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Coronal shear fractures of the capitellum and trochlea: interobserver variability in classifying the fracture and the need for a computed tomography scan for the correct surgical planning

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A R T I C L E I N F O

Keywords:
Coronal fracture
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Level of evidence: Level IV; Case Series; Treatment Study

Background: To determine interobserver agreement in the classification by X-rays and by computed tomography (CT) scan of the coronal shear fractures of the capitellum and trochlea as well as the agreement between these two tests.

Methods: Patients with coronal shear fractures of the capitellum who were managed at our center between January 2008 and December 2017 were included. This retrospective cohort study was carried out with the approval of the ethics committee of our institution (Nº: IIBSP-Cod-2019-02, Ref. 19/070). Clinical, radiographic, and elbow-specific outcomes, including the Mayo Elbow Performance Index, were evaluated. Three observers analyzed the preoperative X-rays from all the cases. Each one of them independently classified the fractures according to the Bryan and Morrey classification (with the modification of McKee et al). The interobserver agreement was calculated by Cohen kappa coefficient. The same methodology was used to analyze the CT scan. Thereafter, one single value was determined for each X-ray and CT scan, from the good interobserver agreements. Finally, the agreement between the global X-ray classification and the global CT scan classification was calculated using the agreement percentage and the Cohen kappa coefficient.

Results: There were 3 males and 6 females, with a mean age of 47 years (range, 18-83). The mean follow-up period was 18 months (12-40). The average Mayo Elbow Performance Index score was 85 (range, 65-100) points. The complications were nonunion in one patient (11 %), degenerative arthritis in 7 (78 %), joint step-off in 5 (55%), and heterotopic ossification in 7 (78%). The agreement analysis between the global X-ray classification and the global CT scan classification showed a 57.1% agreement, with a kappa coefficient of −0.167. These values imply the absence of agreement.

Conclusion: Our results demostrated that simple X-rays do not allow for the adequate interpretation of distal humeral coronal plane fractures. Although an acceptable interobserver agreement was found, there is no agreement when the same fractures were analyzed by CT scan. The authors routinely recommend CT scan to assess the extent of the fracture and perform surgical planning.

Fractures of the capitellum compose 6% of distal humerus fractures and 1% of all elbow fractures.[22] Distal humeral coronal plane fractures may involve the capitellum alone; however, most extend medially to include a portion of the trochlea.[13] Isolated fractures of the trochlea have been described but are especially rare[9,14] (Fig. 1). Capitellum fractures are usually more complex than expected by analyzing plain radiographs. Associated bone and soft-tissue injuries to the elbow occur frequently in capitellar fractures.[34] Rausch et al[30] found injuries to the radial head in more than 37% of all capitellar fractures. Lateral collateral ligament (LCL) injury may be seen in up to approximately 60% of patients with this type of fracture.[9] Preoperative evaluation of the capitellum fracture and its extension to the trochlea and presence or absence of posterior condylar comminution is required to be able to perform surgical planning. This evaluation of the injury will allow planning of the surgical approach, the ability to perform an osteosynthesis versus a hemiarthroplasty and explain the prognosis of the injury to the patient. Computed tomography (CT) scan is therefore regularly recommended.[27] However, objective data are needed to support this recommendation, and at this time, not all hospitals have a

This study was approved by the Ethical Committee of Hospital de la Santa Creu i Sant Pau (IIBSP-Cod-2019-02, Ref. 19/070).

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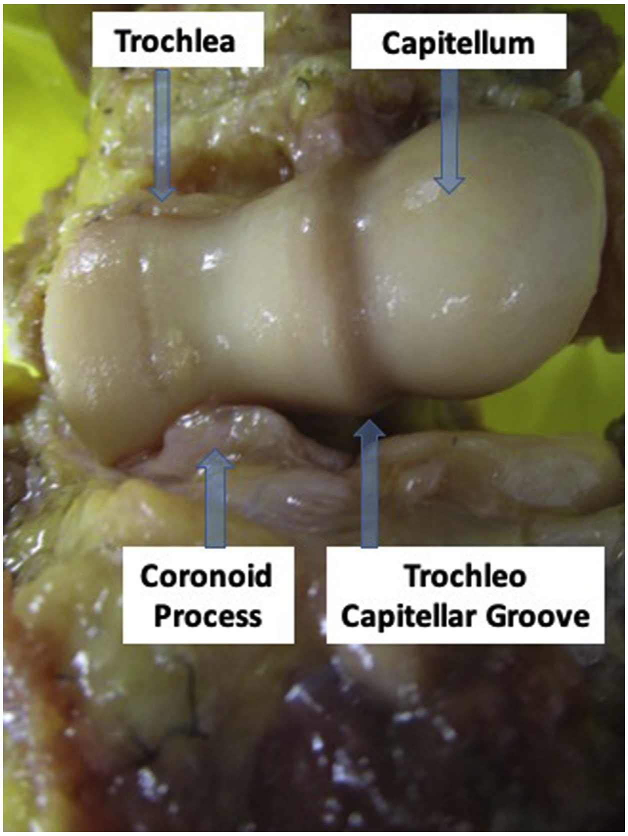

Figure 1 Coronal section of the elbow in a specimen showing the anatomical characteristics of the capitellum and trochlea.

protocol to perform a three-dimensional (3D) CT scan or two-dimensional (2D) CT scan for this type of injury. The hypothesis of this study is that the classification of the capitellum and trochlear fractures only by plain radiography does not adequately agree with the classification obtained by a CT scan and underestimates the complexity of the fracture to carry out an adequate surgical planning. The aim of the study is to determine interobserver agreement in the classification by X-rays and by CT scan of the coronal shear fractures according to the Bryan and Morrey classification (with the modification of McKee et al)[25,26] as well as the agreement between these two tests.

Materials and methods

Patients with distal humeral coronal plane fractures who were managed at our center between January 2008 and December 2017 were included. This retrospective cohort study was carried out with the approvement of the ethics committee of our institution (Protocol number: IIBSP-Cod-2019-02 Ref. 19/070). In this period, we treated 9 patients. Clinical, radiographic, and elbow-specific outcomes, including the Mayo Elbow Performance Index (MEPI), were evaluated. Broberg and Morrey System[5] for grading degenerative arthritis and Brooker System[6] applied to the elbow for classifying heterotopic ossification were used. All cases underwent a preoperative CT scan. Three observers (two consultants and one resident) analyzed the initial simple X-rays from all the cases. Each one of them independently classified the fractures according to the Bryan and Morrey classification (with the modification of McKee et al)[26] (Fig. 2). The interobserver agreement was calculated by Cohen kappa coefficient.[10,20] The same methodology was used to analyze the CT scan. Thereafter, one single value was determined for each X-ray and CT scan, from the good interobserver agreements.

Statistical analysis was performed using IBM SPSS Statistics, version 24.0 (IBM, Armonk, NY, USA). Statistical data were evaluated by descriptive methods. For the results, differences between the two groups were compared by the t-test and Chi-square test. A p value of less than 0.05 was considered significant with a 95% confidence interval. The agreement between the global X-ray classification and the global CT scan classification was calculated using the agreement percentage and the Cohen kappa coefficient.[10] The kappa coefficient provides infomation on interobserver and intraobserver reliability for each study variable.[20] Kappa values have been assigned to subdivisions, with values of 0.00 to 0.20 indicating slight agreement; 0.21 to 0.40, fair agreement; 0.41 to 0.60, moderate agreement; 0.61 to 0.80, substantial agreement; and >= 0.81, almost perfect agreement. A kappa coefficient value lower than 0 indicates complete disagreement, and a value of 1, complete agreement.

Results

There were 3 males and 6 females, with a mean age of 47 years (range, 18-83). The mean follow-up period was 18 months (12-40). The trauma mechanism was a fall on an outstretched hand in 4 patients, traffic accident in 3, and direct blow to the elbow in 2. The nondominant, left side was injured in 8 of the cases. The mean time from admission to operation was 6 days, with a range of 1-22 days. According to the Bryan and Morrey classification (with the modification of McKee et al),[25] 2 fractures were type I, one fracture was type II, and 6 fractures were type IV.

The anterolateral approach which was described by Kaplan as the interval between extensor digitorum communis and extensor carpi radialis brevis was used in 3 cases. The lateral approach which was described by Kocher was used in 4 cases. The remaining 2 cases were managed by the posterior approach. The technique was the posterior approach described by Bryan and Morrey. In 5 patients (55.5%), we changed the surgical approach that we were going to perform in the initial surgical planning when verifying the severity of the fracture by CT scan. Eight patients were treated by open reduction and internal fixation (ORIF) with Acutrak headless compression screws (Hillsboro, OR, USA) (Fig. 3). On the remaining patient, an excision of the osteochondral fragment was performed. Above-the-elbow splint was used for a maximum period of 12 days postoperatively. The fractures were united within 3 months in all the cases. The average MEPI score was 85 (range, 65-100) points, with 1 excellent, 4 good, and 4 fair results. The complications were nonunion in one patient (11%), degenerative arthritis in 7 (78%), joint step-off in 5 (55%), and heterotopic ossification in 7 (78%). Avascular necrosis and implant failure were not seen in any case. Among the 7 patients who developed degenerative arthritis, 3 were grade 1, 2 were grade 2, and 2 were grade 3, according to Broberg and Morrey classification. There were 7 patients with heterotopic ossification. That was grade I in 4 patients, grade 2 in 2, and grade 3 in 1, according to Brooker classification applied to the elbow. Two of the nine patients needed a second surgical intervention owing to elbow stiffness and free articular bodies. There was one concomitant lateral epicondyle fracture. LCL injuries were seen in 3 patients with this type of fracture. There was no neurovascular lesion associated with the injuries. At the end of the follow-up, all fractures were healed, there was no elbow instability or weakness, and no infections developed.

In the interpretation of the radiograph, type I (complete capitellar fracture) of the X-ray classification is the one that was most confused with type IV (capitelum fracture with extend to trochlea).

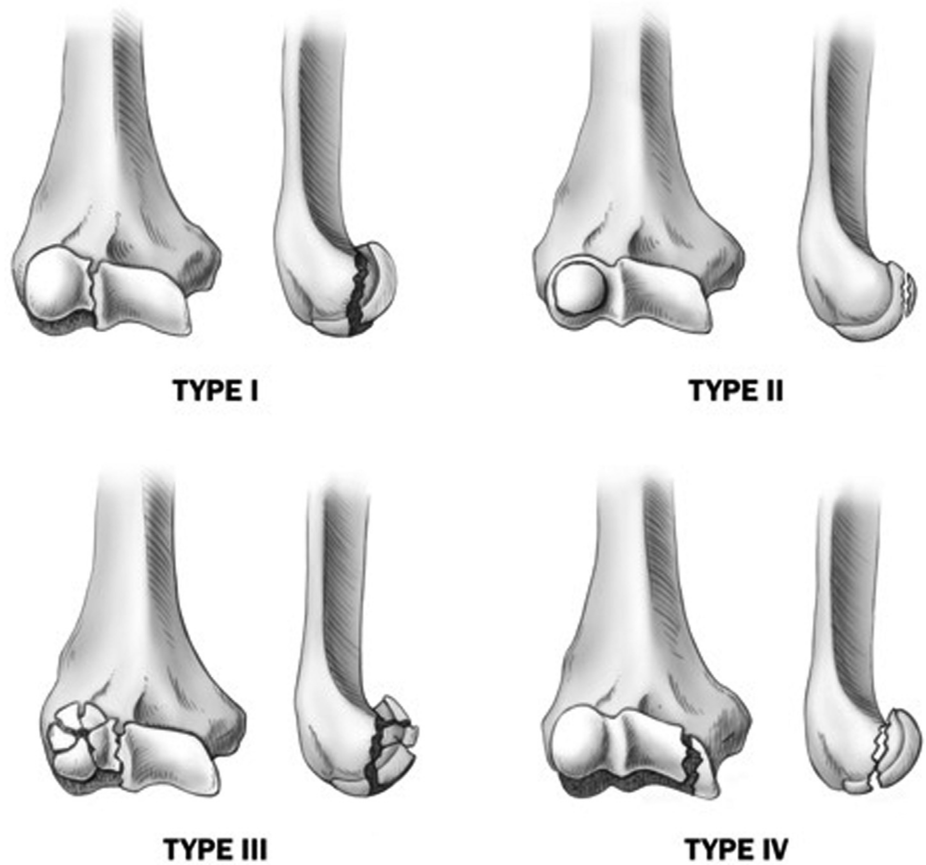

Figure 2 Coronal shear fractures of the capitellum and trochlea according to the Bryan and Morrey classification with the modification of McKee et al.

Observer 1 agreed with its interpretation of the X-rays and CT scan on 7 of 9 X-rays (77.7%), observer 2 agreed on 4 of 9 X-rays (44.4%), and observer 3 agreed on 6 of 9 (66.6%). The Cohen kappa coefficient in the X-ray simple classification, which represents the interobserver agreement, was between 0.449 and 0.757. According to the six categories of strength agreement of kappa by Landis and Koch,[20] these values represent a moderate to substantial correlation. The CT scan percentage agreement was between 85.7% and 100%. The agreement analysis between the global X-ray classification and the global CT scan classification showed a 57.1% agreement, with a kappa coefficient of -0.167. These values imply the absence of agreement.

Discussion

Most capitellum fractures are the result of a low-energy injury, such as a fall on the outstretched hand, with varying degrees of elbow flexion.[9,27] Biomechanical studies have yet to demostrate the mechanisms that cause coronal shear fractures of the distal humerus.[9] Amis and Miller studied various mechanisms of injury for each of the common elbow fractures.[2] The investigation was carried out with 40 specimens in which the elbow fractures were produced in a purpose-built impact-loading rig. There was one capitellar fracture caused by an indirect impact along the radius in full extension and one caused by direct impact to the end of the distal humerus with the elbow at 90º flexion. The most common fracture is a coronal plane to the anterior surface of the humeral shaft, producing a hemispheral fragment which is often displaced proximally.[2] This is usually ascribed to a fall onto the outstretched hand, the radial head acting like piston shearing off the capitellum.[2,11] Direct impacts on the flexed elbow have also been suggested as a mechanism as they have indirect impacts on the flexed elbow, when the radial head pushes the capitelum into a posterior position.[2,11] Alternatively, the fracture may occur after an episode of elbow instability and/or an LCL injury.[9,34] In this injury, the capitellum and trochlea may be sheared off by the radial head and coronoid after the reduction of a dislocation of the elbow.[9] Brouwer et al[7] reported that 33% of patients in their study sustained an elbow dislocation and/or a radial head fracture. An LCL injury or radial head fracture was reported in 57% of patients by Dubberley et al.[12] Radiographs showed a fracture of the capitellum alone or a combined lesion with a trochlea fracture with anterosuperior dislocation of the fragment out of the ulnohumeral joint.[3,27] For some authors, a classification system based on the radiographic patterns of these fractures is recommended.[3,12] In the study published by Jacquot et al, less than three-quarters of respondents determined to correct AO classification based on the standard radiographs, and the level of experience had no influence on this parameter. Reading the CT images resulted in correct fracture classification by 90% of the respondents who initially indicated the wrong fracture type.[17] A recently introduced technique is 3D imaging derived from 2D CT scans or obtained by modeling. This technique has been reported to improve intraobserver and interobserver reliability in assessing distal humerus fracture characteristics without improving determination of the fracture type in most widely accepted classification systems.[8,11,17] A 3D CT scan reconstruction better outlines the fracture and the loss of radiocapitellar alignment.[26] CT improves diagnostic accuracy and, in some cases, changes the surgical strategy.[38] CT did not improve interobserver agreement. Intraobserver agreement was improved by 3D CT but

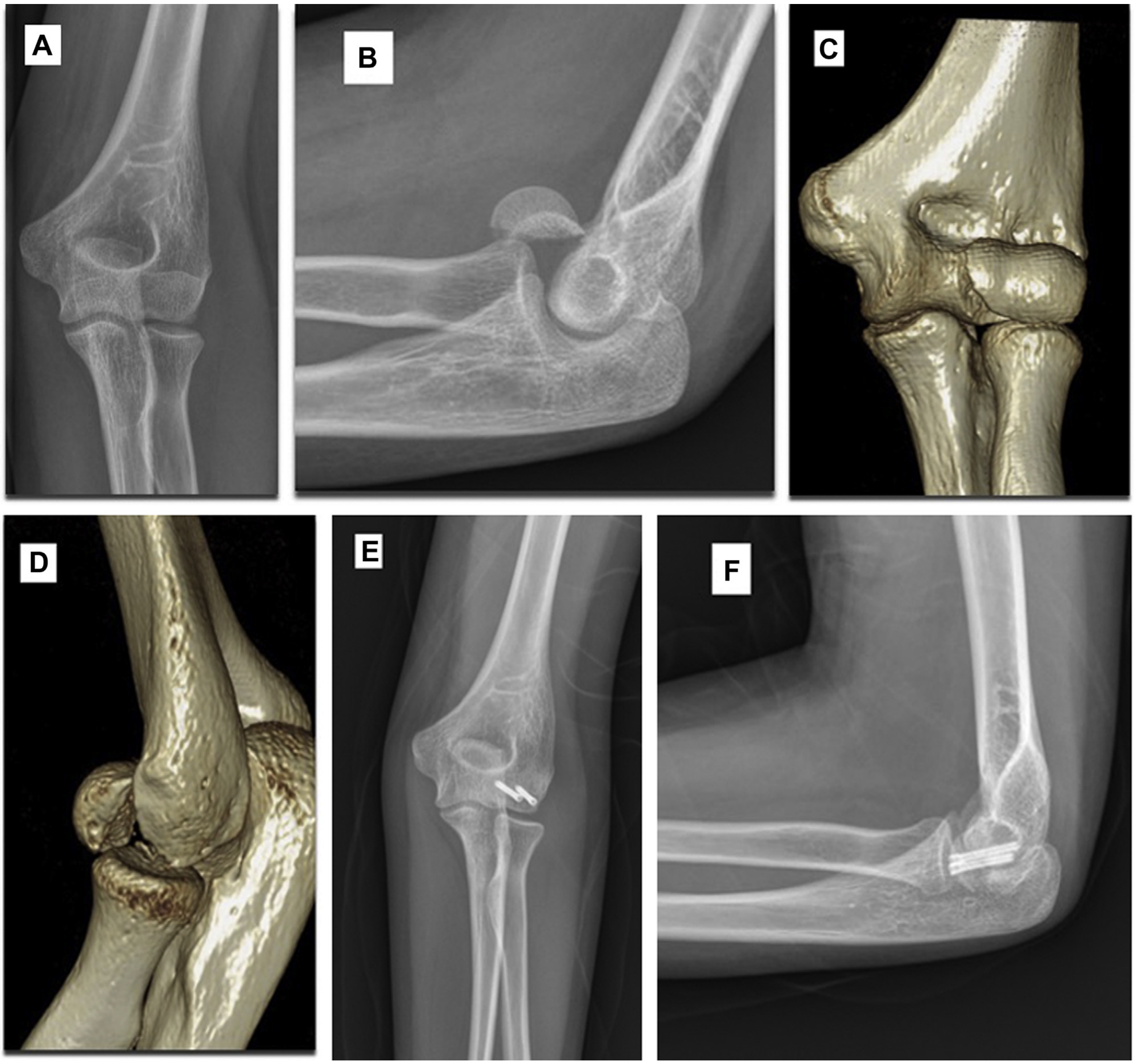

Figure 3 Distal humerus coronal fracture. (**A** and **B**) Preoperative radiographs. (**C** and **D**) A 3-dimensional computed tomography reconstruction. (**E** and **F**) An X-ray image in profile and anteroposterior views shows the fracture fixation.

not by 2D CT.[17] For Doornberg et al,[11] 3D CT scans are easier to interpret than 2D CT scans and are helpful in the anticipation of important fracture characteristics and preoperative planning of the operative treatment of fractures of the distal part of the humerus.

Fracture classification

Several classification systems for coronal shear fractures of the distal humerus have been described.[12,24,26] Bryan and Morrey proposed a classification based on 3 types of capitellum fractures. A type I (Hahn-Steinthal) lesion involves a fracture isolated to the capitellum with attached subchondral bone; type II fractures (Kocher-Lorenz) are those involving primarily the articular cartilage overlying the capitellum; type III (Broberg-Morrey) lesions are defined as comminuted capitellum fractures. A type IV lesion (McKee) was later added to the classification scheme and involves a capitellum fracture that extends medially into the trochlea.[9,13,26,34] Dubberley et al[12] described another classification. Type I fracture involves the capitellum with or without extension to the lateral trochlear ridge (ie, Bryan-Morrey type I equivalent) and may be treated with ORIF through a muscle-splitting approach. Type II fracture involves the capitellum and trochlea as a single fragment (ie, McKee type IV). Access to the medial side of the joint may require a more extensile approach. Type III fracture involves the capitellum and trochlea as 2 independent fragments. Fractures demonstrating posterior condylar comminution are denoted with a B modifier.[9,12] The presence of posterior condylar comminution was found to influence surgeon selection of the fixation method as well as outcome.[12,33]

The Orthopedic Trauma Association classification defines partial articular fractures of the distal humerus as type 13-B. A partial articular fracture in the coronal plane is subclassified as 13-B3. Fractures involving the capitellum are further subdivided as involving only the capitellum (13-B3.1), the trochlea (13-B3.2), or both (13-B3.3).[24]

Surgical approach

Several surgical approaches have been described.[9,26] The optimal choice depends on fracture characteristics and associated periarticular injuries. The deep exposure to the lateral elbow is simplified in situations whereby the LCL has been disrupted or the lateral epicondyle has been fractured.[4,9] If the LCL complex remains intact, the exposure is through the Kocher interval, between the anconeus and extensor carpi ulnaris. To improve visualization of the anterior compartment, a Kocher interval may be extended proximally to release an inferior portion of the extensor digitorum communis muscle. Capitellum fractures extending into the trochlea may not be adequately accessed using laterally based extensile maneuvers. If medial fracture visualization is not satisfactory, the flexorpronator mass may be split and elevated anteriorly off the medial epicondyle as described by Hotchkiss or an olecranon osteotomy may be used.[9,27]

Fracture fixation

Several methods of fixation have been used in the treatment of coronal shear fractures of the distal humerus and include headless compression screws, small fragment cancellous screws, Kirschner wires, and plates.[19,21,27,32,35] ORIF is the predominant method for treating displaced capitellum fractures.[4,19,21,28,36] Arthroscopic assisted reduction and internal fixation of capitellum fractures is among the expanding indications in minimally invasive elbow surgery; however, relatively little has been published on the technique.[19,28] Fragment excision is another one of the treatments for fracture type (Bryan and Morrey types I and II). The largest of the series reported poor results.[31,32] Patients treated early experienced an average of 5º loss of ulnohumeral motion, with those treated later experiencing a 47º loss. All patients treated late experienced some residual pain at the final follow-up.[1,15] Grantham et al reported a valgus instability and compromised outcomes if the capitellum fracture is excised in the setting of medial collateral ligament injury.[15] Total elbow arthroplasty and distal humeral hemiarthroplasty have been recommended for the treatment of comminuted, intra-articular distal humerus fractures not amendable to stable ORIF.[16,23,29] Adolfsson and Nestorson[1] reported the results of 8 patients undergoing hemiarthroplasty for Orthopedic Trauma Association type B3 and C3 fractures of the distal humerus. Primarily good to excellent MEPI scores were reported at an average of 4.5 years of follow-up.[1] Although Kepler et al[18] published a good outcome after radiocapitellar arthroplasty for a capitellum fracture nonunion, larger studies on primary arthroplasty for coronal shear fractures are not available. Fracture classification was also a predictor of postoperative pain and MEPI scores. Patients diagnosed with type I fractures experienced less pain and higher functional MEPI scores than those with type II and III fractures.[37] Posterior comminution and articular fragmentation is an important determinant of outcome after capitellar and trochlear fractures.[3,12,13]

Our study evaluates the difference of opinion in classifying coronal shear fractures of the capitellum and trochlea using radiological classifications. Incorrect classification of such a capitellum fracture by radiography can lead to poor surgical planning. Therefore, and seeing that there is high interpersonal variability in evaluating the extent of the injury, we suggest that a CT scan be performed in a protocolized manner.

The study is limited by the small sample size. Further research is needed to support these findings.

Conclusion

Our results demostrated that simple X-ray does not allow the adequate interpretation of capitellum and trochlea fractures. Although an acceptable interobserver agreement was found, there is no agreement when the same fractures were analyzed by a CT scan. The authors routinely recommend a CT scan in distal humeral coronal plane fractures as the assessment of fracture extension and comminution by plain x-ray is particularly deceptive in this region.

Disclaimer

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References

1. Adolfsson L, Nestorson J. The Kudo humeral component as primary hemiarthroplasty in distal humeral fractures. J Shoulder Elbow Surg 2012;21:451-5. https://doi.org/10.1016/j.jse.2011.07.011.
2. Amis AA, Miller JH. The mechanisms of elbow fractures: an investigation using impact test in vitro. Injury 1995;26(3):163-8.
3. Ashwood N, Verma M, Hamlet M, Garlapati A, Fogg Q. Transarticular shear fractures of the distal humerus. J Shoulder Elbow Surg 2010;19:46-52. https://doi.org/10.1016/j.jse.2009.07.061.
4. Bilsel K, Atalar AC, Erdil M, Elmadag M, Sen C, Demirhan M. Coronal plane fractures of the distal humerus involving the capitellum and trochlea treated with open reduction internal fixation. Arch Orthop Trauma Surg 2013;133: 797-804. https://doi.org/10.1007/s00402-013-1718-5.
5. Broberg MA, Morrey BF. Results of delayed excision of the radial head after fracture. J Bone Joint Surg Am 1986;68:669-74.
6. Brooker AF, Bowerman JW, Robinson RA, Riley LH. Ectopic ossification of following total hip replacement. Incidence and a method of classification. J Bone Joint Surg Am 1973;55:1629-32.
7. Brouwer KM, Jupiter JB, Ring D. Nonunion of operatively treated capitellum and trochlear fractures. J Hand Surg Am 2011;36:804-7. https://doi.org/10.1016/j.jhsa.2011.01.022.
8. Brouwer KM, Lindenhovius AL, Dyer GS, Zurakonwski D, Mudgal CS, Ring D. Diagnostic accuracy of 2- and 3-dimensional imaging and remodeling of distal humerus fractures. J Shoulder Elbow Surgery 2012;21:772-6. https://doi.org/10.1016/j.jse.2012.01.009.
9. Carroll MJ, Athwal GS, King GJW, Faber KJ. Capitellar and trochlear fractures. Hand Clin 2015;31:615-30. https://doi.org/10.1016/j.hcl.2015.07.001.
10. Cohen J. A coefficient of agreement for nominal scales. Educ Psychol Meas 1960:27-46.
11. Doornberg J, Lindenhovius A, Kloen P, Van Dijk NV, Zurakowski D, Ring D. Two and three-dimensional computed tomography for the classification and management of distal humeral fractures. J Bone Joint Surg Am 2006;88:1795-801. https://doi.org/10.2106/jbjs.e.00944.
12. Dubberley JH, Faber KJ, Macdermid JC, Patterson SD, King GJ. Outcome after open reduction and internal fixation of capitellar and trochlear fractures. J Bone Joint Surg Am 2006;88:46-54. https://doi.org/10.2106/jbjs.d.02954.
13. Durakbasa MO, Gumussuyu G, Gungor M, Ermis MN. Distal humeral coronal plane fractures: management, complications and outcome. J Shoulder Elbow Surg 2013;22:560-6. https://doi.org/10.1016/j.jse.2012.07.011.
14. Gonçalves LBJ, Ring DC. Fractures of the humeral trochlea: case presentations and review. J Shoulder Elbow Surg 2016;25:e151-5. https://doi.org/10.1016/j.jse.2016.02.014.
15. Grantham SA, Norris TR, Bush DC. Isolated fracture of the humeral capitellum. Clin Orthop Relat Res 1981;161:262-9.
16. Heijink A, Morrey BF, Eygendaal D. Radiocapitellar prosthetic arthroplasty: a report of 6 cases and review of the literature. J Shoulder Elbow Surg 2014;23: 843-9. https://doi.org/10.1016/j.jse.2014.01.042.
17. Jacquot A, Poussage N, Charrissoux JL, Clavert P, Obert L, Pidhorz L, Sirveaux F, Mansat P P, Fabre T. Usefulness and reliability of two and three-dimensional computed tomography in patients older than 65 years withg distal humerus fractures. Orthop Traumatol Surg Res 2014;100(4):275-80. https://doi.org/10.1016/j.otsr.2014.01.003.
18. Kepler CK, Kummer JL, Lorich DG, Weiland AJ. Radiocapitellar prosthetic arthroplasty for capitellar nonunions. J Shoulder Elbow Surg 2010;19:e13-7. https://doi.org/10.1016/j.jse.2009.07.063.
19. Kuriyama K, Kawanishi Y, Yamamoto K. Arthroscopic-assissted reduction and percutaneous fixation for coronal shear fractures of the distal humerus: report of two cases. J Hand Surg Am 2010;35:1506-9. https://doi.org/10.1016/j.jhsa.2010.05.021.
20. Landis RJ, Koch GG. An application of hierarchical kappla-type statistics in the assessment of majority agreement among multiple observers. Biometrics 1977;33:363-74.
21. Lee JJ, Lawton JN. Coronal Shear Fractures of the Distal Humerus. J Hand Surg Am 2012;37:2412-7. https://doi.org/10.1016/j.jhsa.2012.09.001.

22. Lopiz Y, Rodriguez-Gonzalez A, García-Fernández C, Marco F. Open reduction and internal fixation of coronal fractures of the capitellum in patients older than 65 years. J Shoulder Elbow Surg 2016;25:369-75. https://doi.org/10.1016/j.jse.2015.12.004.
23. Mahirogullari M, Kiral A, Solakoglu C, Pehlivan O, Akmaz I, Rodop O. Treatment of fractures of the humeral capitellum using herbert screws. J Hand Surg Br 2006;31:320-5. https://doi.org/10.1016/j.jhsb.2006.02.002.
24. Marsh JL, Slongo TF, Agel J, Broderich JS, Creevey W, DeCoster TA, et al. Fractures and dislocation classification compendium -2007. Orthopaedic Trauma Association classification, database and outcomes committee. J Orthop Trauma 2007;21(10 Suppl):S1-133. https://doi.org/10.1097/00005131-200711101-00001.
25. McKee MD, Jupiter JB, Bamberger HB. Coronal shear fractures of the distal end of the humerus. J Bone Joint Surg Am 1996;78:49-54.
26. McKee MD, Veillette CJ, Hall JA, Schemitchs EH, Wild LM, McCormack R, et al. A multicenter, prospectiva, randomized, controlled trial of open reduction-internal fixation versus total elbow arthroplasty for displaced intra-articular distal humeral fractures in elderly patients. J Shoulder Elbow Surg 2009;18:3-12. https://doi.org/10.1016/j.jse.2008.06.005.
27. Mighell M, Virani NA, Shannon R, Echols EL, Badman BL, Keating CJ. Large coronal shear fractures of the capitellum and trochlea treated with headless compression screws. J Shoulder Elbow Surg 2010;19:38-45. https://doi.org/10.1016/j.jse.2009.05.012.
28. Mitani M, Nabeshima Y, Ozaki A, Mori H, Issei N, Fuji H, et al. Arthroscopic reduction and percutaneous cannulated screw fixation of a capitellar fracture of the humerus: a case report. J Shoulder Elbow Surgery 2009;18:e6-9. https://doi.org/10.1016/j.jse.2008.07.007.
29. Ravishankar MR, Kumar MN, Raut R. Choice of surgical approach for capitellar fractures based on pathoanatomy of fractures: outcomes of surgical management. Eur J Orthop Surg Traumatol 2017;27:233-42. https://doi.org/10.1007/s00590-016-1877-5.
30. Rausch V, Königshausen M, Schildhauer TA, Gessmann J, Seybold D. Fractures of the capitellum humeri and their associated injuries. Obere Extremität 2018;13:33-7. https://doi.org/10.1007/s11678-018-0441-9.
31. Ring D. Articular fractures of the distal part of the humerus. J Bone Joint Surg Am 2003;85:232-8. https://doi.org/10.2106/00004623-200302000-00008.
32. Ruchelsman DE, Tejwani NC, Kwon YW, Egol KA. Open Reduction and Internal Fixation of Capitellar Fractures with Headless Screws. J Bone Joint Surg Am 2009;91(Suppl 2):38-49. https://doi.org/10.2106/jbjs.h.01195.
33. Ruchelsman DE, Tejwani NC, Kwon YW, Egol KA. Coronal plane partial articular fractures of the distal humerus: current concepts in management. J Am Acad Orthop Surg 2008;16:716-28. https://doi.org/10.5435/00124635-200812000-00004.
34. Sabo MT, Fay K, McDonald CP, Ferreira LM, Johnson JA, King GJW. Effect of coronal shear fractures of the distal humerus on elbow kinematics and stability. J Shoulder Elbow Surg 2010;19:670-80. https://doi.org/10.1016/j.jse.2010.02.002.
35. Sano S, Rokkaku T, Saito S, Tokunaga S, Abe Y, Morilla H. Herbert screw fixation of capitellar fractures. J Shoulder Elbow Surg 2005;14:307-11. https://doi.org/10.1016/j.jse.2004.09.005.
36. Singh AP, Singh AP, Vaishya R, Jain A, Gulati D. Fractures of capitellum: a review of 14 cases treated by open reduction and internal fixation with Herbert screws. Int Orthop 2010;34:897-901. https://doi.org/10.1007/s00264-009-0896-9.
37. Trinh TQ, Harris JD, Kolovich GP, Griesser MJ, Schickendantz MS, Jones GL. Operative management of capitellar fractures: a systematic review. J Shoulder Elbow Surg 2012;21:1613-22. https://doi.org/10.1016/j.jse.2012.03.008.
38. Watts AC, Morris A, Robinson CM. Fractures of the distal humeral articular surface. J Bone Joint Surg Br 2007;89:510-5. https://doi.org/10.1302/0301-620x.89b4.18284.