a complete transverse break of the distal one inch of the radius with dorsal displacement of the distal fragment; non-displaced fractures were not included. A considerable number of fractures showed comminution, impaction, or extension into the radiocarpal joint.

METHODS AND MATERIAL

The Workmen's Compensation Board files of the New York State Department of Labor (New York City District) contain some 1,400,000 cases at any one time, which represent the claims folders for the previous ten years. These are catalogued on International Business Machine cards under a number of keys, permitting rapid tabulation of Colles' fracture cases. The medical section of each case folder contains the treating physician's initial report of injury and therapy, with fuller details in a report made two weeks later; it also contains the progress notes, discharge note, details on Workmen's Compensation Board examinations, x-ray reports, reports of insurance-physician's examinations, and, where pertinent, consultant reports and death reports. There is also the report of the final Workmen's Compensation Board examination with a detailed description of the functional and anatomical findings, and the decision of the Board as to the permanent disability in percentage of loss of function of the hand.

For the years investigated, all case folders, to the number of 5,000, classified under Colles' fracture, fracture of the wrist, and fracture of the radius, were obtained; the latter classifications contained a large number of Colles' fractures. Then the Colles' fracture charts were tabulated; completeness of data was the sole requirement for inclusion. Because of administrative details, only half of the cases from 1946, 1947, and 1948 were available. All of the cases from 1945 and 1949, whether included in our main tabulations, were listed as to the type of fracture. Some further cases were drawn from the 1940 and 1941 files; the war years were largely omitted to avoid prejudice in our correlation, although there was no significant difference between the cases of 1945 (injuries of 1944) and of 1949 (injuries of 1948). Fractures of the carpus in these two years were also noted.

Our tabulation for each case of Colles' fracture consisted of: (1) case number; (2) sex; (3) age; (4) involved limb; (5) Workmen's Compensation Board's final estimation of percentage of disability (percentage of loss of function of the hand); (6) functional loss (rotation, supination, palmar flexion, dorsiflexion, lateral mobility, and exact defects of digit motion) as none, mild, moderate, marked, or complete; (7) diminution of grip (mild, moderate, marked, or complete); (8) nature of fracture (simple or compound, etc.).

Adapted from a report by Bacorn and Kurtzke to the Workmen's Compensation Board. The conclusions are those of the authors and do not necessarily represent the opinions or policy of the Workmen's Compensation Board. This paper is published with the permission of Miss Mary Donlan, Chairman of the New York State Workmen's Compensation Board.

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impacted, comminuted, or into the radiocarpal joint); (9) degree of residual deformity (none, enlargement, or mild, moderate, or marked deformity); (10) involvement of the ulnar styloid (with or without union); (11) mechanism of injury; (12) treatment (site, reduction, anaesthesia, duration of immobilization, type of physical therapy if given, and duration); (13) sequelae and complications; and (14) time between injury and the final disability award.

The total number of cases thus studied was over 2,100, but obviously not every factor could be evaluated in each case. There were in addition some 1,100 radiocarpal fractures other than Colles' which were listed as to anatomical type.

**DISCUSSION OF DATA**

In the two years studied most thoroughly (1945 and 1949), Colles' fracture was found to constitute by far the most frequent individual fracture of the radius. In 1945, there were 650 Colles' fractures out of 1,071 radial fractures; in 1949, 662 Colles' fractures were found in 1,118 radial fractures. This gives a total of 1,312 Colles' fractures out of 2,189 fractures of the radius—an incidence of 60 per cent. (Chart II). The next most frequent class of fractures was that of the radial head (proximal) with an incidence of 14 per cent. (306 cases). Fractures of the shaft of the radius extending from the neck to within one inch of the radio-carpal articulation constituted 6.2 per cent. or 136 of these 2,189 radial fractures. The remaining 19.8 per cent. were fractures other than Colles', although they occurred within one inch of the joint: 132 cases (6 per cent.) were fractures of the radial styloid; 22 (1 per cent.) were Smith's fractures, that is, "reversed Colles' fractures"; and 12.8 per cent. were of a heterogeneous group which included fissure fractures, transverse fractures (whether incomplete or non-displaced), and chip fractures.

It was impossible for us to determine an accurate incidence of Colles' fracture among the general population, since no figures were available on the total number of workers covered by the Workmen's Compensation Law. However, we were able to determine the incidence of Colles' fracture among all Workmen's Compensation Board cases for the years of 1945 and 1949, in which there were 1,312 cases of Colles' fracture out of 133,764 Workmen's Compensation Board cases in the New York City District — an incidence of 0.98 per cent. The frequency in 1945 was 1.02 per cent.; in 1949 it was 0.95 per cent.

During this study it was also possible to determine the distribution of fractures of the carpus (Chart II). In these same years (1945 and 1949) there were 408 fractures of the carpal bones, or less than one-fifth the number of radial fractures and one-third the number of Colles' fractures. Of these, thirty-one were undifferentiated, but among the remaining 377 carpal fractures, that of the navicular constituted 70.8 per cent. (267 cases). The next most frequent fracture was that of the triangular (14.3 per cent. or fifty-four cases); then came fracture of the lunate (5.6 per cent. or twenty-one cases). The remaining five bones accounted for but 9.3 per cent. There were eight fractures (2.1 per cent.) each of the pisiform, the greater multangular, and the hamate, as well as nine (2.4 per cent.) of the capitate, with but two fractures (0.5 per cent.) of the lesser multangular. Some of these carpal fractures were multiple.

It was interesting to note that Colles' fracture, the mechanism of which demands transmission of the force through the carpus, was accompanied by but ten fractures of the navicular (0.5 per cent.); no other carpal bone was so involved.

In the years 1945 and 1949, 700 fractures, comprising 58 per cent. of a total of 1,206 cases, occurred in males, whereas 42 per cent. (506 cases) were found in females. The ratio in either year was the same as their other, but for our total of 2,115 Colles' fractures the incidence was 56.5 per cent. male to 43.5 per cent. female. The sex ratio of all Workmen's Compensation Board cases for 1945 and 1949 was 84 per cent. male to 16 per cent. female. In 1945 it was 81.2 per cent. male to 18.8 per cent. female; in 1949, 88.7 per cent. male to 13.3 per cent. female. In other words, despite a five-to-one ratio for
COLLES' FRACTURE

In 1945, there were 2566 cases of radial and carpal fractures, of which 1338 were fractures of the radius, representing an incidence of 0.95 per cent. In 1945 and 1946, 908 fractures of the radius were found. In 1945, there were 189 radial fractures, representing 0.95 per cent of the total of 19,714 fractures. The sex ratio for fractures of the radius was 130 males to 65 females. In 1946, there were 200 radiocarpal fractures among 2115 cases. The distribution of disability is shown in Chart 1.

Distribution of disability (as a percentage loss of hand function) in 2132 cases of Colles' fracture.

Note: In this and the following Charts, the author uses the symbol Fx to stand for "fracture."
all Workmen's Compensation Board cases, there was almost a one-to-one ratio for Colles' fracture. This we believe was in large part due to the large number of female domestics who had suffered falls resulting in Colles' fracture. Since Colles' fracture is not primarily an occupational hazard, we obtain a sex ratio more closely approximating that of the general population rather than the heavily weighted ratio found in occupational injuries. We can in no other way explain the higher relative incidence in the female.

In 2,103 cases of Colles' fracture, there were found to be 944 fractures of the right radius (44.9 per cent.), and 1,159 (55.1 per cent.) of the left. Included are twenty cases of bilateral Colles' fracture (0.94 per cent.). The higher incidence of fracture in the left wrist does not appear to be of any known significance. There were twenty-seven cases in which the fracture was compound, an incidence of 1.3 per cent.

The mechanism of injury in a Colles' fracture, as is well known, is most frequently the result of a fall on the palm of the outstretched hand. In only 8.4 per cent. (178 cases) was there a different mode of causation—such as being struck by a heavy object, injuries by machines, and chauffeur's fracture. The classical picture of Colles' fracture is a complete transverse break with dorsal displacement of the distal fragment. However, in a considerable proportion of the cases there was comminution, impaction, or extension into the radio-carpal joint. An accurate estimation of the incidence of such forms was impossible, since the reports were usually not sufficiently complete. It was our impression that such forms tended to result in a higher disability.

The primary treatment (reduction and immobilization) took place in a hospital in 55 per cent. (1,179 cases) of the fractures, while a local physician performed this service in the remaining 45 per cent. (953 cases).

Reduction of Colles' fracture was performed in 88.3 per cent (1,348) of the 1,527 fractures in which this factor could be assessed. Of these, 1,232 (81.9 per cent.) were single reductions, fifty-six (3.7 per cent.) required a second attempt, and sixteen (1 per cent.) needed a third manipulation. There were only twenty-four fractures (1.6 per cent.) in which an open reduction was performed. In 179 Colles' fractures (11.7 per cent.), there was no attempt at reduction, although, in our judgment (based upon the x-ray reports, the course of treatment, and the final deformity), eighty of these (5.2 per cent.) were of such a nature that reduction should have been performed. Among these were a number of cases of Colles' fracture in which the patient refused manipulation.

Anaesthesia was used in the reduction of 471 Colles' fractures; in the remainder, this factor was either unknown or anaesthesia was not used, it being impossible to determine which. One hundred and sixty-eight (36 per cent.) were reduced under local infiltration anaesthesia, including but one in which brachial block anaesthesia was used. General anaesthesia (inhalation or intravenous) was used in the reduction of 303 fractures (64 per cent.).

Physical therapy was given in all but 3.4 per cent. of a total of 1,440 cases, with 684 cases in which the type of treatment was not reported. While every conceivable form of therapy from hot soaks to histamine iontophoresis was used, the most popular was diathermy. The frequency of treatment most often noted was three times a week, which is the maximum for which fees are authorized under the Workmen's Compensation Law. The duration of treatment varied from 0.5 to twenty-four months, with a mean or average of...
-to-one ratio for Colles' fracture is not primarily roximating that of the occupational injuries.

e female.

4 fractures of the right hand are twenty cases of fracture in the left wrist: seven cases in which the right wrist, is most frequently 4 per cent. (178 cases) heavy object, injuries of fracture is a complete however, in a consideration: tension into the radio-

h was impossible, since resolution that such forms place in a hospital in performed this service

(1,348) of the 1,527 per cent.) were single sixen (1 per cent.) was sixen (1.6 per cent.) in one. (1,640 cases) x-ray reports, the cent.) were of such a number of cases s; in the remainder, impossible to deter-

under local infil-

ida was used. General of 303 fractures (64,440 cases, with 684 conceivable form of most popular was a week, which Compensation Law. 4 as mean or average * d by the number in the

<table>
<thead>
<tr>
<th>Age Group</th>
<th>All Colles' Fractures</th>
<th>All W.C.B. Cases, 1945 and 1949</th>
</tr>
</thead>
<tbody>
<tr>
<td>II under 20</td>
<td>54</td>
<td>2.6</td>
</tr>
<tr>
<td>III 20-29</td>
<td>127</td>
<td>6.2</td>
</tr>
<tr>
<td>IV 30-39</td>
<td>257</td>
<td>12.3</td>
</tr>
<tr>
<td>V 40-49</td>
<td>563</td>
<td>27.4</td>
</tr>
<tr>
<td>VI 50-59</td>
<td>683</td>
<td>33.5</td>
</tr>
<tr>
<td>VII 60-69</td>
<td>325</td>
<td>15.9</td>
</tr>
<tr>
<td>VIII 70-79</td>
<td>38</td>
<td>1.9</td>
</tr>
<tr>
<td>IX 80-89</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>2,047</td>
<td>100.0</td>
</tr>
</tbody>
</table>

The average disability in all cases of Colles’ fracture regardless of age, adequacy of treatment, or severity of fracture is 24 per cent. loss of function of the hand. The range of disability is from 0 to 100 per cent.; both median and mode** are 20 per cent. loss of function (Chart I). In 94 per cent. of the cases, there was a resultant disability of less than 50 per cent. loss of hand function. This loss, as found by Workmen’s Compensation Board examiners, is considered a permanent condition not amenable to further treatment.

In 2,047 cases of Colles’ fracture the ages ranged from fourteen to seventy-eight years with an average age of 48.2 years (median and mode each fifty years) (Chart III).

This bears out the generally accepted opinion that Colles’ fracture is a condition of the older age groups. More concrete evidence of this is afforded by a comparison of the age distribution of Colles’ fractures with that of all Workmen’s Compensation Board cases of 1943 and 1949, New York City District (Table I), in which 68.6 per cent. of all Workmen’s Compensation Board patients are under the age of fifty, whereas 51.4 per cent. of the patients with Colles’ fracture are aged fifty or over. A distribution index (defined as the percentage frequency of Colles’ fractures per age group over the percentage frequency of all Workmen’s Compensation Board cases for the same age-group) shows a sine-curve ratio ranging from 0.35 for the 20–29 age group to 1.68 for the 60–69 age group, whereas

* The median is the value in a class so chosen that the members above and below this value are equal in number when the class is arranged with its members in sequence.

\[
\text{median} = M_d = \frac{(N + 1)}{2}
\]

For grouped data, median = \( M_d = \frac{N}{2} \)

** The mode of a class is that member which occurs most frequently. \( M_o \) = mode.
### TABLE II

**Age-Disability Correlation in 2,051 Cases of Colles’ Fracture**

(Workmen’s Compensation Board Cases, New York City District)

<table>
<thead>
<tr>
<th>Disability Groups</th>
<th>Total</th>
<th>Age Groups in Decades</th>
<th>II Under 20</th>
<th>III 20-29</th>
<th>IV 30-39</th>
<th>V 40-49</th>
<th>VI 50-59</th>
<th>VII 60-69</th>
<th>VIII 70-79</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-9</td>
<td>160</td>
<td>7.8</td>
<td>24 45.3</td>
<td>23 18.5</td>
<td>36 13.8</td>
<td>36 6.4</td>
<td>30 4.4</td>
<td>11 3.1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>10-19</td>
<td>653</td>
<td>30.9</td>
<td>21 39.6</td>
<td>63 50.8</td>
<td>180 33.3</td>
<td>104 20.8</td>
<td>167 21.3</td>
<td>82 19.2</td>
<td>6</td>
<td>16.2</td>
</tr>
<tr>
<td>20-29</td>
<td>615</td>
<td>30.0</td>
<td>6 11.5</td>
<td>25 20.2</td>
<td>67 25.7</td>
<td>109 29.0</td>
<td>83 21.4</td>
<td>98 30.3</td>
<td>11</td>
<td>29.7</td>
</tr>
<tr>
<td>30-39</td>
<td>340</td>
<td>16.6</td>
<td>1 1.9</td>
<td>9 7.3</td>
<td>38 14.6</td>
<td>74 13.1</td>
<td>125 20.1</td>
<td>90 21.3</td>
<td>11</td>
<td>29.7</td>
</tr>
<tr>
<td>40-49</td>
<td>174</td>
<td>8.5</td>
<td>0</td>
<td>2 1.6</td>
<td>12 4.6</td>
<td>45 8.0</td>
<td>68 9.9</td>
<td>83 13.3</td>
<td>4</td>
<td>10.8</td>
</tr>
<tr>
<td>50-59</td>
<td>57</td>
<td>2.8</td>
<td>1 1.9</td>
<td>1 0.8</td>
<td>5 1.9</td>
<td>13 2.3</td>
<td>22 3.2</td>
<td>21 4.0</td>
<td>2</td>
<td>5.4</td>
</tr>
<tr>
<td>60-69</td>
<td>45</td>
<td>2.2</td>
<td>0</td>
<td>1 0.8</td>
<td>3 1.2</td>
<td>8 1.4</td>
<td>15 2.2</td>
<td>17 3.2</td>
<td>1</td>
<td>2.7</td>
</tr>
<tr>
<td>70-79</td>
<td>17</td>
<td>0.8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4 0.7</td>
<td>7 1.0</td>
<td>5 1.5</td>
<td>1</td>
<td>2.7</td>
</tr>
<tr>
<td>80-89</td>
<td>3</td>
<td>0.1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3 0.9</td>
<td>0</td>
<td>3.0</td>
</tr>
<tr>
<td>90-99</td>
<td>6</td>
<td>0.3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2 0.4</td>
<td>1 0.1</td>
<td>2 0.6</td>
<td>1</td>
<td>2.7</td>
</tr>
<tr>
<td>100</td>
<td>1</td>
<td>0.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>2,051</td>
<td>100.0</td>
<td>53 100.0</td>
<td>124 100.0</td>
<td>261 100.1</td>
<td>565 100.0</td>
<td>687 100.0</td>
<td>324 100.0</td>
<td>37 99.9</td>
<td>2,051 100.0</td>
</tr>
</tbody>
</table>
### Table

<table>
<thead>
<tr>
<th></th>
<th>100.0</th>
<th>124.0</th>
<th>261.0</th>
<th>565.0</th>
<th>100.0</th>
<th>687.0</th>
<th>100.0</th>
<th>324.0</th>
<th>100.0</th>
<th>37.0</th>
<th>99.9</th>
<th>2051.0</th>
<th>100.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>53.0</td>
<td>100.0</td>
<td>124.0</td>
<td>261.0</td>
<td>565.0</td>
<td>100.0</td>
<td>687.0</td>
<td>100.0</td>
<td>324.0</td>
<td>100.0</td>
<td>37.0</td>
<td>99.9</td>
<td>2051.0</td>
</tr>
</tbody>
</table>

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### Chart III

*Age Distribution in 2047 cases of Colles' Fracture (5-yr. periods)*

<table>
<thead>
<tr>
<th>Age Groups</th>
<th>% Frequency</th>
<th>Colles' Fracture per Decade</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>1.7%</td>
<td></td>
</tr>
<tr>
<td>20-24</td>
<td>6.7%</td>
<td></td>
</tr>
<tr>
<td>25-29</td>
<td>7.0%</td>
<td></td>
</tr>
<tr>
<td>30-34</td>
<td>6.7%</td>
<td></td>
</tr>
<tr>
<td>35-39</td>
<td>6.7%</td>
<td></td>
</tr>
<tr>
<td>40-44</td>
<td>7.0%</td>
<td></td>
</tr>
<tr>
<td>45-49</td>
<td>6.7%</td>
<td></td>
</tr>
<tr>
<td>50-54</td>
<td>6.7%</td>
<td></td>
</tr>
<tr>
<td>55-59</td>
<td>6.7%</td>
<td></td>
</tr>
<tr>
<td>60-64</td>
<td>7.0%</td>
<td></td>
</tr>
<tr>
<td>65-69</td>
<td>6.7%</td>
<td></td>
</tr>
<tr>
<td>70-74</td>
<td>2.6%</td>
<td></td>
</tr>
<tr>
<td>75+</td>
<td>1.0%</td>
<td></td>
</tr>
</tbody>
</table>

### Chart IV

*Age Distribution Colles' Fracture 1945 & 1949 vs. All W.C.B. Cases 1945 & 1949*

*Distribution Index*  

<table>
<thead>
<tr>
<th>Decades</th>
<th>% Frequency Colles' Fx. per Decade</th>
</tr>
</thead>
<tbody>
<tr>
<td>II</td>
<td>0.10</td>
</tr>
<tr>
<td>III</td>
<td>0.70</td>
</tr>
<tr>
<td>IV</td>
<td>1.75</td>
</tr>
<tr>
<td>V</td>
<td>1.75</td>
</tr>
<tr>
<td>VI</td>
<td>1.75</td>
</tr>
<tr>
<td>VII</td>
<td>1.00</td>
</tr>
<tr>
<td>VIII</td>
<td>0.50</td>
</tr>
<tr>
<td>IX</td>
<td>0.25</td>
</tr>
</tbody>
</table>

*% Frequency Colles' Fx. per Decade / % Frequency All W.C.B. per Decade*
if the age distribution of Colles' fractures were proportional to that of all Workmen's Compensation Board cases, the distribution index would remain constant at 1.00 (Chart IV).

It is commonly felt that not only are Colles' fractures more numerous in the older age groups but they are, in addition, more serious; patients in such groups may expect a higher disability. By a correlation of age and disability, it was determined that the mean percentage loss of function for each successively older age group ranges from 9.4 loss of function for the first group (age less than 20) to 32.3 loss of function for the seventh group (age 70-79), with a straight-line slope approximating an increase in mean percentage disability of 3.7 per decade (Chart V-A; Table II). The mean of each age subgroup has been proved by statistical methods* to be significantly different from the mean of all cases of Colles' fracture, except where the curve of disability-age correlation crosses the value of the mean of all cases. In addition, each age subgroup has been shown to be significantly different** from the means of its contiguous groups — except in the last (70-79) where there is a small number of cases.

* The standard deviation of the mean of the subgroup was compared with the mean of all Colles' fractures. When the two means differ by more than twice the standard deviation of the subgroup, they are statistically different 95 per cent. of the time.

\[
\sigma_M = \sqrt{\frac{\sigma_s^2}{n-1}} = \sqrt{\frac{\sigma_s^2}{n-1}}
\]

For all Colles' fractures

\[
\sigma_M = \frac{14.5}{\sqrt{2131}} = 0.314
\]

For subgroup a

\[
\sigma_{Ma} = \sqrt{\frac{14.5}{n-1}}
\]

\* \* T = the critical ratio of the difference between two means. If T is greater than \* for 95 per cent. of the time.

\[
T = \frac{M_a - M_b}{\sigma_d}
\]

The T's found were 4.02, 3.24, 3.32, 2.39, 5.49, and 0.63, respectively.
distribution of fractures were proposed that of all the Compensation Commission's cases, the distribution would remain 0.00 (Chart IV). Monly felt that Colles' fractures are numerous in the young but they are more severe in elderly groups. A higher correlation of disability, it was shown, is found in such groups as those over 70 years of age. Thus age has been shown to be one important factor in the determination of the final percentage of loss of function in cases of Colles' fracture. Another important element in this regard is the adequacy of reduction and immobilization. These two factors are of course related. In a study such as this, it is impossible to differentiate the two; but one factor incorporates both elements: namely, the degree of residual deformity as adjudged by the Workmen's Compensation Board's medical examiners. Residual deformity has been arbitrarily classified into five categories, the first being the return to the normal contour size and the second, an enlarged wrist in the absence of deformity. The next three classes are those of true deformity (mild, moderate, and marked) which is most often a "silver-fork" character. A deformity-disability correlation was set up and the results showed conclusively that disability increases directly with the degree of deformity in a straight line having a slope of approximately 6 per cent. loss of function per "grade" of deformity (Chart VI-A). The mean percentage disability ranged from 10.6 (no deformity) to 42.1 (marked deformity). A statistical comparison between two adjacent means showed a significant difference in all cases but one, and that was between enlargement only and mild deformity in which the difference was remarkably insignificant, tending to show that they are but two names for the same grade of deformity. In addition, by cumulative distribution* curves, these two "grades", namely, enlargement and mild deformity, are shown to be identical.

Thus we have only four classes of deformity: none, mild, moderate, and marked, with a slope of 10 per cent. disability per grade of deformity. We have found that 86 per cent. of the patients with no residual deformity have a disability of less than 20 per cent., whereas only 3 per cent. of those with marked deformity have this same disability (Chart VI-B; Table III). The significance of this conclusion—that is, that there is a positive

* Cumulative distribution curves plot the cumulative frequency percentage (abscissa) against cumulative percentage disability (ordinate) for each class involved in the correlation.—here it is disability.
TABLE III
DEFORMITY-DISABILITY CORRELATION IN 2,113 CASES OF COLLES' FRACTURE

<table>
<thead>
<tr>
<th>Types of Residual Disability</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>O</td>
</tr>
<tr>
<td>No Enlargement</td>
<td>No Deformity</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>0-9</td>
<td>64</td>
</tr>
<tr>
<td>10-19</td>
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<td>60-69</td>
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<tr>
<td>80-89</td>
<td>0</td>
</tr>
<tr>
<td>90-99</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>166</td>
</tr>
</tbody>
</table>

correlation between residual deformity and disability—is proved by statistical methods, including the $x^2$ test*, using the null hypothesis that there is no correlation between deformity and disability.

One often hears that a cast should be left on a fractured limb for a period just sufficient for adequate callus to form and that immobilization for periods beyond this greatly enhances the probability of an increased final disability, or that immobilization per se for some two to three months can cause a permanent loss of function, where none would have resulted had there been no cast present (for example, in sprains treated as fractures). To test this hypothesis, we correlated the duration of immobilization with the percentage of disability in 1,654 cases of Colles' fracture immobilized for periods ranging from zero to sixteen weeks (one case of eighteen weeks) (Chart V-B; Table IV). The average period of immobilization for all of these Colles' fractures was 5.4 weeks, the median being five weeks, the mode four weeks.

By the testing of the means of successive two-week periods of immobilization (and also of four-week periods) against the mean of all cases of Colles' fracture, there was found to be no significant difference between the means of the individual subgroups and the mean of all Colles' fractures. We further tested the significance of our entire distribution by

* $x^2$ test:

$$x^2 = \sum \left( \frac{(o - e)^2}{e} \right)$$

$$\sigma = \sqrt{2 \frac{\chi^2 \sigma - \sqrt{2n - 1}}{R \cdot C \cdot (C - 1)}}$$

The null hypothesis sets up a theoretical frequency of an ideal distribution (bell) curve. If the hypothesis is correct, $\sigma$ will be less than 1 in two-thirds of the cases.

$$\sigma = \sqrt{2 \cdot 710.9} - \sqrt{2 \cdot 40 - 1} = 29$$

THE JOURNAL OF BONE AND JOINT SURGERY
<table>
<thead>
<tr>
<th>Percentage of Disability (10 percentiles)</th>
<th>Weeks of Immobilization (in periods of 2 weeks)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-1.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No.</td>
<td>Per cent.</td>
</tr>
<tr>
<td>0-9</td>
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<td>10.1</td>
</tr>
<tr>
<td>10-19</td>
<td>1</td>
<td>17</td>
</tr>
<tr>
<td>20-29</td>
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<tr>
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<td>80-89</td>
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<td>0</td>
</tr>
<tr>
<td>90-99</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>6</td>
<td>101</td>
</tr>
</tbody>
</table>

TABLE IV

IMMobilization-Disability Correlation in 1,653 Cases of Colles' Fracture
determining \( r \), the coefficient of correlation.* This coefficient is a number which ranges from \(-1.000\) to \(+1.000\). Plus or minus 1.000 signifies perfect positive or negative correlation; 0.000 signifies an absolute lack of correlation. The value we found for \( r \) was \(+0.0974\) which is considered to represent no statistically valid correlation. Further, we checked the validity of our figure for \( r \) by determining \( \sigma \), which was found to be less than one-third the

\[
\begin{align*}
\text{Coefficient of correlation:} \\
\text{r} &= \frac{N \sum fx \, dy - (\sum fx \, dx)(\sum fy \, dy)}{\sqrt{[N \sum fx \, dx^2 - (\sum fx \, dx)^2][N \sum fy \, dy^2 - (\sum fy \, dy)^2]}} \\
&= \frac{7.66 \times 10^6}{7.86 \times 10^6} = 0.974 \\
\text{Significance of r:} \\
\sigma_r &= \frac{1 - r^2}{\sqrt{N - 1}} = \pm 0.024 \\
r, \text{ as greater than } 3\sigma_r \text{ is significant.}
\end{align*}
\]

*Coefficient of correlation:
value of $r$, therefore $r$ is significant. We have sufficient data to substantiate the conclusion reached. Thus there is no correlation between the duration of immobilization and the percentage of disability in Colles’ fracture, within reasonable limits.

The defects of function caused by Colles’ fracture are those of pronation and supination of the forearm, movements about the wrist (palmar flexion, dorsiflexion, and lateral mobility), and flexion and extension of the digits about the metacarpophalangeal and interphalangeal joints.

In 2,122 cases of Colles’ fracture, defect in pronation was present in 28.2 per cent., defect in supination in 36.9 per cent., defect in palmar flexion in 94.5 per cent., in dorsiflexion 80 per cent., and in lateral mobility 49.4 per cent. of the cases. It is obvious that by far the most frequent permanent defect was in palmar flexion, rather closely followed by limitation of dorsiflexion (Chart VII). The average limitation of motion in palmar flexion (of those having any defect) was approximately one-half the normal range, or a “moderate” defect. Dorsiflexion and lateral mobility had an average limitation which appeared to be slightly less than palmar flexion, although it could not be quantitated because of the arbitrary classification used in describing such defects. (The Workmen’s Compensation Board findings for restriction of passive motion were classed as mild, moderate, marked, and complete to which we have given approximate values of one-fourth, one-half, three-fourths, or four-fourths loss of range of motion.) Pronation and supination showed a lower average defect much closer to mild restriction (one-fourth loss). These defects are probably not due, in any large measure at least, to any disuse atrophy of the muscles of the forearm since they are determined approximately one year after injury. Pronation and supination defects may conceivably be explained on the basis of a mechanical block to full movement caused by the enlargement of the bone due to callus formation, radial tilt, and shortening, since the only muscles relating to these motions which can be involved at the distal end of the radius are the pronator quadratus and the brachioradialis (supinator longus). There is considerable danger that the former could be disrupted anywhere beyond its origin, since it lies upon the radius. However, we have found that pronation was restricted in only one-fourth of the patients, and in these, the restriction was most often mild. The brachioradialis may be involved since its insertion is on the radial styloid, but it plays a minor role in forearm supination. The flexores and extensores carpi are probably involved in or near the carpal tendon sheaths, and the mechanism is probably a traumatic synovitis with some adhesions. Flexion and extension defects in the wrist may also be due to loss of radial tilt and shortening of the distal portion of the radius with callus. These latter causes will also explain the defects in digit motion which were found to be present in almost one-half of the cases of Colles’ fracture (47.5 per cent.).

The most frequent of all defects of the digits was in flexion of the distal phalanx of the index finger (43.6 per cent.). Flexion of the distal phalanges of the fingers (35 to 44 per cent.) was involved more often than either motion of any other joint. For any given joint, flexion defects were about twice as frequent as extension defects. The thumb was the digit least involved (20 per cent. of flexion and 9.4 per cent. of extension). Metacarpophalangeal joints (20 to 25 per cent. of flexion) were involved insignificantly more often than the proximal interphalangeal joints.

There was residual diminution of the grip in 34.6 per cent. of 2,130 cases of Colles’ fracture. Only 3 per cent. of the total number of patients with Colles’ fracture had an impairment which was classed as more than moderate; in 14.9 per cent. it was mild and in 18.7 per cent., moderate, with twelve (0.6 per cent.) showing complete loss of grip.

Non-union of Colles’ fracture was extremely rare, being found in only four Colles’ fractures (0.2 per cent.), but there were fourteen (0.7 per cent.) fractures which showed delayed union. Traumatic neuritis was extremely rare also, with only four cases of median-nerve involvement (0.2 per cent.) recorded, and only one case of ulnar-nerve involvement.

There were three cases of causalgia (0.1 per cent.), as well as three cases of Sudeck’s...
atrophy (0.1 per cent.) and four of Dupuytren’s contracture (0.2 per cent.). Persistent pain was noted in 2 per cent., and in 1 per cent. of the cases of Colles’ fracture, limitation of shoulder motion was of significance.

Of 1,660 cases of Colles’ fracture, there were 887 fractures of the ulnar styloid (53.2 per cent.), with 228 (13.7 per cent.) cases of non-union reported. Of the fractures of the ulnar styloid, 25.7 per cent. were, therefore, followed by non-union.

It has been stated above that the final Workmen’s Compensation Board award was made approximately one year after the initial injury, by which time the residual defects were considered permanent. The lapse of time between injury and the Workmen’s Compensation Board award in 1,055 cases was 12.0 months (mean, median, and mode), with a range of from four to fifty-one months.

DISCUSSION OF RESULTS

The first evident fact is the high incidence of Colles’ fracture; it constitutes 1 per cent. of all Workmen’s Compensation Board cases, and 60 per cent. of fractures of the radius. It is also a fracture with a low incidence of complications, which in this study included compound fracture, non-union and delayed union, navicular and ulnar-styloid fractures, neuritis, causalgia, Sudeck’s atrophy, Dupuytren’s contracture, limitation of shoulder motion, and persistent pain of the wrist. However, this fracture is not the benign condition many consider it to be. Cassebaum found no serious functional disability in his study of Colles’ fracture, but we have seven patients in whom the loss of hand function was 90 per cent. or more, and over 3 per cent. of all the patients have disabilities of 60 per cent. or more. The average permanent loss of function of the hand in over 2,000 cases of Colles’ fracture has been found to be 24 per cent. The percentage disabilities upon which this figure is based were adjudicated by the experienced physicians who compose the medical board of the Workmen’s Compensation Board. In cases of doubt as to the fitting award, a panel composed of three senior Workmen’s Compensation Board physicians was employed, and, as a final arbiter, the medical director of the Workmen’s Compensation Board. Along the way, the patient’s physician, insurance-company doctors, and independent experts were often called upon to aid in the judgment of the final award. Therefore, we may consider each award to be an accurate estimate of disability, based solely upon the deficits in function (range and power of motion) found at the final examination. As an estimate of the basis for such awards, here are the findings in a typical patient who was awarded 25 per cent. disability: moderate limitation of palmar flexion and dorsiflexion, mild limitation of lateral mobility, and mild flexion defects of the distal interphalangeal joints of the index, middle, and ring fingers, as well as an enlarged wrist.

However, it must be admitted that such defects as are most usually found are of minor importance for the unspecialized use of the hand; a loss of 50 per cent. of the range of motion does not imply a hand only half usable, for very seldom do we employ the full range of any joint motion. Even an ankylosed wrist is serviceable so long as the digits, especially the first two, are reasonably agile. Nevertheless, such considerations should not militate against the recognition of actual disability.

As to the correlations set up in the paper, little need be said. It was expected that increasing age would mean increasing disability, and that the greater the deformity, the greater would be the loss of function; but it is well to have support for such statements, especially since some authors have made different statements. The one somewhat unexpected aspect was the lack of correlation between duration of immobilization and disability. Although the limit of immobilization was only sixteen weeks, it is the extreme one is likely to encounter, and within this range it was found that disability did not increase with the prolongation of the period of immobilization. The factors which we feel are of greatest importance in the effort to obtain an end result with a low disability are (1) accurate reduction, (2) adequate immobilization, and (3) early and persistent active motion.
CONCLUSIONS

From a study of a total of 2,132 cases of Colles' fracture from the files of the Workmen's Compensation Board, New York State Department of Labor, New York City District, the following conclusions were drawn:

1. Colles' fracture constituted 60.0 per cent. of fractures of the radius.
2. Incidence of Colles' fracture among Workmen's Compensation Board cases, New York City District, in 1945 and 1949 was 1 per cent.
3. Of all carpal fractures, that of the navicular constituted 70.8 per cent.
4. The ratio of males to females in Colles' fracture was 58 per cent. to 42 per cent. for 1945 and 1949, whereas the male-to-female ratio for all Workmen's Compensation Board cases for the same years was 84 per cent. to 16 per cent.
5. The left radius was involved in Colles' fracture in 55.1 per cent. of the cases; the right in 44.9 per cent. These figures include 0.94 per cent. of bilateral Colles' fracture.
6. The incidence of compound fractures among Colles' fractures was 1.3 per cent.
7. In 91.6 per cent. of the cases, the mechanism of injury was a fall on the outstretched hand.
8. A considerable proportion of Colles' fractures showed one or more of the following: comminution, impaction, and extension into the radiocarpal joint.
9. Reduction of Colles' fracture was performed in 88.3 per cent. Of the total number of fractures, 3.7 per cent. were manipulated a second time, and 1.0 per cent. required a third manipulation. In only 1.6 per cent. of the total was open reduction performed. Of the 11.7 per cent. in which no reduction was performed, it was our conclusion that almost one half required such manipulation.
10. In the 471 cases in which it was known that anaesthesia was given for reduction, anaesthesia was used in 36 per cent. and general (gaseous and intravenous) anaesthesia in the remaining 64 per cent.
11. The average duration of treatment was four months.
12. Physical therapy was used in 96.6 per cent. of the cases, exclusive of active and passive motion. This varied widely in type, frequency, and duration, without appearing to affect appreciably the ultimate results.
13. The average (mean) percentage loss of function (disability) in all patients with Colles' fracture was 24 per cent. loss of the hand, based upon the findings of the Workmen's Compensation Board medical examiners. The range of disability was 0 through 100 per cent. Of all patients with Colles' fractures 94 per cent. had a resultant disability of less than 50 per cent. loss.
14. The mean age of all patients with Colles' fracture was 48.2 years; the median and mode were fifty years; the range was fourteen to seventy-eight years inclusive.
15. The age distribution in Colles' fracture has been found to be significantly higher than that of all Workmen's Compensation Board cases for 1945 and 1949. Of all Workmen's Compensation Board cases, 68.6 per cent. of the injuries occurred in people under the age of fifty, whereas 51.4 per cent. of Colles' fractures were in people of fifty or over.
16. The percentage of disability in Colles' fracture increased directly with age, at a rate of approximately 4 per cent. loss of function per decade.
17. Residual deformity (as an inverse measure of adequacy of reduction and immobilization) has been found to have a direct correlation with disability, at a rate of 10 per cent. loss of function per grade of deformity (none, mild, moderate, marked).
18. The duration of immobilization in Colles' fracture had no effect upon final residual disability.
19. The most frequent defect in passive motion about the wrist was in palmar flexion, present in 94.5 per cent. of the cases; defect in dorsiflexion was found in 80 per cent. Limitation of rotation of the forearm was present in one third and limitation of lateral wrist motion in one half the cases.
20. Forty-eight per cent. showed restriction of motion of the digits (flexion and extension), with flexion defects being twice as frequent as extension; the distal interphalangeal joints were most often afflicted, and the index finger was the most, with the thumb the least, often involved digit.

21. One third of the patients with Colles' fracture showed residual diminution of the grip which was mild or moderate in severity in all but 3 per cent. of the total number of cases.

22. Non-union of Colles' fracture was found in 0.2 per cent. and delayed union in 0.7 per cent. of the cases. Other complications included traumatic neuritis (0.2 per cent.), causalgia (0.1 per cent.), Sudeck's atrophy (0.1 per cent.), Dupuytren's contracture (0.2 per cent.), persistent pain (2 per cent.), limitation of shoulder motion (1 per cent.), compound fracture (1.3 per cent.), concomitant navicular fracture (0.5 per cent.).

23. Fifty-three per cent. of the cases of Colles' fracture were accompanied by avulsion fracture of the ulnar styloid, and of these latter, one-fourth remained ununited.

24. The interval between injury and final Workmen's Compensation Board medical examination and award was twelve months (mean, median, and mode).

NOTE: The invaluable aid of Miss Jeanette Hanlon and her Research and Statistics Section, Workmen's Compensation Board, and of Miss Donlan, is gratefully acknowledged.

REFERENCES

DISCUSSION

THE USE OF IPRONIAZID IN THE TREATMENT OF BONE AND JOINT TUBERCULOSIS

(Continued from page 625)

rate from injections into the sinuses, abscesses, or cavities is so uncertain that proper blood levels cannot be controlled. Oral administration, to treat the patient's body as a whole, is the best and the safest.

For the same reasons the dosage should not be increased above 4 milligrams per kilogram of body weight except for very short times and with the realization that patients will become toxic. If you have a patient who is dreadfully ill, you may be scared into trying 6 milligrams per kilogram of body weight. Within twenty-four hours you will find that patient neurotoxic. If you continue to push this higher dosage, you are in danger of causing the development of a psychosis. Injection of material into a patient on a satisfactory oral dosage has been found to upset the balance and cause toxicity.

Local treatment will not touch tubercle bacilli buried in the calcified lesions or in sloughed-off pieces of abscess wall. The drug must be circulated in a definite concentration that will destroy the \textit{Mycobacterium tuberculosis} and not damage living tissue cells.

Even with a proper dosage you have to watch for toxicity. You can forget all other manifestations of toxicity, if you will examine the patient every day as to reflexes. If these become severely hypertonic, even though there is no clonus, the drug dosage should be decreased.

Do not use the drug in combination with streptomycin at present. You will confuse yourself as to toxicity and results. Other qualified investigators are working this problem out. Await their reports. Remember you cannot use it at half dosage. Do not experiment as regards dosage: watch your patients and you will find this material a great help in the treatment of bone and joint tuberculosis.

THE JOURNAL OF BONE AND JOINT SURGERY
Severely comminuted distal radial fracture as an unsolved problem: Complications associated with external fixation and pins and plaster techniques

Seventy-six patients with severely comminuted distal radial fractures were treated at two institutions, of which the overwhelming majority were Frykman class VIII. Fifteen fractures were open. Thirty patients were seen at the University Hospital; 17 had pins and plaster and 13 had external fixation. Forty-six patients were seen at Kaiser Hospital; all had pins and plaster treatment. The complication rate for those with pins and plaster at the University Hospital was 53%; the complication for external fixation rate was 62%. The affiliated-hospital complication rate was 52%. All patients with ipsilateral forearm shaft and carpal fractures developed a nonunion of the carpal fracture. Few patients maintained anatomic reduction, and many had significant intra-articular malalignment. External fixation with threaded half pins did not obviate pin problems in our series. These methods may help manage severely comminuted distal radial fractures, but complications should be anticipated and alternative treatment considered, especially when ipsilateral carpal or forearm shaft fractures are present. (J HAND SURG 11A:157-65, 1986.)


Since Colles' original description, some authors continue to claim good results with minimal treatment of displaced distal radial fractures. The vast majority of authors, however, agree that results correlate directly with restoration of normal anatomy. These fractures can also be associated with serious complications. Although acceptable reduction can be obtained, it is often difficult to safely maintain reduction with cast immobilization. Various techniques have been described to better maintain reduction, including immobilization in supination, early distal ulna resection, tension band wiring, percutaneous pinning, Rush rods, and open reduction with internal fixation. Since its description by Bohler in 1929, traction maintained by transfixed pins incorporated in plaster has been widely recommended. Although this technique restores length well, it does not restore normal palmar angulation of the distal radius. Pin complications are common and can lead to a reoperation rate as high as 16%. Other problems...
include difficulty managing large open wounds, complications associated with circumferential plaster, intrinsic tie down by the distal pins, rotation of the fracture about the distal pins, and difficulty of adjustment.

These problems led to a resurgence of external fixation as originally described by Anderson and O'Neil in the management of these injuries; all authors describe improved results in the management of these fractures with this technique. Many of these reports do not differentiate minimally displaced fractures from extensively comminuted high-energy fractures. Serious complications including failure of fixation, iatrogenic fractures, pin infections, pin tract osteomyelitis, and loss of reduction continue to be reported with this technique at a rate of 15% to 23% in some series describing "good" results. The wrist ligaments in Colles' fractures created in cadaver models have been reported to remain intact; reduction of intra-articular comminution with this treatment is said to occur by traction on these ligaments, so called "ligamentotaxis". Although some authors describe invariable intra-articular reduction with traction techniques, many have found this not to be the case. None of the articles quoted here address the quality of reduction of intra-articular comminution provided by external fixation.

It has been our experience that the severely comminuted distal radial fracture secondary to high-velocity trauma is often not adequately reduced with external fixation or pins and plaster alone and that pin problems often occur to complicate both of these forms of treatment. We do not give a long-term functional follow-up, but instead evaluate several key points in the management of patients with severely comminuted distal radial fractures: (1) the ability to restore anatomic length and angulation, (2) the ability to correct intra-articular displacement, and (3) short-term complications comparing external fixation to pins and plaster as they occur in a younger and often multiple-injured population. We retrospectively reviewed the experience of several orthopedists at two institutions with 76 patients with severely comminuted distal radial fractures treated with either pins and plaster or external fixation.

Method

All patients had severely comminuted, displaced distal radial fractures, graded type III through VIII by the classification of Frykman; most were Frykman class VIII (Table I). The mechanism of injury is shown in Table II; more than one third were the result of high-speed motor vehicle accidents. All patients were treated by either the attending staff or residents supervised by staff members. Thirty patients were seen at the University of California at Davis Hospital; 17 had pins and plaster and 13 had external fixation. The mean age was 36.9 years for external fixation and 40.1 years for pins and plaster. Eleven of the fractures were open; three patients in each group had an additional associated bone fracture, and six in each group had severe, multisystem injuries. Follow-up ranged from 3 to 22 months with a mean of 6 months. Forty-six patients were seen at Kaiser Permanente Medical Center, Sacramento, Calif.; all had pins and plaster treatment. The mean age was 48.9 years. Four had open fractures, five had associated fractures, and five had severe, multisystem trauma. Follow-up ranged from 3 to 36 months and averaged 9.6 months.

Indications for operation at both institutions were (1) gross comminution with little chance of restoring length nonoperatively, (2) failure of initial closed reduction and splinting under hematoma block in the emergency room, or (3) loss of initial reduction with plaster treatment at follow-up of 1 to 2 weeks. Most patients were operated on on the day of injury, frequently in conjunction with operative procedures for their other in-
Fig. 1. Preoperative, postoperative, and follow-up measurements of radial angulation and length, calculated according to the method of Van der Linden and Ericson for each study group.

Fig. 2. Preoperative, postoperative, and follow-up measurements of palmar angulation for each study group.

Fig. 3. Preoperative, postoperative, and follow-up measurements of radial and dorsal displacement for each study group.

Severely comminuted distal radial fractures
Table III. Amount of radiocarpal displacement preoperatively, postoperatively, and at follow-up for each study group, measured as the greatest distance in millimeters

<table>
<thead>
<tr>
<th>Study Group</th>
<th>Preoperative (mm)</th>
<th>Postoperative (mm)</th>
<th>Follow-up (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>University Hospital, pins and plaster</td>
<td>3.6</td>
<td>2.2</td>
<td>2.3</td>
</tr>
<tr>
<td>University Hospital, external fixation</td>
<td>3.6</td>
<td>2.4</td>
<td>2.4</td>
</tr>
<tr>
<td>Kaiser, pins and plaster</td>
<td>3.9</td>
<td>2.3</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Table IV. Complications for each study group, shown as number and percentage of total cases

<table>
<thead>
<tr>
<th>Complication</th>
<th>University Hospital, Pins and plaster</th>
<th>University Hospital, External fixation</th>
<th>Kaiser Hospital, Pins and plaster</th>
</tr>
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<tbody>
<tr>
<td>Pin infection</td>
<td>0</td>
<td>3 (23%)</td>
<td>3 (6.5%)</td>
</tr>
<tr>
<td>Loose pins</td>
<td>3 (18%)</td>
<td>2 (15%)</td>
<td>11 (23%)</td>
</tr>
<tr>
<td>Pin tract osteomyelitis</td>
<td>0</td>
<td>0</td>
<td>3 (6.5%)</td>
</tr>
<tr>
<td>Iatrogenic fracture</td>
<td>1 (9%)</td>
<td>0</td>
<td>4 (8.6%)</td>
</tr>
<tr>
<td>Nonunion</td>
<td>0</td>
<td>1 (7.6%)</td>
<td>2 (4.3%)</td>
</tr>
<tr>
<td>Iatrogenic nerve palsy</td>
<td>1 (5.9%)</td>
<td>1 (7.6%)</td>
<td>0</td>
</tr>
<tr>
<td>Loss of reduction</td>
<td>3 (18%)</td>
<td>1 (7.6%)</td>
<td>6 (13%)</td>
</tr>
<tr>
<td>Radioulnar synostosis</td>
<td>1 (5.9%)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>% of patients with complications</td>
<td>53%</td>
<td>61%</td>
<td>52%</td>
</tr>
</tbody>
</table>

plane. Although ulnar variance can be considerable, average radial length was taken to be 12 ml from the distal ulna. In addition, intra-articular displacement along the radiocarpal joint was measured on preoperative, postoperative, and follow-up films. Normal values for dorsal and radial displacement were not given by Van der Linden and Ericson; the normal values shown here were obtained by averaging the measurements for those patients who had contralateral wrist films. Significant loss of reduction was defined as that of sufficient degree in which corrective surgery was recommended or performed.

Results

Twenty-eight of 30 patients reviewed from the University Hospital and 44 of 46 patients treated at Kaiser Hospital had sufficient x-ray films taken for preoperative, postoperative, and follow-up measurements. Radiographic measurements obtained are shown in Figs. 1 through 3. In general, radial angulation and length were reasonably well restored with both of these techniques. Palmar angulation was not restored to normal with either technique. Intra-articular displacement is shown in Table III. Intra-articular radiocarpal displacement was generally decreased, but not returned to anatomic alignment. In most cases, a significant and unacceptable amount of displacement existed at the radiocarpal joint despite many attempts at manipulation and rereduction with both techniques (Figs. 4 through 10). There were no infections in any of the soft tissue wounds and no cases of osteomyelitis at the fracture sites in any of the open fractures.

Complications are shown in Table IV. Fifty-three percent of the patients treated at the University Hospital experienced at least one complication. With external fixation 61% of the patients experienced complications. Most of these complications were related to pin problems despite the use of threaded half pins. Fifty-two percent of the patients treated with pins and plaster at the affiliated hospital had complications. No pin tract osteomyelitis occurred in our small series of external fixation. Pin infections resolved with oral antibiotics in all but four patients who required pin removal. All loose pins were removed; five of these eleven patients had their fractures rereduced in the operating room and had the loose pin replaced at a different site. Iatrogenic metacarpal fractures were treated with closed reduction and casting; all iatrogenic ulnar fractures were treated with internal fixation. Nonunion at the distal radius led to bone grafting in two patients and wrist fusion in one. Iatrogenic nerve palsies were treated with decreasing wrist flexion and resolved in all patients by follow-up. The amount of loss of reduction requiring subsequent operative reconstruction varied for each surgeon; however, these patients tended to have severe residual deformities, including a mean radial length of −11 ml
Severely comminuted distal radial fractures

Fig. 4. Twenty-six-year-old man injured in a motorcycle accident. Preoperative x-ray films show a comminuted Frykman class VIII fracture with moderate displacement of the radial styloid fragment.

and a mean dorsal tilt of 9.6° at follow-up. Two patients with ipsilateral scaphoid fractures and one with a radial shaft fracture were treated with pins and plaster. All developed nonunion of these associated carpal fractures. Five (28%) patients with pins and plaster treated at the University Hospital were unable to complete 6 weeks of immobilization with pins secondary to pin-related complications. Four (30%) of those with external fixation had similar complications. Fourteen (30%) of the patients treated at the affiliated hospital were unable to complete the initial form of treatment. Reoperation rate for the externally fixed group was 38% (five of 13). Three patients with pins and plaster were reoperated on at the University Hospital (17%) and nine at Kaiser Hospital (20%).

Discussion

In low-velocity injuries with minimal displacement and little soft tissue injury, the improvement in reduction offered by distraction techniques can often be sufficient to expect a good result with acceptable complication rates. This, however, is often not the case in the extremely displaced high-velocity injury that frequently occurs in younger patients. The Frykman classification system does not differentiate these injuries, since the amount of displacement of the fracture fragments is not one of the criteria. The mean age of patients in our series with pins and plaster was younger than in most series, and in general the patients were more severely traumatized with a concomitant increase in complications. Cer-
Fig. 7. Severely displaced, comminuted Frykman class VIII fracture in a motorcycle rider.

Fig. 8. Initial reduction obtained with external fixation. Note displacement of palmar fragment with unreduced depression of the lunate fossa of the radius.

Fig. 9. Rereduced at 10 days with open reduction of lunate associated fragment. Better alignment but still has displacement of lunate fossa and dorsal angulation on the lateral film.

Fig. 10. Follow-up at 6 months.

certainly, the data represented here would indicate that careful patient selection and meticulous technique in the use of pins and plaster is mandatory; complications should be anticipated in regards to pin problems and failure to obtain or maintain reduction.

Our small series of external fixation of these fractures did not resolve this high rate of pin complications. Although some suggest a lower incidence of pin problems with threaded half pins, in those series with reasonable follow-up in which complications are reported, failure rates secondary to pin problems are often disturbingly high.\textsuperscript{55,56} Our study does not address long-term function and thus cannot speak to several issues when comparing external fixation versus pins and plaster, such as intrinsic tie down and better hand and elbow motion. Both of these theoretical advantages are attractive, especially in the older patient in whom stiffness is a problem and fractures tend to be low-energy,
minimally displaced injuries. The low incidence of wound complications, with either technique, minimal complications with circumferential plaster, and similarity of quality of reduction shown here do not defend the increased cost of external fixation over pins and plaster. External fixation did not obviate pin problems in our series.

Carpal and forearm shaft fractures are unusual with distal radial fractures, although they have been previously reported. Smith et al. reported several ipsilateral injuries treated with external fixation, all of which healed. None of the fractures treated this way in our series healed. The traction required to maintain reduction of the distal radius in the severely comminuted fracture leads us to recommend against its use with ipsilateral carpal fractures unless additional internal fixation of the long bone or carpal fracture is also performed.

Perhaps most discouraging in our evaluation was the quality of reduction obtained with these techniques. We have shown, as have others, reasonable restoration of radial length. Anatomic palmar tilt was not restored in most cases, as has been previously reported. This is of some concern, since at least one report associates failure to restore palmar tilt with symptomatic midcarpal instability. It has also been our experience that the "die punch" fragment is not often reduced with distraction techniques alone. DePalma's work with Colles' fractures created in cadavers is often quoted as definitive evidence that the wrist ligaments in these injuries remain intact. As some individuals gain expertise with open reduction of these fractures, soft tissue injury associated with Colles' fractures has been found to be not infrequent in vivo. It seems possible that the integrity of the wrist ligaments in these severe injuries is not always adequate for reduction by "ligamentotaxis." Most of the displaced radiocarpal comminution was not reduced adequately with either technique in our series; because these were often young laborers, significant delayed radiocarpal arthritis constitutes a serious problem. Although long-term results in our series are unknown, the residual 2 to 3 ml step off shown in our patients causes us some concern, since radiocarpal arthritis has been shown to be present in more than 90% of wrists with similar displacement at long-term follow-up.

In summary, although pins and plaster or external fixation may provide an acceptable result for an isolated low-energy injury, the complication rate in our series for younger, often multiple-injured patients was high. All carpal and forearm shaft fractures treated with distraction developed nonunion. Reduction of intra-articular radiocarpal displacement was rarely anatomic, and significant displacement often remained despite repeated reduction. Perhaps open reduction and internal fixation or external fixation combined with limited internal fixation can better reduce this displacement; until future series demonstrate better results with these or other techniques, the comminuted distal radial fracture remains very much an unsolved problem.

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