### RESEARCH

Intercarpal ligamentous laxity in cadaveric wrists

The purposes of this study were to define the range of laxity of the interosseous ligaments in cadaveric wrists and to determine whether this correlated with age, the morphology of the lunate, the scapholunate (SL) gap or the SL angle. We evaluated 83 fresh-frozen cadaveric wrists and recorded the SL gap and SL angle. Standard arthroscopy of the wrist was then performed and the grades of laxity of the scapholunate interosseous ligament (SLIL) and the lunotriquetral interosseous ligament (LTIL) and the morphology of the lunate were recorded. Arthroscopic evaluation of the SLIL revealed four (5%) grade I specimens, 28 (34%) grade II, 40 (48%) grade III and 11 (13%) grade IV. Evaluation of the LTIL showed 17 (20%) grade I specimens, 40 (48%) grade II, 28 (30%) grade III and one (1%) grade IV.

On both bivariate and multivariate analysis, the grade of both the SLIL and LTIL increased with age, but decreased with female gender. The grades of SLIL or LTIL did not correlate with the morphology of the lunate, the SL gap or the SL angle. The physiological range of laxity at the SL and lunotriquetral joints is wider than originally described. The intercarpal ligaments demonstrate an age-related progression of laxity of the SL and lunotriquetral joints. There is no correlation between the grades of laxity of the SLIL or LTIL and the morphology of the lunate, the SL gap or the SL grade. Based on our results, we believe that the Geissler classification has a role in describing intercarpal laxity, but if used alone it cannot adequately diagnose pathological instability.

We suggest a modified classification with a mechanism that may distinguish physiological laxity from pathological instability.

Arthroscopy of the wrist is increasingly used to evaluate injuries of the intercarpal ligaments. It has led to more frequent and accurate diagnosis of such injuries, of which a tear of the scapholunate interosseous ligament (SLIL) is the most common. The aim of earlier diagnosis and treatment of these injuries has been to correct carpal instability and prevent the development of osteoarthritis of the wrist. The challenge is to determine what degree of injury causes instability and therefore requires treatment.

In 1996, Geissler et al described the only system of arthroscopic classification of injuries to the intercarpal ligaments. Since its publication, it has been used as the main method of classifying tears of the SLIL and lunotriquetral interosseous ligament (LTIL). However, it has some weaknesses. It was derived from patients with displaced intra-articular fractures of the distal radius, it has never been studied in atraumatic wrists, and has not been evaluated for intra- and inter-observer reliability. We thus need to establish whether it can be applied to atraumatic wrists.

Geissler et al stated that an intra-articular scapholunate (SL) and lunotriquetral (LT) gap > 1 mm, the width of a small joint probe (Geissler grade II or greater), was pathological. In our experience during arthroscopy of the wrist for other reasons, such as arthroscopic excision of a ganglion or repair of the triangular fibrocartilage complex (TFCC), the gap between the SL and LT joints is often > 1 mm. This suggests that the normal range of physiological intercarpal laxity extends beyond the limits described by Geissler et al.

Previous anatomical studies have noted disruptions of the SLIL in 28% to 35% of cadaver wrists and of the LTIL in 32% to 49%. However, these investigations were not performed using arthroscopic techniques, and therefore the relationship between the degree of disruption of the SLIL or the LTIL could not be correlated with an arthroscopic gap. An arthroscopic study evaluating the physiological range of laxity of the interosseous ligaments would support the use of Geissler’s classification in the diagnosis of injuries of the
intercarpal ligaments, and should be performed before this classification is used as a guide to the treatment of injuries to the intercarpal ligaments.

The aims of this study were to define the range of physiological laxity of the intercarpal ligaments in cadaveric wrists, to determine whether this laxity depends on age, and to investigate whether laxity of the intercarpal ligaments correlates with the type of lunate, the SL gap or the SL angle.

Materials and Methods

We evaluated 83 fresh-frozen, trans-forearm amputation specimens (53 males, 30 females, 40 right arm, 43 left arm, 35 pairs) from cadavers with a mean age of 72 years (53 to 89). The wrists were stored at -20°C and thawed to room temperature prior to evaluation.

Posteroanterior and lateral radiographs were taken of the specimens. The SL gap was measured on the posteroanterior radiographs.1 On the lateral radiographs the SL angle was measured using the tangential method.13 Wrists demonstrating clinical or radiological evidence of previous trauma or surgery were excluded from the study. Specimens demonstrating radiological or arthroscopic evidence of severe pancarpal arthritis involving both the radiocarpal and midcarpal spaces were also excluded. We initially obtained 87 specimens but four were excluded from the study, as one had a previous midcarpal fusion and three had severe pancarpal arthritis.

Arthroscopy was performed using the technique described by Geissler et al.13 The forearm was secured to a traction tower and traction of 10 lbs (4.5 kg) was applied to the hand and wrist. The radiocarpal and midcarpal joints were accessed and assessed. A small probe could be rotated through 90°, which displaced the bones slightly. When the probe was de-rotated, however, some specimens had enough resistance in their ligaments to allow the carpal bones to return to their original position. Based on this observation, we subdivided the grade III class. In grade IIIA the carpal bones would reduce after the probe was de-rotated, but in grade IIIB they would not.

Statistical methods. Cochran-Mantel-Haenszel chi-squared tests were used to evaluate the relationship between categorical variables and an ordinal variable, or between two ordinal variables. Various correlation coefficients were calculated between ordinal and continuous or two ordinal variables. Pearson’s correlation coefficient was used for two continuous variables. Spearman’s ρ coefficient was used for an ordinal and a continuous variable, and Kendall’s τb coefficient was used for two ordinal variables.

Ordered logistic regression analysis was used to explore the effect of the different variables on the grades of SLIL and LTIL. The proportional odds assumption was checked and found to hold in all models. All potential predictors of grades of SLIL and LTIL were first used as single predictors in bivariate models for the grades separately. In addition, a multivariate model including age, the SL gap, gender and type of lunate was used. Because some of the records for left and right wrists belonged to the same patient, the models were adjusted for this correlation using generalised estimating equations. A p-value < 0.05 was considered statistically significant.

Results

Evaluation of the SLIL in all specimens revealed four (5%) grade I specimens, 28 (34%) grade II, 40 (48%) grade III and 11 (13%) grade IV. Assessment of the LTIL showed 17 (20%) grade I specimens, 40 (48%) grade II, 25 (30%) grade III and one (1%) grade IV. Our results are compared to those of Geissler et al13 for the SLIL and LTIL (Figs 1 and 2).

No significant correlation was seen between the grades of the SLIL and LTIL on bivariate analysis (chi-squared = 0.00, p = 0.99) (Kendall’s τb correlation coefficient = -0.01, p = 0.89). There was no association between gender and the grade of SLIL (chi-squared = 0.56, p = 0.35). However, a significant association was seen between gender and the grade of LTIL (chi-squared = 4.18, p = 0.04).

We devised the modified classification after the initial group of 24 specimens had been assessed, and hence only the remaining 59 specimens were evaluated with the modi-
fied classification. For the SLIL, 38 specimens were classified as Geissler grade III, with 29 (74%) grade IIIA and nine (26%) grade IIIB. For the LTIL, 17 were classified as Geissler grade III, with 11 (65%) grade IIIA and six (35%) grade IIIB (Table II).

There were 38 (46%) type I lunates and 45 (54%) type II. There was no statistically significant association between the type of lunate and the grade of either the SLIL or the LTIL (p = 0.32 and p = 0.52, respectively).

On radiological evaluation, the mean SL gap was 2.1 mm but 70 specimens (85%) demonstrated a gap of 2 mm or less, 13 (15%) had a gap > 2 mm. There was no correlation between age and the SL gap (Spearman’s p = 0.14, p = 0.21) or between the SL gap and the SLIL grade (chi-squared = 0.33, p = 0.57; SL grade was analysed as an ordinal variable because our data only exhibited four categories). There was no correlation between the SL gap and grade of LTIL (chi-squared = 0.86, p = 0.35). The mean SL angle for all specimens was 50°, with two (2%) having an angle > 30° and 80 (97%) angles ranging from 30° to 70°. One specimen had a SL angle > 70°. There was no correlation between the SL angle and age (Pearson’s correlation coefficient = 0.17, p = 0.12). When correlation coefficients were calculated for the variables related to the SL angle and the SL gap, no significant correlation was observed (Table III).

Bivariate ordered logistic regression models predicting SLIL grade showed that age was the only statistically significant factor (Table IV). In a multivariate model adjusted for gender, SL angle and the type of lunate, age remained the only significant predictor of the grade of SLIL (Table V). The bivariate models predicting the grade of LTIL showed that both age and gender independently predict the grade (Table VI). This was confirmed in a multivariate model, as age and gender were significant predictors of the grade of LTIL (Table VII).

<table>
<thead>
<tr>
<th>SLIL grade</th>
<th>LTIL grade number (%)</th>
<th>number (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>4 (7)</td>
<td>15 (25)</td>
</tr>
<tr>
<td>II</td>
<td>18 (31)</td>
<td>26 (44)</td>
</tr>
<tr>
<td>IIIA</td>
<td>20 (34)</td>
<td>11 (19)</td>
</tr>
<tr>
<td>IIIB</td>
<td>9 (15)</td>
<td>6 (10)</td>
</tr>
<tr>
<td>IV</td>
<td>8 (14)</td>
<td>1 (2)</td>
</tr>
</tbody>
</table>

* SLIL, scapholunate interosseous ligament
† LTIL, lunotriquetral interosseous ligament

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Arthroscopic evaluation of injuries to the intercarpal ligaments has recently become more common.1,6 The most commonly used arthroscopic grading system for intercarpal ligament injuries was published by Geissler et al,13 based on 60 patients who had undergone arthroscopically assisted fixation of an acute displaced intra-articular fracture of the distal radius (Table I). Because this study was based on fractured wrists, it is difficult to apply the classification to all patients undergoing arthroscopy without first determining the physiological range of ligament laxity present in the wrist. Based on our results, we believe that the Geissler classification has a role in describing intercarpal laxity, but cannot adequately diagnose pathological instability.

There has not been an arthroscopy-based study evaluating the range of physiological intercarpal ligament laxity. Previous anatomical studies have noted disruption of the SLIL in 28% to 35% of cadaveric wrists and of the LTIL in 32% to 49%.17-20 Viegas et al19 dissected 393 cadavers and of the LTIL or TFCC and chondromalacia of the lunate.

Although they were able to show a correlation between the type II lunate and chondromalacia of the proximal pole of the hamate, they did not attempt to assess whether there was a correlation between the type II lunates and tears of the LTIL. They demonstrated that the percentage of tears of the interosseous ligaments increased with age, but did not show statistical significance for this trend. Only 20% of the specimens in this study were fresh-frozen cadavers, which introduced potential error due to embalming. In our study all the specimens were fresh-frozen, we demonstrated a statistically significant correlation between increasing grades of SLIL and LTIL and increasing age, and found no correlation between the grade of LTIL and the type of lunate.

Wright et al17 studied 62 cadaveric wrists with an average age of 78 years at death. They found tears of the SLIL in 29% of cases, with the majority (67%) being incomplete lesions, of which 44% were central. They found a statistically significant correlation between tears of the SLIL and chondromalacia of the scaphoid, and concluded that age-related tears of the interosseous ligaments of the wrist occur differently from traumatic tears. They hypothesised that the secondary constraints of the wrist remain intact during ageing and prevent the development of carpal instability and degeneration of the scapholunate advanced collapse (SLAC) wrist. They suggested that the secondary constraints in the wrist remain intact in the presence of incomplete tears. Our study showed a significant age-related increase in intercarpal movement without radiographic signs of carpal instability. Our modification to Geissler’s criteria is based on the same hypothesis presented by Wright et al.17

Lee et al18 studied 96 cadaveric wrists with an average age of 75 years at death to determine the incidence of tears of the interosseous ligaments. They found that 35% had tears of the SLIL involving 40% of its insertion, and 49% had tears of the LTIL involving 52% of its insertion. They concluded that there is a correlation between larger tears and chondromalacia. However, large interosseous ligament tears can be present without arthrosis. This suggests that an isolated large tear of an intercarpal ligament, without additional injury, may not result in carpal instability. This

Discussion

Table V. Multivariate models predicting the scapholunate interosseous ligament grade, which increased significantly with increasing age. The remaining variables had no significant effect on the grade

<table>
<thead>
<tr>
<th>Effect</th>
<th>p-value*</th>
<th>Odds ratio (95% CI†)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>0.0009</td>
<td>1.09 (1.03 to 1.14)</td>
</tr>
<tr>
<td>Scapholunate angle</td>
<td>0.42</td>
<td>1.02 (0.98 to 1.06)</td>
</tr>
<tr>
<td>Gender</td>
<td>0.58</td>
<td>0.78 (0.32 to 1.88)</td>
</tr>
<tr>
<td>Lunate type</td>
<td>0.21</td>
<td>1.68 (0.74 to 3.82)</td>
</tr>
</tbody>
</table>

*A p-value < 0.05 was considered statistically significant
† CI, confidence interval

Table VI. Bivariate models predicting the lunotriquetral interosseous ligament grade, which increased significantly with increasing age but decreased significantly in women. The remaining variables had no significant effect on the grade

<table>
<thead>
<tr>
<th>Effect</th>
<th>p-value*</th>
<th>Odds ratio (95% CI†)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>0.0003</td>
<td>1.04 (1.00 to 1.08)</td>
</tr>
<tr>
<td>Scapholunate angle</td>
<td>0.34</td>
<td>1.02 (0.98 to 1.05)</td>
</tr>
<tr>
<td>Gender</td>
<td>0.03</td>
<td>0.41 (0.18 to 0.94)</td>
</tr>
<tr>
<td>Lunate type</td>
<td>0.41</td>
<td>1.39 (0.63 to 3.06)</td>
</tr>
</tbody>
</table>

*A p-value < 0.05 was considered statistically significant
† CI, confidence interval

Table VII. Multivariate models predicting the lunotriquetral interosseous ligament grade, which increased significantly with increasing age but decreased significantly in women. The remaining variables had no significant effect on the grade

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<th>p-value*</th>
<th>Odds ratio (95% CI†)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>0.0003</td>
<td>1.05 (1.01 to 1.09)</td>
</tr>
<tr>
<td>Scapholunate angle</td>
<td>0.65</td>
<td>1.01 (0.98 to 1.04)</td>
</tr>
<tr>
<td>Gender</td>
<td>0.02</td>
<td>0.37 (0.16 to 0.83)</td>
</tr>
<tr>
<td>Lunate type</td>
<td>0.42</td>
<td>1.38 (0.63 to 3.01)</td>
</tr>
</tbody>
</table>

*A p-value < 0.05 was considered statistically significant
† CI, confidence interval
supports our contention that the integrity of the secondary restraints of the SL and LT joints is crucial in determining whether a tear of an intercarpal ligament will result in pathological instability of the wrist.

We have attempted to determine the normal range of laxity of the intercarpal ligaments. A recent study by Edwards and Johansen found 96% (43 of 45) of SLILs to be greater than grade I and 100% (45 of 45) of LTILs greater than grade I in middle-aged patients (mean age 42 years) undergoing arthroscopic excision of a ganglion. These findings are inconsistent with the conclusion of Geissler et al that ligaments of grade II to IV are pathological. The question then arises that if a patient is clinically asymptomatic, with a negative Watson scaphoid shift and finger extension tests, is the gap at the SL joint due to physiological laxity instead of pathological instability? This question becomes important if the Geissler classification is used to guide treatment. For example, should patients with Geissler grade II or III SLILs be treated surgically at the time of diagnostic arthroscopy? Without knowledge of the physiological range of laxity of the intercarpal ligaments, it would be difficult to conclude what degree of intercarpal gap was truly pathological and required treatment. We found an increase in the grades of SLIL and LTIL compared to Geissler et al and consider that the differences can be explained if grade II and some grade III ligaments are within the normal range of physiological laxity.

Our modification of Geissler’s classification requires clinical validation. As previous studies have shown, the majority of tears of the SLIL and LTIL are partial. Bio-mechanical studies have shown that some combination of primary and secondary stabilisers of the SL joint must be injured before radiological carpal instability occurs. With complete sectioning of the SLIL alone, radiological findings of dorsal intercalary segment instability (DISI), with an SL angle > 70° and a gap > 2 mm, do not occur. In Geissler’s classification the attenuation observed in grade II ligaments is a partial tear of the central portion of the ligament, as described by Wright et al. It is not until the stronger dorsal aspect of the ligament is torn that gap in the SL joint is observed in grade III ligaments. In our modified classification, the difference between grade IIIA and IIIB ligaments may be demonstrated as a dynamic stress that could be used to evaluate the integrity of the secondary stabilisers of the SL joint, namely the radioscapocapitate, radiolunate and scaphotrapezial ligaments. It is possible that the resistance felt by the probe as it is rotated through 90° is the action of the secondary stabilisers reacting to the stress placed on the SL joint. We believe that the secondary stabilisers are intact with grade IIIA laxity and incompetent with grade IIIB and IV. Although the secondary stabilising structures were not deliberately observed through arthroscopy, we believe that the proposed modification provides an arthroscopic stress test of the secondary restraints of the SL and LT joints that may be used to diagnose the progression from pre-dynamic to dynamic instability, as described by Watson et al. In the stages of SL instability described by Wolfe, progression from occult instability (stage I) to dynamic instability (stage II) may be reflected in the differences between grades IIIA and IIIB in our modified Geissler classification.

We also attempted to identify an association between intercarpal ligamentous laxity and the morphology of the lunate. The incidence of type II lunates (54%) in this study fell within the range of previous studies (46% to 72%) which have shown an increased incidence of chondromalacia of the hamate associated with the type II lunate, which has a separate articular facet for the proximal pole of the hamate. A reasonable assumption would be that the chondromalacia was the result of an increased load at the hamate-lunate-triquetrum articulation which could lead to increased strain on the LTIL. We could not demonstrate any significant differences in the grades of LTIL or SLIL between wrists with type I or type II lunates.

The major limitations of this study were due to the use of cadavers. The specimens were of an advanced age and had an unknown clinical history. Although we attempted to rule out severe wrist trauma by excluding wrists with evidence of previous fracture or severe arthritis, we could not confirm that they were not subjected to trauma during their lifetime. An additional limitation was the lack of documentation of the exact location of arthritic changes within the carpus. Finally, we did not include an evaluation of the intra- and inter-observer reliability of the Geissler classification or our modified classification.

This study demonstrates that the range of laxity at the SL and LT joints in cadaveric wrists is wider than originally described. Geissler grade II and some grade III intercarpal ligaments, which previously have been assumed to be pathological, are present in half of cadaver wrists and may represent physiological laxity. Intercarpal ligaments demonstrate an age-related progression of laxity in the SL and LT joints. Female gender is correlated with a lower grade of LTIL than male gender. There is no correlation between the grades of SLIL or LTIL and morphology of the lunate, the SL gap or the SL grade. We believe that the Geissler classification has a role in describing intercarpal laxity, but if used alone it cannot adequately diagnose pathological instability. We suggest a modification that provides more descriptive information and propose a mechanism that may distinguish physiological laxity from pathological instability within this modified classification. In the future, we hope to validate our modified classification by correlating it with clinical symptoms and outcomes to enhance our ability to diagnose carpal instability.

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