Radiographic and Computed Tomography Correlation of Kienböck's Disease: Is There a Need to Revisit Staging with Improved Imaging?

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Abstract

Carpal height ratio and ulnar variance on plain X-ray were measured and compared to the width/height ratio of the lunate as measured on a computed tomography (CT) scan in 50 patients with Kienböck's disease. Width/height ratio of the lunate was also measured in a series of 50 controls. No correlation between ulnar variance and fractures was found. Conversely, the correlation between carpal height ratio on X-ray and width/height ratio on a CT scan was statistically significant. Similarly, the correlation between ulnar variance and width/height ratio was statistically significant. We have concluded that width/height ratio while correlating with carpal height is a better measure of lunate collapse. It also appeared that lunate collapse precedes carpal collapse, specifically most if not all lunates have collapsed prior to reduction in carpal height ratio. Finally, while we are unable to conclude the level at which the width/height ratio of lunate becomes unreconstructable, it does appear that in all Litchman stage 3b and most if not all of 3a the shape of the lunate has altered significantly.

Keywords

- Kienböck's disease
- radiographic
- correlation

Kienböck's disease is avascular necrosis of the lunate that leads to a progressive collapse of the bone followed by the chronic collapse of the carpus, leading ultimately to secondary arthritis of the wrist.

Various types of surgical treatment have been undertaken, but the evidence is still not strong to support any particular procedure. What is becoming clearer, however, is that surgical techniques can be classified into reconstructive and salvage. The latter essentially being either a proximal row carpectomy or partial/total wrist fusion. The former can be a form of either leveling or decompression procedure with or without vascular or nonvascular bone graft in an attempt to restore the normal lunate.¹ A particular difficulty at this time is to assess whether the lunate can be reconstructed such that it can heal in a satisfactory or acceptable shape.

Traditionally, Lichtman's classification² (►Fig. 1) is based on plain X-ray examination. Patients with stages 1, 2, and

possibly 3a, where the lunate has retained some normality, could be considered for reconstruction, whereas those with stages 3b and 4 with significant loss of lunate shape could be candidates for salvage. The advent of improved imaging, particularly computed tomography (CT) scans, has allowed a more detailed assessment of the lunate bone. The purpose of this study is to compare the various traditional radiographic measurements with CT parameters to identify any correlation and allow better targeting of surgical procedures and improved prognosis.

We also measured the width and height ratio of 50 age- and sex-matched controls. These are patients who had undergone CT scans of scaphoid fractures.

Materials and Methods

In our study, we included 50 patients with established Kienböck's disease. Two independent observers

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Fig. 1 Stage 1: normal X-ray, signal intensity changes on MRI (magnetic resonance imaging). Stage 2: lunate sclerosis on plain X-ray; fracture lines may be present on CT (computed tomography) scan. Stage 3: collapse of the lunate articular surface. Stage 3A: normal carpal alignment and height. Stage 3B: fixed scaphoid rotation, proximal capitate migration, loss of carpal height. Stage 4: lunate collapse along with radiocarpal or midcarpal arthritis.

(I.A.T., A.M.) undertook various measurements from plain X-rays and CT scans.

Standard PACS (GE) was used to look at the digital X-ray and CT images. Measurements on X-rays included the carpal height ratio (►Fig. 2)³ and the ulnar variance. (►Fig. 3).⁴ Normal carpal height ratio is reported to be 0.54 ± 0.03 within the normal population.³

Measurements on the CT scan included the width and height ratio of the lunate (►Fig. 4) and noted any fractures in either the coronal or sagittal planes (►Fig. 5).

The CT scanner used was a Siemens SOMATOM Definition Edge 128-slice CT to produce 1-mm slices in both antero-posterior and sagittal planes.

Statistical Analysis

Statistical analysis was performed using SPSS statistics software version 22. Two-way mixed and absolute agreement intraclass correlation coefficients (ICC) were calculated to determine interobserver variability for carpal height ratio, ulnar variance, width/height (W/H) ratio of the lunate, and fracture score.

Visual inspection of Q-Q plots was used to assess for normality of the data, and following this, Spearman's corre-

Fig. 2 Carpal height ratio (b/a).

lation coefficient was used to assess the correlation between carpal height ratio and W/H lunate ratio, carpal height and fractures, and ulnar variance and fractures. A p -value of <0.05 was considered statistically significant.

Results

The images of 50 patients were analyzed; of these, 28 were males and 22 females. The average age was 39, ranging from 20 to 74. The measurements of the two observers were compared using ICC (►Table 1).

The ICC for carpal height ratio, ulnar variance, and fractures shows an excellent agreement between the two observers.⁵

ICC for W/H lunate ratio (0.66) shows an acceptable agreement between the two observers.

No correlation was found between carpal height ratio and fractures ($p = 0.21$) nor between ulnar variance and fractures ($p = 0.22$).

The correlation between carpal height ratio (X-ray) and W/H lunate (CT scan) was -0.317 , with a p -value of 0.03 (statistically significant). This is represented graphically in ►Fig. 6. The correlation between ulnar variance (X-ray) and W/H lunate (CT scan) was -0.355 , with a p -value of 0.01 (statistically significant). Of the 50 age- and sex-matched controls, the mean W/H ratio was 1.86 ± 0.30 .

Fig. 3 Ulnar variance measurement.

Fig. 4 Width/height ratio of width/height lunate.

Discussion

Since the initial description of Kienböck's disease and its classification using plain X-ray, improved imaging techniques have become available. This has resulted in the increased use of various imaging tools, particularly magnetic resonance imaging (MRI) and CT scans. While an MRI scan is useful in the early stage of the disease, CT scans particularly allow a better assessment of the lunate, particularly collapse or the presence of a fracture. Collapse is measured by loss of height and increased width or spreading on sagittal images. A CT scan is also useful in identifying the various shapes of the lunate and fracture patterns.^{2,3} From a surgical perspective, however, what is required is some guidance as to whether to proceed to reconstructive or salvage surgery. By reconstructive, it is meant that the procedure is undertaken to allow the lunate to heal in a satisfactory shape. Typical procedures would include radial or capitate shortening with a supplementary vascular or nonvascular bone graft. By salvage, it is meant that the lunate may not be reconstructed to a satisfactory shape, such that if healing were to occur, deformity would be such that further symptoms and potentially early osteoarthritis would ensue. Typical procedures would be either a fusion or proximal row carpectomy.

With regard to what is or is not reconstructable, most surgeons would regard the presence of three or more fracture fragments as taking a lunate beyond preservation. With regard to the lunate shape, however, the situation is more difficult. At this time, there are no real data on, firstly, what is normal and, secondly, what would be satisfactory. Our sample of controls identified a normal W/H ratio of 1.86 ± 0.30 . As can be seen, most of our series on Kienböck's disease have a significantly higher ratio.

Fig. 5 Fractures of the lunate.

Table 1 Results of measurements of two observers

	Carpal height ratio	Ulnar variance	W/H lunate	Fractures
ICC	0.96	0.98	0.66	0.96
95% confidence interval	0.93–0.97	0.96–0.99	0.25–0.75	0.93–0.97

Abbreviations: ICC, intraclass correlation coefficient; W/H, width/height.

Fig. 6 Showing the correlation between the carpal height ratio and the width/height ratio of the lunate.

With regard to Lichtman's classification (► **Fig. 1**), certainly stages 1 and 2 would be suitable for reconstruction, while stages 3B and 4 are more suitable for salvage. What is not clear is to how to treat patients with stage 3A. Within that group, there are patients with normal carpal alignment and height and a collapsed and fragmented lunate. Somewhere within this spectrum of normal-to-collapsed lunate will lie a threshold. On the one side, the lunate will be suitable for reconstruction, and on the other side, it will be beyond reconstruction.

Bain and Begg⁶ have proposed the following alternate classification system based on arthroscopic findings. This is based upon the number of nonfunctional articular surfaces. Authors describe a normal articular surface as having a normal glistening appearance or minor fibrillation, with a normal hard subchondral bone on palpation.

- Grade 0: all articular surfaces are functional and normal.
- Grade 1: one nonfunctional articular surface, typically the proximal articular surface of the lunate.
- Grade 2: two nonfunctional articular surfaces.
- Grade 2A: the proximal lunate and the lunate facet of the radius.
- Grade 2B: proximal articular surface of the lunate, and distal articular surface of the lunate.
- Grade 3: three nonfunctional articular surfaces: The lunate facet of the radius, and proximal and distal articular surfaces of the lunate with a preserved capitate.
- Grade 4: All four articular surfaces are nonfunctional.

With regard to the above, we would certainly agree that patients who have significant articular cartilage changes, reconstruction of the lunate would be inappropriate. In effect, they are Lichtman grade 4. In addition, using the Bain and Begg classification, it appears that only grade 0 and possibly some grade 1 may be reconstructible.

Few studies have looked at the use of CT scan in the management of this condition. Our results have shown no correlation between carpal collapse, ulnar variance, and the presence of fractures. Traditionally, it has been held that fractures are correlated with an advanced stage of the disease process. That is with an increased number of the fractures the more advanced the collapse of the lunate. Our results have shown that this is not the case and that lunates can fragment early in the disease process.

W/H ratio has shown a correlation with ulnar variance, which could suggest that W/H ratio is a better predictor of carpal collapse. This suggests that the wrist with a CT scan showing a W/H ratio of 2.75 ± 0.05 and negative ulnar variance will be at a high risk of carpal collapse. Our study suggests that CT and radiographs were, however, comparable in delineating advanced collapse. When considering the correlation between W/H of the lunate, as measured on a CT scan, and carpal height ratio, as measured by a plain X-ray (► **Fig. 6**), most of our patients had a carpal height ratio of 0.54 and a W/H ratio of 2.6, which is significantly higher than a normal 1.86. This would indicate that lunate collapse precedes carpal collapse. Indeed, most, if not all, lunates have collapsed prior to a reduction in carpal height ratio. As such, carpal height ratio may not be a good measure of whether a lunate is reconstructable.

Conclusions

Having measured carpal height ratio and ulnar variance on plain X-rays and compared it to W/H ratio of the lunate as measured on a CT scan, in 50 patients with Kienböck's disease, we can conclude that the number of fractures does not correlate with carpal collapse, that is to say that fragmentation of the lunate can occur early in the disease process. We would also conclude that W/H ratio, as measured on a CT scan, while correlating with carpal height ratio is a better measure of lunate collapse. A series of controls has revealed a normal ratio to be 1.86 (standard deviation ± 0.30). At this time, while normal W/H ratio and no fractures would undoubtedly be suitable for reconstruction, it is not clear at what measurements the lunate becomes unreconstructable. Finally, fractures of the lunate can appear early in the disease process and do not correlate with carpal collapse.

Note

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Conflict of Interest

None declared.

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