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WRIST KINEMATICS

Row, column or both?

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Analysis of radiographs of 52 wrists showed that, from ulnar to radial deviation, the amount of scaphoid shortening and ulnar translation of the scaphoid varies in a normal distribution. There is a significant correlation between the two measurements, such that the more the scaphoid shortens the less it translates and vice versa. Females subjects were more likely to have greater scaphoid shortening and less translation. It is felt that carpal kinematics thus cover a spectrum from the “row” theory to the “column” theory which is normally distributed and that women are more likely to have a column type wrist. This variation may affect the result of treatment of scapholunate dissociation by techniques such as scapho-lunate fusion. A “CR index” is proposed so that the tendency of a wrist towards row or column theory can be quantified. This may be used to predict the success of some surgical procedures in the treatment of scapholunate dissociation. Journal of Hand Surgery (British and European Volume, 1995) 20B: 2: 165-170

Theories on how the individual carpal bones move fall into two main areas. Classical anatomists divided the carpus into two rows with the scaphoid bridging the two rows. The distal row consisted of hamate, capitae, trapezium and trapezoid with the distal pole of the scaphoid, and the proximal row consisted of triquetrum, lunate and proximal scaphoid pole. The theory stated that flexion and extension occurred at the mid carpal joint and radial and ulnar deviation by the scaphoid sliding down the slope of the distal radius.

Navarro (1921) originally proposed the column theory. He suggested that the carpus was made up of three columns: the central column of lunate, capitae and hamate at which flexion extension occurred; the lateral column of scaphoid, trapezium and trapezoid; and the medial column of triquetrum and pisiform. Talesnik (1976) modified this theory to accommodate modern impressions that the distal row acted effectively as a single unit with the lunate. He left the lateral column as the scaphoid and the medial column as the triquetrum and left out the pisiform, since it is a sesamoid bone. The theory essentially suggests that the central column controls flexion and extension with radial and ulnar deviation occurring by rotation of the scaphoid and triquetrum about the central column.

Lichtman et al (1981) returned to a modification of the original row theory with the “oval ring concept” which suggests that movement occurs between capitae and lunate in radial and ulnar deviation as well as flexion and extension. He implies that the scapho-trapezial and triquetro-hamate joints act as physiological links which, if damaged, cause abnormal movements between individual bones. Weber (1984) feels that the movements are controlled by the shape of the surface of the triquetrum as it rides on the hamate.

Some authors have measured the angles of the different bones. Ruby et al (1988) found that the scaphoid rotated a mean of 51° in radial and ulnar deviation compared with lunate rotation of 35°, while Horii et al (1991) found little difference between these bones.

Controversy and uncertainty therefore remain as to how the proximal row behaves in radial and ulnar deviation.

MATERIAL AND METHODS

Radiographs were taken of 52 wrists in radial and ulnar deviation. 19 wrists were from normal volunteers and the remaining 33 from patients under investigation for wrist symptoms. The latter patients were all subsequently investigated by cineradiography and radio-carpal and mid-carpal joint arthroscopy of the wrist, and were found to have either no pathology or no evidence of intercarpal ligamentous injury or joint surface abnormality. 26 were male and 26 female, with a mean age of 35 years. 28 were right wrists and 24 were left wrists.

Antero-posterior radiographs were taken with the patients seated, the shoulder abducted 90°, the elbow flexed to 90° and the forearm in neutral rotation. The patients were asked actively to place the wrist in radial and ulnar deviation to its fullest extent without allowing the palm of the hand to leave the X-ray film. The following measurements were made:

1. The distance from the most proximal and ulnar point on the scaphoid to the central crest on the distal pole which indicates the junction of the facets for the trapezium and trapezoid (Fig 1). The value obtained in radial deviation was divided by the value in ulnar deviation (RD/UD) to eliminate error caused by individual variation in range of movement and different magnification of radiographs. The central crest distally was used to minimize the effect of rotation of the scaphoid.

2. In 36 of the wrists a further measurement was taken. These wrists consisted of 19 normal patients and 17 of the patients with wrist symptoms. A vertical line was dropped from the radial styloid and the most ulnar point on the scaphoid and the distance measured between them in radial and ulnar deviation (Fig 2). The difference between the two values was divided by the...
length of the scaphoid in ulnar deviation as measured in (1) for the same reasons as in (1). This value was termed the translation ratio.

3. The sex and age of the patient and the side X-rayed.

The values were plotted on a histogram and analyzed using normal plot tests, correlation and regression analysis using the Minitab statistical package on an Ambra personal computer.

RESULTS

The ratio of the length in radial deviation and the length in ulnar deviation (RD/UD) was plotted as a histogram (Fig 3). Observation and analysis confirmed that the values approximated to a normal distribution with a mean of 0.81 and standard deviation of 0.1.

The amount of scaphoid translation was also plotted and analyzed in a similar fashion (Fig 4). This also approximated to a normal distribution with mean of 0.26 and standard deviation 0.09.

RD/UD was correlated against the translation ratio. The correlation coefficient was 0.498. Regression analysis showed a significant relationship between RD/UD and the translation ratio ($P=0.002$; Fig 5). Thus the more the scaphoid shortens the less it translates and vice versa.

Student $t$-test analysis showed that there was no statistical difference between the right and left wrists, but that female subjects had a significantly lower RD/UD ratio ($P=0.0023$) and a significantly lower translation ratio ($P=0.002$). Thus women had a greater tendency to scaphoid shortening and less translation and were of the 'column' type wrist.

The RD/UD ratio can be used to predict how close a wrist is to row and column theory. A perfectly 'row' wrist would have a RD/UD ratio or CR index = 1, similar to the appearance of Figure 1, while a column wrist would have a CR index of approximately 0.5, similar to Figure 6.

DISCUSSION

Because of its position crossing from proximal to distal carpal rows, the crucial role of the scaphoid in wrist kinematics has been emphasized by many authors (MacConaill, 1941; Gilford et al, 1943; Mayfield et al, 1976) However, there remains a basic division between authors as to the whether the scaphoid, and with it the
Fig 2  Method of measurement of scaphoid translation.

Fig 3  Graph showing variation in RD/UD ratio.
proximal carpal row, flexes and extends from radial to ulnar deviation or slides up and down the slope of the radius. The major disadvantage in all studies on the kinematics seems to be the small number of wrists studied. Ruby et al (1988), in studying the range of movement of individual carpal bone, records a range of flexion of the scaphoid in radial to ulnar deviation from 31.2° to 70.6° in only four wrists. Horii et al (1991), in showing little variation between the movements of these bones, only studied five wrists. Taliesnik (1976) studied 17 wrists and suggested changes to Navarro’s columnar carpus theory based on the anatomy of the wrist ligaments without apparently looking at the way the bones moved. Johnston (1907) based his ideas on carpal kinematics on ten wrists all placed in different positions, thus effectively using two wrists to look at radial and ulnar deviation. Throughout these studies authors have attempted to identify a common model for the mechanics of the wrist joint. This is a reasonable assumption as most joints in the body seem to have a standard mechanical design. Our study shows that wrist joints cover a kinematic spectrum as far as the movement of the proximal row is concerned.

Although it is not possible from the measurements that we have taken to confirm that the scaphoid shortens by flexing, many authors have demonstrated that the major movement of the scaphoid in radial to ulnar deviation of the wrist is flexion with a small amount of rotation (Johnston, 1907; MacConaill, 1941; Lichtman et al, 1981; Weber, 1984; Ruby et al, 1988; Sennwald et al, 1993). The variation in the amount of shortening of the scaphoid in our study seems to match the variation in the range of flexion found in other studies.

Clinical relevance
It is possible that the variation in wrist type may explain some clinical puzzles. The treatment of scapho-lunate dissociation remains one of the major challenges in hand surgery. Scapho-lunate fusion remains an attractive solution but only about one out of seven achieve bony union (Conyers, 1990; Hom and Ruby, 1991). It is possible that the successful patients are those with a “row” type wrist and a high CR index with little rotational stress on the attempted fusion. In experimental studies on scapholunate fusion a significant difference in range of movement is achieved. It is likely that those wrists with
a low CR index would be likely to have a reduced range of movement.

In a previous study (Kelly and Stanley, 1990) we were unable to explain why some patients with arthroscopically proven scapho-lunate ligament injuries did not take up the dorsal intercalated segment instability (DISI) pattern (Linscheid et al, 1972). It is likely that in those patients with a high CR index in which the scaphoid flexes minimally, when scapho-lunate ligament injury occurs the scaphoid is unable to flex into the DISI position. This would seem to be confirmed by Berger et al (1982) who found little change in scapholunate position and movement before and after scapholunate ligament sectioning in eight wrists. This emphasizes the importance of directly viewing the scapholunate ligament, either by magnetic resonance imaging or arthroscopically, in the symptomatic patient rather than depending on plain radiographs showing the DISI collapse pattern.

The variation between male and female wrists is also of interest. Whether this variation has clinical significance is purely speculative.

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