A NEW RADIOGRAPHIC METHOD OF MEASURING CARPAL COLLAPSE

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We assessed carpal collapse by measuring the capitate-radius (CR) distance on standard plain radiographs. This new method required validation of diagnostic accuracy, so we compared it with the method of Nattrass et al known as revised carpal height (RCH).

We studied wrist radiographs from 16 normal subjects and 11 patients with unilateral Kienböck's disease. We found that there was a significant difference in the left/right CR index between the normal wrists and those with Kienböck's disease (p < 0.001). The use of left/right RCH index showed no significant difference (p = 0.30). Diagnostic accuracy was shown to be higher for the CR index using ROC curves.

We then assessed 40 normal wrists and found the mean CR index to be 0.999 ± 0.034, and suggest that values less than 0.92 are abnormal. The CR index can be used for diagnosis in unilateral carpal collapse, and for monitoring progress where the condition is bilateral.

Received 3 April 1995; Accepted after revision 20 August 1996

In the assessment of disorders of the wrist such as rheumatoid arthritis or Kienböck’s disease it is important to know the degree of carpal collapse.2,3 A method of measurement based on the ratio between the carpal height and length of the third metacarpal has been proposed,2,4 but in 1994, Natrass et al showed that the use of the length of the capitate instead of the third metacarpal was more accurate.1 This is the revised carpal height (RCH) ratio. The average value is 1.57 in the normal population, with a standard deviation of 0.05, and it is possible to calculate the left/right RCH index. The method is known to have some drawbacks and the capitate may have different shapes.5

MATERIALS AND METHODS

We studied the radiographs of two groups of people: normal (16 patients with no history of wrist disease) and 11 patients with unilateral carpal collapse due to Kienböck’s disease. There were 14 men and 13 women, with an average age of 30.6 (± 12.6 SD) years. Eleven doctors participated in the study, all having attended a 30-minute course on measurement techniques. All radiographs were taken by a standard method, with no variation in tube-
subject-film distances. The radiographs were mixed and
carpal collapse was measured by the CR distance and the
RCH ratio. Testing for differences was first performed on
the averages of 11 measurements made by the doctors
taking part in the study. After that differences were tested
for each participant separately.

We applied the Wilcoxon test (non-parametric analogue
for paired t-test) to assess the difference between the
pathological and healthy hands in the pathological group,
since each patient had one affected and one healthy wrist.
To compare the difference between the pathological
(\(n = 11\)) and healthy group (\(n = 16\)) we used the Mann-
Whitney test (MW). The diagnostic accuracy of the two
methods was estimated and demonstrated using Receiver
Operating Characteristic (ROC) curves.\(^7\) The ROC curve
shows the sensitivity vs specificity of a method for differ-
ent cut-off values, and the relation between the true-posi-
tive and false-positive results. An ideal curve would start
vertically (increase of true-positive rate), touch the upper
left corner (cut-off value) and continue horizontally to the
upper right corner (increase of false-positive rate). An
oblique (diagonal) curve is less desirable because it shows
that increasing the cut-off value raises the true-positive and
false-positive rates simultaneously (Fig. 2).

To estimate the average value of CR in normal wrists we
measured radiographs from another 24 healthy volunteers
to give a total of 40 pairs of healthy wrists. On all these
films, one of the authors (VZ) measured the CR distances,
to calculate the estimated left/right ratio for a normal
population.

RESULTS
The statistical results for the calculated parameters are
shown in Table I. We found the lowest normal CR index to
be 0.92.

### Table I. Details of statistics for carpal height ratios. CR and RCH indexes are left/right ratios and represent average hand pairs. The RCH is calculated and consecutively averaged over single hands

<table>
<thead>
<tr>
<th></th>
<th>Range</th>
<th>Mean</th>
<th>SD</th>
<th>95% CI limit</th>
<th>Min</th>
<th>Median</th>
<th>Max</th>
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<tbody>
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<td>CR index</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11 abnormal</td>
<td></td>
<td>0.87</td>
<td>0.085</td>
<td>0.81 - 0.93</td>
<td>0.72</td>
<td>0.88</td>
<td>1.02</td>
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<tr>
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<td></td>
<td>0.99</td>
<td>0.038</td>
<td>0.97 - 1.01</td>
<td>0.92</td>
<td>1.00</td>
<td>1.05</td>
</tr>
<tr>
<td>40 normal*</td>
<td></td>
<td>0.99</td>
<td>0.034</td>
<td>0.99 - 1.01</td>
<td>0.92</td>
<td>1.00</td>
<td>1.07</td>
</tr>
<tr>
<td>RCH</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>1.48</td>
<td>0.097</td>
<td>1.42 - 1.55</td>
<td>1.31</td>
<td>1.51</td>
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<td>1.52 - 1.62</td>
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<td>1.56</td>
<td>1.74</td>
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<tr>
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<td>0.082</td>
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<td>0.028</td>
<td>0.97 - 1.00</td>
<td>0.92</td>
<td>0.99</td>
<td>1.03</td>
</tr>
</tbody>
</table>

* extended group including the 16 normal subjects from the study and 24 healthy volunteers
In the patients with Keinböck’s disease the CR distance and the RCH ratio were decreased in the affected wrist when compared to the contralateral healthy wrist. Wilcoxon’s test showed that the difference for CR was more significant ($p = 0.004$) than for the RCH ratio ($p = 0.033$).

When averaged over all observers only the CR index was significantly lower ($p < 0.001$; MW) in the pathological group ($n = 11$) compared to the normal group ($n = 16$). The RCH indexes in the two groups were not significantly different ($p = 0.300$, MW). When the measurements obtained by each observer were analysed there was a clear-cut advantage for CR. All 11 observers found a significantly decreased CR in the pathological group when compared to the normal group ($p < 0.01$; MW test). With the RCH index one observer failed to differentiate between the normal and pathological group ($p > 0.05$, MW), and two others found a decreased RCH index with a difference which was not highly significant ($0.01 < p < 0.05$; MW). The other eight observers found a highly significant difference in RCH index ($p < 0.01$; MW).

The ROC curves showed that much better diagnostic accuracy was achieved with the capitate-radius distance (Fig. 2) than the RCH.

DISCUSSION

Our study has shown that direct capitate-radius measurement has a better diagnostic accuracy than the RCH ratio. The advantage of CR measurement is shown by the highly significant differences between the abnormal and the healthy side in the same patient, and between values for the normal and pathological groups.

A more accurate method of measurement of carpal collapse will allow better staging of the common disorders that produce carpal collapse. It is difficult to define ‘normal range’ for carpal height because the concept that mean ± one standard deviation provides ‘representative normal sample’ is not correct.\(^6\)\(^5\) One example is the carpal height ratio which is reported to be 0.54 ± 0.03 for a normal population,\(^1\) but another study of healthy subjects found values that ranged from 0.462 to 0.608.\(^6\)

In unilateral disease, when the opposite healthy hand can be used as a standard, reference to a ‘normal value’ is not needed. Direct left-right comparison of the CR distance is the most logical and effective way to estimate the carpal collapse.

When considering measurement it is important to analyse the ‘rounding-up error’. Naked-eye measurement using a millimetre scale is only possible with rounding-up to 0.5 mm (that is with 0.5 mm precision), so there may be an error of ± 0.25 mm for each measured distance. When two distances are measured for one result, then the overall error for that parameter is the product of the two rounding-up errors. For the RCH ratio it can be calculated that the standard error caused by rounding-up errors exceeds the limits of the reported normal range of ± 0.04.\(^4\) For the RCH index as a left/right ratio, the errors must be multiplied again, which further reduces the precision of the method. The CR index has a lower overall error because only one distance is measured on each radiograph.

In patients with bilateral pathology an estimation of carpal collapse on the initial radiographs is impossible because ‘normal’ values in the population are known to differ.\(^7\) However, progression of the disease can be estimated by comparing consecutive CR measurements from the same hand. A ratio of the new and old CR distances of the same hand which is lower than 0.95 (lower rounding error limit) should be considered to be significant.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

REFERENCES